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BIBLIOGRAPHY ON SEMICONDUCTOR DETECTORS

A compilation of selected literature abstracts
as guide to recently public available R. & D. publications
in semiconductor radiation detector techniques
covering the period 1963 - 1967.

by

E. BOCK

1967

Directorate Dissemination of Information
Center for Information and Documentation - CID

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by E. BOCK

European Atomic Energy Community - EURATOM
Directorate Dissemination of Information
Center for Information and Documentation - CID
Brussels, December 1967 - 138 Pages - FB 175

Bibliography presenting 629 abstracts of publications dealing with Semiconductor Detector Techniques covering the period 1963-1967.

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ABSTRACT

Bibliography presenting 629 abstracts of publications dealing with Semiconductor Detector Techniques covering the period 1963-1967.

INTRODUCTION

In recent years semiconductor detectors have grown steadily in importance in nuclear technology. Owing to their versatility, compactness and relatively high resistance to radioactive radiations, these detectors have attracted the interest of many scientific and technical experimenters and sparked off a continuous advance in instrumentation and measurement technique. Naturally, this scientific interest in refinement and further development has been followed by an avalanche of publications. It is very difficult for the instrumentation specialist or nuclear engineer to do his own job, namely, investigating his own specific problems, and at the same time keep abreast of the latest state of the art or acquire a rapid and comprehensive insight into new developments affecting his particular field. The practical engineer in the laboratory faces the almost overwhelming task of, on the one hand, carrying out his frequently time-consuming and expensive series of experiments and, on the other hand, reading and understanding a vast number of publications in his special field and assessing their value or lack of it. This is a more than full-time occupation. Here is an opportunity for a modern documentation and information service, which can help the laboratory scientist by selecting the relevant material for him and presenting it in a condensed form. At the suggestion of Professor Bertolini of the Euratom Joint Research Centre at Ispra, the present compilation seeks to present a selection of publications on semiconductor techniques which will help instrument makers, reactor physicists and users of these instruments, together with the interested laymen, to inform themselves quickly and comprehensively about technical innovations and developments from the short notes before studying and analysing the original publications. The compiler is aware that, owing to its cursory character and the rapid advance of technical developments, this compilation will be only a short-lived aid to the instrument specialist. He would therefore like to point out the possibilities afforded by the **Euratom semi-automatic documentation system** for obtaining up-to-date information in the future.

Lastly, the compiler would like to thank the kindly helpers, advisers and initiators of this work, who by their diligence, perseverance and continual encouragement made its present form possible. Among many other sources, the report collection of the Euratom library, the Nuclear Science Abstracts and the reference files of the Euratom Centre for Information and Documentation (CID) were used as basic material.

Brussels,
August 1967

THE COMPILER

ROUGH SUBJECT-INDEX

The following rough subject-index represents an attempt to provide the user of this compilation with a time-saving short indication of the main topic of the publication concerned. The catchword type of designation applied to a measurement method, a concept or an instrument component (e.g. TOTAL CROSS-SECTION MEASUREMENT, PATENT, PIN, PRE-AMPLIFIER) always refers to semiconductor detectors.

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ABSTRACTS

1 INVESTIGATION OF THE ANOMALY IN THE RESPONSE OF SILICON SEMICONDUCTOR RADIATION DETECTORS AT LOW TEMPERATURES.

W.R. Dodge, S.R. Domen, A.T. Hirshfeld, and D.D. Hoppes (National Bureau of Standards, Washington, D.C.).

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: 295-303 (Feb. 1965).

Investigation of the response anomaly in silicon semiconductor radiation detectors cooled to temperatures below 40°K was continued. Experiments with surfacebarrier detectors show that the mean temperature at which normally ionized impurity atoms accept electrons (as deduced from dE/dx measurements of the depletion depth) is a slowly varying function of the impurity concentration. This behavior is expected from the dependence of the Fermi level on the temperature, impurity concentration and ionization energy. Below the narrow temperature interval in which the majority of the impurity atoms accept electrons and hence become electrically neutral, particles which produce low ionization densities (beta particles) produce pulse heights with room temperature magnitudes, while particles with high ionization densities (alpha particles) produce pulse heights which are lower than those characteristic of room temperature operation and which depend on the detector bias voltage. The results of experiments conducted to investigate polarization effects in lithium-drifted semiconductor radiation detectors are described.

2 CYCLOTRON TESTS TO DETERMINE THE RESPONSE OF SOLID-STATE DETECTORS TO PROTONS OF ENERGIES 50 TO 160 Mev FOR USE IN A PROTON SPECTROMETER.

Gary W. Grew (Langley Research Center, Hampton, Va.).

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: 308-13 (Feb. 1965).

Tests were conducted at the 160-Mev Harvard cyclotron on fully depleted solid-state detectors. This work was done in conjunction with a feasibility study of a proposed proton spectrometer consisting of two dE/dx detectors in a coincident telescope arrangement that can analyze protons over an energy range from 0.5 Mev to greater than 200 Mev. The surface barrier sensors were exposed to protons of energies varying from 50 to 160 Mev to determine the response of these sensors to high-energy protons. The two major parameters to be determined were the most probable energy loss in the detector by protons of energy E and the resolution of the energy-loss distribution. The results of the tests are compared with the Symon treatment of the Landau effect. The proposed proton spectrometer is also discussed briefly.

3 CORRELATION BETWEEN LITHIUM DRIFT MOBILITY AND MINORITY-CARRIER DRITF MOBILITY IN GERMANIUM.

Armantrout G.A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 370-372.

The minority-carrier drift mobility of driftable and nondriftable germanium was measured in an effort to determine the presence of an impurity which reduced the lithium drift mobility but did not affect the resistivity and lifetime of some of the material used to make lithium-drift detectors. The measurements were made at 77°K where the mobility is limited by impurity scattering rather than lattice scattering. The mobility was measured as a function of temperature for five samples of Ge which had varying lithium drift mobilities. Good correlation was found between the driftability of the material and the minority-carrier drift mobility at 77°K. Estimated impurity levels in the range of 10^{14}-10^{15}/cm^3 apparently reduce the effective lithium mobility, while impurity concentrations greater than 5×10^{15} make the Ge unsuitable for making lithium-drift detectors.
A mass-spectrometer analysis indicated that the impurity apparently has a mass number less than Mg; oxygen is a likely possibility due to its known behavior with Li in silicon.

4 MONITORING OF SILICON DETECTOR SYSTEMS WITH PULSED GaAs.

Robert W. Kuckuck (Univ. of California, Livermore) and J. Chong Lee.

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: 356-60 (Feb. 1965). (UCRL-7957).

The use of the closely matching emission of GaAs and the spectral response of silicon detectors are proposed as an optical method if monitoring overall nuclear detector system response. A GaAs diode is a high-speed current device which emits light with an intensity linearly related to the electrical input over a wide range and which has a frequency response well beyond that of normal silicon detectors. The speed of the GaAs source permits overall evaluation of the silicon detector and its associated circuitry. Where applicable, the optical monitoring of nuclear detector systems with compact GaAs sources offers a highly flexible alternative to isotope and electrical pulse methods. Experimental behavior of some typical sources and detectors and the results of a procedure developed to monitor a nuclear pulse detector system are presented.

5 MONTE CARLO CALCULATIONS OF SEMI-CONDUCTOR DETECTOR RESPONSE TO GAMMA RAYS.

K.M. Wainio and G. F. Knoll (Univ. of Michigan, Ann Arbor).

Trans. Am. Nucl. Soc., 8: 61-2 (May 1965).

6 SILICON CARBIDE HIGH-TEMPERATURE NEUTRON DETECTORS FOR REACTOR INSTRUMENTATION.

R. R. Ferber and G. N. Hamilton (Westinghouse Electric Co., Pittsburgh).

Trans. Am. Nucl. Soc., 8: 72-3 (May 1965).

7 CHARACTERISTICS OF SOME LARGE, COAXIAL LITHIUM DRIFT SEMICONDUCTOR GAMMA-RAY SPECTROMETERS.

Tavendale A.J.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 315-327.

Large-volume, lithium drift germanium and silicon diodes have been fabricated using the "coaxial" configuration and their diode and gamma-ray spectrometer characteristics investigated at liquid nitrogen temperatures (77°K).
Techniques are described which have been used to drift volume up to 40 cm^3 from 10 ohm-cm, Ga-doped germanium and 22 cm^3 from 1100 ohm-cm, B-doped silicon Drift data, diode d.c. conditions for best spectrometer operation, and experimental resolutions for Co-57, 60 source gamma-rays are tabulated for Ge diodes, 14.5 - 40 cm^3 active volume, and other sections taken from these. Gamma-ray spectra up to 17 MeV gamma-ray energy are presented for typical diodes.
Resolutions (FWHM) of 2.0, 3.4 and 7.3 keV on the full-energy peak of 122, 1173 and 2754 keV gamma-rays have been obtained from a 14 cm^3 Ge (Li) diode using a cooled, FET input stage pre-amplifier.
The performance of a coaxial Ge(Li) diode with a guard-ring construction for high bias voltage operation is described.
Coaxial Si(Li) diodes primarily intended for application as gamma-ray pair spectrometers have been drifted to 22 cm^3 active volume. The spectral responses to 122 and 2754 keV gamma-rays from a smaller, 11,5 cm^3 Si(Li) diode are given. Problems in drifting "single-ended" coaxial Si(Li) diode structures are discussed.

8 (MLM-1221) MOUND LABORATORY PROGRESS REPORT FOR OCTOBER 1964.

J. F. Eichelberger, G. R. Grove, and L. V. Jones (Mound Lab., Miamisburg, Ohio).

Oct. 22, 1964. Contract AT-33-1-GEN-53. 24 p. Dep. (mn); $1.00(cy), 1(mn) CFSTI.

As an alternate to internal-gas-phase proportional counting for detection of trace quantities of ^{85}Kr in Kr and Xe, work was started on the quantitative determination of conversion electrons from ^{85}Kr in a thin film of material condensed cryogenically. Preliminary experiments with Li drift detectors showed that this method possesses the energy resolution required for quantitative measurement. In particular, resolution of conversion electrons at 623 kev and 655 kev arising from conversion of the 661-kev gamma ray from ^{137}Cs is satisfactory. Twelve cylinders of P-10 gas (90% Ar 10% CH_4) were found to contain 1×10^{-8} mole % tritium as determined by liquid scintillation counting.

9 NEW CONCEPTS IN NUCLEAR PULSE AMPLIFIER DESIGN.

Blankenship J.L., Nowlin C.H.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 495-507.

Network analysis and synthesis techniques were applied to design a new experimental nuclear pulse amplifier whose performance is superior to any other similar type of amplifier. The amplifier is designed to closely approximate desirable overall transfer functions. The instrument consists of broadband, fixed-feedback amplifiers and a novel passive, linear lumped-element network. The gain of the amplifier is adjusted by passive, constant-impedance attenuators. The variation of crossover time with attenuator position (for both fine and coarse controls) is less than ± 0.50 nsec., and it is not necessary to make separate trimming adjustements for each attenuator setting.
The pulse-shaping network yields a unipolar output pulse having a monotonic return to the base line and having a theoretical signal-to-noise ratio superior to that of any published lumped-element network, and having minimum pile-up distortion for a given noise-corner time-constant. The bipolar pulse has nearly equal-amplitude positive and negative peaks, but with no tertiary overshoot. No delay lines are used. Minimum pile-up distortion and excellent recovery from overload are achieved by the use of pole-zero concellation techniques throughout the system. This amplifier was evaluated for overload recovery, crossover walk, pile--up distortion, common mode rejection, and noise-to-signal ratio.

10 (CLOR/IBJ-II-36/D) MULTI-GUARD-RING GOLD-SILICON SURFACE-BARRIER DETECTORS.

J. Roman, A. Dabrowski, S. Glowacki, M. Jagusztyn, M. Slapa and J. Chwaszczewska.

Centralne Laboratorium Ochrony Radiologiczej, Warsaw (Poland), 1965, 11, p., Dep.

Gold-silicon surface-barrier beta spectrometers with multi-guard-rings (3000-5000 ohm-cm n-type silicon) have been made. The devices have proved to be very stable in long-term operation and to withstand at room temperature a reverse bias greater than 1500 volts. The reverse current passing through the signal electrode and the guard-rings was less than 1 μamp at 1000 volts bias. The beta particles and internal-conversion electrons energy spectra have been measured. The energy resolution at room temperature was of about 9 kev (f.w.h.m.) for 625 kev electrons.

11 (ORNL-P-1089) ABSOLUTE ENERGY CALIBRATION OF SOLID-STATE DETECTORS FOR FISSION FRAGMENTS AND HEAVY IONS.

H. W. Schmitt, W. M. Gibson, J. H. Neiler, F. J. Walter, and T. D. Thomas (Oak Ridge National Lab., Tenn.). [1965].

Contract [W-7405-eng-26]. 19 p. (CONF-650301-11). Dep.(mn); $1.00(cy), 1(mn) CFSTI.

From Symposium on the Physics and Chemistry of Fission, Salzburg, Austria.
The response of silicon semiconductor detectors to ^{252}Cf, ^{235}U, and ^{239}Pu fission fragments and to monoenergetic bromine nad iodine ions was studied to obtain information from which precise particle energies can be obtained from

pulse-height measurements. Measurements were made for surface-barrier and diffused junction detectors of widely varying resistivities with different window thickness and diffusion depth and for a broad range of operating conditions. The experiment is described and the results are analyzed.

12 (WCAP-2644) MINIATURE NEUTRON DETECTOR DEVELOPMENT.

Quarterly Progress Report, April 1 - June 30, 1964.

J. Weisman, ed. (Westinghouse Electric Corp., Pittsburgh, Pa. Atomic Power Div.).

July 15, 1964. Work Performed under United States — Euratom Joint Research and Development Program. Contract AT(30-1)-2827. 17 p. (EURAEC-1150). Dep. (mn); $1.00(cy), 1(mn) CFSTI.

Work has continued on the development of silicon carbide diodes for the detection of neutrons under sustained high-temperature, high-flux conditions. A technique was developed for evaporating a thin film of ^{235}U on the surface of the diode. Diodes so processed successfully counted fission fragments produced by exposure to a neutron source. The greatest emphasis during this period has been placed on the preparation of a high temperature mounting for counting diodes. Such a mounting will allow the entire assembly to be repeatedly heated to temperatures up to 1300°C. It is expected that this will allow substantial annealing of irradiation damage. Configurations which successfully withstand this thermal cycling have been developed but units so processed have shown a very poor α counting ability.

13 (WCAP-2666) MINIATURE NEUTRON DETECTOR DEVELOPMENT.

Final Report.

J. Weisman, ed. (Westinghouse Electric Corp., Pittsburgh, Pa. Atomic Power Div.).

Oct. 1964. Work Performed under United States — Euratom Joint Research and Development Program. Contract AT(30-1)-2827, 85 p. (EURAEC-1278). Dep. (mn); $3.00(cy), 2(mn) CFSTI.

This report summarizes the results of the development of miniature silicon carbide neutron detectors carried out from June 1961 to September 1964. The program has developed surface junctions capable of detecting charged particles. The detector diodes are produced by diffusing aluminium into SiC crystals to a predetermined depth. The 3-stage diffusion process used is reproducible and has a good yield of useable diodes. A technique for converting the diodes into neutron detectors by vapor deposition of ^{235}U has been developed. Such diodes have been shown capable of counting thermal neutrons up to 800°C. Radiation damage studies have shown the diodes to have appreciably more radiation resistance than similar silicon diodes. However, the lifetime of present structures within a power reactor is estimated to be only between 100 and 1000 seconds. There is evidence that substantially improved lifetimes can be obtained by annealing the diodes at temperatures above 1000°C. Substantial efforts have been made to develop diode contacts which will withstand these temperatures but these efforts have not been successful. The diodes would appear to have significant utility for flux mapping in high temperature criticals and for some space exploration applications.

14 dE/dx SURFACE-BARRIER SILICON DETECTORS.

T. Krogulski, J. Chwaszczewska, and M. Jaskola (Inst. of Nuclear Research, Warsaw).

Nukleonika, 10: 69-75(1965). (In Russian).

A new technology of type dE/dx surface-barrier detectors was developed. The detectors obtained had thickness 70, 50, 40, 30, and 25 μ, active area 1—1.5 cm^2 while their barrier could be broadened over the whole geometrical detector thickness. The detectors were studied by means of natural polonium and thorium α sources and 24-Mev α-particles and 127-Mev deuterons from the cyclotron.

15 SOLID STATE POWER MAPPING INSTRUMENT.

Robert Steinberg and William B. Schwab (U. S. Atomic Energy Commission).

U. S. Patent 3,160,567. Dec. 8, 1964.

A radiation detector was designed for mapping reactor neutron flux. It consists of a plurality of probes, each probe having a plurality of ^{235}U-coated p-n junction diodes connected in series, means to guide the probes along a fuel element, a motor drive, and means for determining the position of the probes along the fuel element.

16 (MLM-1245) MOUND LABORATORY PROGRESS REPORT FOR FEBRUARY 1965.

J. F. Eichelberger, G. R. Grove, and L. V. Jones (Mound Lab., Miamisburg, Ohio).

Feb. 26, 1965 . Contract AT(33-1)-Gen-53. 26 p. Dep. (mn); $2.00(cy), 1(mn) CFSTI.

Techniques are being developed for preparing and reworking semiconductor radiation detectors. Si-barrier detectors were prepared with resolutions of the order of 2.5% (FWHM) for 4.88-Mev alpha particles from ^{209}Po. Alpha groups from a mixture of polonium-208, -209, and -210 at 4.88, 5.11, and 5.30 Mev are resolved completely.

17 INVESTIGATIONS OF ELASTIC p-p SCATTERING AT HIGH ENERGIES BY MEANS OF TRANSISTOR COUNTERS.

Yu. K. Akimov, A. I. Kalinin, V. A. Nikitin, V. S. Pantuev, V. A. Sviridov, A. I. Sidorov, and M. N. Khachaturyan.

Zh. Eksperim. i Teor. Fiz., 48; 767-9 (Feb. 1965) (In Russian).

Solid-state counters were placed in vacuum at an angle of 87.7° to a proton beam at a distance of 3 meters from a target which was struck by 10-Bev protons. The target was an organic polymeric film 0.7 μ thick. The dimensions of the surface-barrier counter were $3 \times 4 \times 0.09$ mm^3. The counting time was 10 minutes. The amplitude analyzer clearly showed a peak due to 2.2-Mev recoil protons. The peak width at half the height was 330 kev (15%). The half width $\Delta E/E$ was $\sim$18% in a nuclear emulsion, that is, somewhat broader than the distribution obtained with the solid-state counter. Protons whose range is included in a silicon layer 0.7 mm thick can be identified by the solid-state counter.

18 (SGAE-PH-10/1964) MESSUNG DER KINETISCHEN ENERGIE DER SPALTBRUCHSTUCKE DER U-235 SPALTUNG.

(Measurement of the Kinetic Energy of Fission Fragments from U-235 Fission).

M. Schneeberger and H. P. Axmann.

(Oesterreichische Studiengesellschaft fuer Atomenergie GmbH, Seibersdorf. Physik-Institut). Oct. 1964. 8 p.

Phosphorus-diffused (np) silicon detectors were used in ionization study of the kinetic energy of fission fragments from ^{235}U fission. The energy distribution of the fission fragments was measured to determine the counting properties of the semiconductor detectors. For the measurement of the kinetic energy, a two-detector system with the uranium foils, two amplifier stages, and recording unit was used. A two-dimensional energy analysis was made of the kinetic energy in the form of a contour diagram.

19 ON THE AMPLIFICATION OF TRANSVERSE OPTICAL PHONONS.

H. N. Spector (Illinois Inst. of Tech., Chicago).

Nuovo Cimento (10), 37: 1731-3 (June 16, 1965).

A previous phenomenological treatment (Phys. Rev., 132: 679(1964)) in which it was found that transverse optical phonon modes in semiconductors can be excited only by coupling them to the longitudinal mode is discussed. It is shown that this result arises due to neglect of the effect of the a-c magnetic field, which arises from the lattice vibrations, on the electron current.

20 NOISE ANALYSIS FOR A SILICON PARTICLE DETECTOR WITH INTERNAL MULTIPLICATION.

Haitz R.H., Smits F.M.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 198-207.

Internal carrier multiplication in a particle detector makes possible a reduction in the noise contribution of the following amplifier. The carrier multiplication, however, introduces additional noise from two sources. First, the statistical nature of the multiplication process gives rise to variations in the magnitude of the carrier multiplications. Second, as pointed out by Shockley, I the inherent statistical spatial fluctuations of impurity density within the space charge layer of a p-n juntion lead to corresponding local fluctuations of the avalanche breakdown voltage V_b. At a bias below V_b this corresponds to local fluctuations of the multiplication factor M. The significance of both noise sources is evaluated. It is found that in general multiplication will improve the energy resolution only for the detection of low energy particles and for moderate values of M. The findings are illustrated by detailed calculations for a silicon junction having a breakdown voltage of 30 volts with a corresponding space charge layer thickness of 1.3 microns, appropriate for low energy particle detection.

21 (NYO-3267-2) USE OF ISOTOPES AND SLOW NEUTRONS IN DIAGNOSIS AND TREATMENT OF NEOPLASMS.

Massachusetts General Hospital, Boston. Physics Research Lab. and Massachusetts General Hospital, Boston. Neurosurgical Service). [1965].

Contract AT (30-1)-3267. 45 p. Dep.(mn); $2.00(cy), 1(mn) CFSTI.

Recent developments are reported in the use of ultra short-lived positron-emitting radioisotopes with a camera-type scintillation detector for the localization of tumors. The advantages of 6-hr ^{99m}Tc and 1.8-hr ^{18}F for rapid diagnosis and low radiation dose to the patient are discussed. Results are summarized from investigations of the use of ^{10}B-neutron capture reactions for the selective destruction of infiltrating gliomas in selected patients. Results indicate this mode of therapy combines some of the most attractive features of external radiation therapy and internal isotope therapy. A number of boron compounds were synthetized and evaluated in mice for their selective deposition in tumors. Data are included on boron analogs of biologically-important compounds, B-containing antibodies, and miscellaneous B compounds. The development of thermoluminescent dosimeters for γ dosimetry and solid state probes using LiF plastics or H_3BO_3 as powder or solutions in water for the detection of α particles from ^{10}B is discussed. Neutron spectra were measured by threshold foil activation and converted to a differential dose spectra by use of dose-flux relationships. A computer was used in reactor neutron dose calculations and a code was developed for the IBM 7090 for the calculation of neutron spectrum and total neutron dose. The code gave excellent results with a minimum of input data and computer time when used for dose calculations on the Medical Beam Facility of the M.I.T. reactor.

22 SPECTROMETRIC ANALYSIS OF BETA-RADIATION USING SEMICONDUCTOR DETECTORS.

Hashizume A., Legrand J., Hareux F. (Centre d'Etudes Nucléaires, Saclay, France).

Vienna, International Atomic Energy Agency, 1965.

Preprint No. SM-61/66, 24 p. (In French). (CONF-650507-18).

From IAEA Symposium on Radioisotope Sample Measurement Techniques in Medicine and Biology, Vienna.

The identification and analysis of pure β emitters are often necessary in connection with the biological and medical applications of radioisotopes. Junction, surface-barrier and lithium-ion drift silicon detectors were used to analyze complex β spectra. The detectors were placed in a vacuum (10^{-3} mm Hg) at a temperature of —30°C. The resolving power of the best detector varied with temperature from 20 to 8 kev. Since the stability and resolving power of the spectrometer with junction detectors were far superior to those of the counters with organic scintillators, analytical precision was substantially improved. The results obtained for a large number of mixtures, including $^{32}P + {}^{33}P$, $^{89}Sr + (^{90}Sr + {}^{90}Y)$, etc., were compared. The results bring out the considerable advantages of this method (ease of analysis, precision, detection of low concentrations, etc.) over the conventional techniques.

23 (EUR 2274.e) PRELIMINARY RESULTS ON TIMING WITH PHOTOMULTIPLIERS AND SOLID-STATE DETECTORS.

Bertolini G., Mandl V., Pedrini A., Stanchi L.

(European Atomic Energy Community, Ispra (Italy). Joint Nuclear Research Center). 1965. 56 p. Dep.(mn).

Electronic instruments for a delayed coincidence spectrometer in the nanosecond region were developed, and a half life measurement of the 73.6-Kev excited level of ^{239}Np was performed. Preliminary measurements of the time resolution with photomultipliers were done.

24 (N64-18291) PROGRESS REPORT ON PARTICLE DETECTION AND PARTICLE DETECTORS.

Ziock K., Ritter R. C.

(Virginia Univ., Charlottesville). Nov. 30, 1963. 4 p. (NASA-CR-53389). $1.10 (CFSTI).

An investigation is conducted of a method for increasing the active volume of lithium-drifted germanium semiconductor detectors . This method involves a combination of lithium-drifting and special geometrical configurations.

25 (NP-14962) THE NONDESTRUCTIVE TESTING OF FUEL ELEMENTS BY MEANS OF COMPTON RECOIL SPECTROMETRY.

Annual Report. (Oesterreichische Studiengesellschaft für Atomenergie GmbH, Seibersdorf. Physik-Institut). [1962]. IAEA Contract 180/RB. 32 p. Dep.(min).

Results of research are presented which show that it is possible to isolate the 661-kev ^{137}Cs gamma line after fuel burning time of about 2 years and 2 weeks cooling time using Compton spectrometers with semiconductor detectors for Compton-electron determination. Design and performance of this system are described.

26 (ZfK-PhA-16) EIN STABILER UND RAUSCHARMER LADUNGSEMPFINDLICHER VORVERSTARKER FÜR HALBLEITERDETEKTOREN.

(A Stable and Low-Noise Charge-Sensitive Preamplifier for Semiconductor Detectors).

Kemnitz Peter, Kaufmann Claus.

(Deutsche Akademie der Wissenschaften zu Berlin (East Germany) and Zentralinstitut für Kernphysik, Rossendorf bei Dresden (East Germany)). Sept. 1964. 14 p. Dep. (mn).

A low-noise charge-sensitive preamplifier for semi-conductor detectors is described. After a survey of the properties of the preamplifier that are required for spectrometry, some methods for the practical realization of these requirements are discussed. A variant of the Hahn circuit is especially suitable for this purpose. It produces a noise half-value width of 2.6 kev for silicon with forming time constants from 0.3 to 0.5 μsec. The effective input capacity is 8nF. This corresponds to a change of the input pulse height of about 1% with a change of the input capacity from 20 to 100 pF.

27 SEMICONDUCTOR RADIATION DETECTORS.

Deme Sandor.

Atomtech. Tajekoztato, 8: 244-5(1965). (In Hungarian).

Semiconductor-type detectors were first used for the detection of alpha particles, at a resolution of 0.6%. Recent advances in the preparation of high-purity Si made it possible to build spectrometers with a thicker barrier layer, suitable for studying high-energy protons and other charged particles. The barrier layer of the new Li-type detectors is more than 5 mm thick; these instruments may be used for the spectrometry of 2-Mev electrons with a resolution of 40 to 50 kev. The greatest achievement during the last 2 years in this field was the development of the high-resolution Ge gamma spectrometer. As a general rule, the resolution of semi-conductor detectors is about ten times better than that of scintillation spectrometers, but their efficiency is low. Therefore, they are especially suited for studies in low-energy nuclear physics. The chief drawback of these instruments is their price and their short useful life; they lose their excellent resolution after a few months in operation or 1 to 2 years of storage. On the other hand, their fabrication is simple enough to allow their preparation at the research institutes by the workers themselves.

28 A LARGE-VOLUME, COAXIAL, LITHIUM-DRIFT, GERMANIUM GAMMA-RAY SPECTROMETER.

Malm H. L., Tavendale A. J., Fowler I. L. (Atomic Energy of Canada Ltd., Chalk River, Ont.).

Can. J. Phys., 43: 1173-81 (July 1965). (AECL-2301).

A high-resolution, germanium p-i-n diode gamma-ray spectrometer was made using the coaxial method of lithium drift. The detector described is $\sim$16 cm^3 in sensitive volume, three to four times that of the largest "planar" drifted diodes of this type rescribed to date. Its performance as a spectrometer is comparable with that of smaller diodes; resolutions (fwhm) of 3.3 and 4.8 kev were obtained at γ-ray energies of 122 and 1,333 kev respectively with a detector bias of 1,000 to 1,500 v. Typical γ-ray spectra obtained with sources of ^{57}Co, ^{60}Co, ^{137}Cs, and Th(B+C+C″) are shown. Also shown are curves of intrinsic full-energy peak efficiency over a range of energies. This efficiency is 2.5% at 1,300-kev γ-ray energy — comparable to that of a NaI scintillation spectrometer 1 in. in diameter by 1 in. long.

29 SEMICONDUCTOR RADIATION DETECTORS.

Terada D.

Genshiryoku Kogyo, 9: No. 8, 49-56 (1963).

(In Japanese).

Advantages of semiconductor detectors are given, with emphasis on p-n silicon detectors of 2.5, and 12.5 mm dia. The results of studies on alpha particles to 13 Mev showed the energy output is linearly dependent on the alpha energy. Spectrum resolution is high: the alpha spectrum from ^{210}Po, measured with a 12.5-mm-dia detector, showed a half-width of 24 kw. For wider application of such detectors the lithium-drift method is used, the high diffusion coefficient permitting a high transfer coefficient. Such a detector with a semiconductor is equivalent to a gas-filled ionization chamber. Its external appearance and construction are identical with a p-n detector. Its window diameter is 5 mm, useful area 20 mm^2, characteristic zone thickness 1500 m.

30 GAMMA ASSAY WITH LITHIUM DRIFTED GERMANIUM SEMICONDUCTOR NUCLEAR DETECTORS.

Friedland S. S. (Solid State Radiations Inc., Los Angeles).

Vienna, International Atomic Energy Agency, 1965.

Preprint No. SM-61/55, 12 p. (CONF-650507-33). ORINS.

From IAEA Symposium on Radioisotope Sample Measurement Techniques in Medicine and Biology, Vienna.

The characteristics and applications of the semiconductor nuclear radiation detector which has been fabricated from germanium and compensated to high resistivity by the Pell lithium drift method to obtain a large sensitive volume for gamma ray detection are presented. Detector thicknesses of 1 to 4 mm are readily fabricated whereas 6 mm and greater are low yield devices. Areas of 1 to 6 cm^2 are available only yield depends inversely upon the area. Gamma resolutions of less than 10 kev are obtainable under standard laboratory conditions and less than 3 kev under ideal conditions. Such high resolutions will have immediate effect on gamma assay as it may prove possible in many applications to remove the need for chemical separation. Results with ^{207}Bi, ^{166}Ho, and other sources will be shown.

31 IMPROVEMENTS IN OR RELATING TO SILICON SEMICONDUCTORS.

Messier Jean (Commissariat à l'Energie Atomique).

British Patent 979,844. Jan. 6, 1965. Priority date Nov. 24, 1961, France.

A process is described for the production of a semiconductor device that includes a silicon diode obtained by diffusion of donor and acceptor materials into the regions adjacent to parallel faces of a plate that includes an intrinsic Si semiconductor element having a resistivity of at least 5000 Ω cm. The intrinsic Si is prepared from low p conductivity Si formed by the floating zone method and subjected to thermal neutron bombardment. The irradiated Si is annealed for about 12 hr at 550°C. A heat treatment is necessary to cause the activator materials (donor and acceptor) to diffuse into the Si plate. The heat treatment is carried out in a neutral atmosphere followed by a cooling stage in which the temperature is reduced by at least 5°C/min. The resulting semiconductor device withstands a high reverse voltage, and is useful in ionization and nuclear radiation detectors.

32 NUCLEONICS HANDBOOK OF REACTOR RESEARCH AND TECHNOLOGY.

New York, Nucleonics, (1965). 255 p. $2.00.

General reference data are given on nuclear instrumentation for medicine and biology, measuring gamma activity with whole-body counters, world development of whole-body counters, autofluoroscopes, gamma and positron scintillation camera, solid-state dosimeters for *in vivo* measurement, miniature p-i-n junctions for *in vivo* dosimetry, computer techniques, radiotracers in medicine, tailoring the isotope to the need, optimization of a scanning method using ^{99m}Tc, biological aspects in the choice of scanning agents, high-geometry system for counting low activity levels, developments in nuclear-particle detections, semiconductor and scintillator data analysis, semiconductor detectors, semiconductor properties and applications, isotope costs and availability, isotope-generator reliability and safety, generator performance and mission prospects, RBE for solar-flare protons, separation distance for ^{90}Sr and ^{244}Cm, single-stage spaceships, missions for nuclear instruments, surface-barrier detectors for isotopic age measurements, Van de Graaff nuclear structure studies, medical research with high-energy heavy particles, activation analysis, radiation effects on transistors in space and in-line fission-product monitor.

33 IN VIVO RADIATION DOSIMETRY FOR CLINICAL AND EXPERIMENTAL RADIATION THERAPY.

Roswit Bernard, Malsky Stanley J., Amato Charles G. (Veterans Administration Hospital, Bronx, N. Y).

Progr. Clin. Cancer, 1: 96-126 (1965).

An extensive account of the development, characteristics, and applications of solid-state, *in vivo* dosimeters is given. A systematic and critical survey was made of existing dosimeters, employing certain criteria generally regarded

as essential and desirable for any proposed *in vivo* dosimetry system (detectors, applicators, reader, and instrumentation). Examination of ionization chambers, Geiger counters, scintillation crystals, chemical dosimeters, photographic emulsions, and solid state detectors showed that none, with the exception of the solid state materials, satisfied most of these criteria. Their outstanding limitation was excessive size, but other faults included marked energy dependence, unsatisfactory dose range, costliness, poor read-up technology, sterilization problems, and unavailability. The solid state materials, however, appeared to provide the best sources for development of successful *in vivo* dosimetry systems, and two solid state systems, both based on the production of luminescence, were used as a basis for the *in vivo* dosimetry developed. The development of a miniature radiophotoluminiscent (RPL) glass rod dosimeter (measuring 1 by 6 mm) is discussed. This dosimeter, with appropriate shielding and screening, can be employed effectively in clinical and investigative studies where accurate *in vivo* measurements are essential. Also described are RPL dosimeters, made in the form of a cylinder: 1 mm in outside dia and 6 mm in length. Spheres 5 mm in dia have also been made. These glass dosimeters are comprised of a matrix and an added impurity of dope; silver metaphosphate — the radiation sensitive element. When x or γ rays are absorbed by the glass, disassociation takes place and photochemical reactions follow. There is a net formation of atomic silver of zero valence, which in the proper electronic environment as provided by the host absorb uv light and re-emits it as orange-yellow light, the intensity of which is directly proportional to the amount of radiation absorbed. This is the basis for this relative dosimetry system, ionizing radiation exciting the radiation-sensitive glass. The orange-yellow fluorescence is detected, using a yellow bypass filter and a suitable photo-multiplier tube: the output current of the tube is amplified and a read-out system is employed using a dc microammeter. The characteristics of some glasses are listed in a table, and are extensively discussed. These dosimeters cost less than $.50 each. The glass is fabricated as long rods having the desired diameter, and these rods are cut into small cylinders, 6 mm high. The use of regular composition glass to measure the γ exposure delivered by a mixed radiation field containing both γ rays and neutrons is also considered. Clinical applications of the *in vivo* system of dosimetry in radiation therapy, using screened, predised, gold-shielded glass rods which are energy independent in the whole therapy range from 250 to 2000 kev, including radium, radon, irridium-192, cobalt-60 and cesium-137, are considered. Its accuracy was good ($\pm 7\%$), and it was dependable in all tissue volumes, even for total-body radiation. Precise radiographic localization within the body is possible because of the opaque gold shield. With the dosimeter so miniaturized it is possible to place it with safety and ease in nearly every body tissue organ and space in the living patient. Although RPL dosimetry has solved many clinical problems in radiotherapy, it has certain limitations. Its range is restricted to from 10 to 15,000 R; and its energy response in the very low-energy region (as in diagnostic radiology) is unsatisfactory, even when low Z glass is used. A complementary dosimetry system based on the principle of radiothermoluminescence (RTL) may overcome these deficiencies. The estimated range for RTL dosimeters is slightly less than 1 mR to almost 250,000 R.

34 BIOLOGICAL, MEDICAL, AND ENVIRONMENTAL RESEARCH PROGRAM. CURRENT MAJOR ADVANCEMENTS.

P. 183-201 of "Fundamental Nuclear Energy Research, 1964." Washington, D. C., Atomic Energy Commission, 1964.

The development of silicon diode detectors for low-energy x and γ measurements and Li-drifted Ge detectors of measurements of high-energy γ radiation; the development of instruments for use in studies of the color and time course of delayed light in illuminated plants and the relation of delayed light to fluorescence; the development of a low-level multidimensional γ spectrometer for use in coincidence measurements of characteristic photons of radionuclides in a mixture; the development of an automated recording densitometer for use in film badge processing and data recording; and the development of procedures for measuring atmospheric radioactivity and fallout.

35 APPLICATION OF LITHIUM-DRIFTED GERMANIUM SOLID-STATE DETECTORS TO THE DETERMINATION OF HAFNIUM IN ZIRCONIUM OXIDE BY ACTIVATION ANALYSIS.

Girardi Francesco, Guzzi Giampaolo, Pauly Jules (European Atomic Energy Community — Joint Nuclear Research Center, Ispra, Italy).

Radiochim. Acta, 4: 109-10 (June 1965).

Samples (about 0.1 g of zirconium oxide) were irradiated for two hours in the reactor in a flux of about 2×10^{13} n/cm^2/sec. The irradiated capsule was then left for 2 to 7 days to allow for the decay of the short-lived interfering radioactivities, especially that of $^{97}Zr + ^{97}Nb$. Then the radioactivity was measured by means of a lithium-drifted germanium detector. The gamma spectrum of an irradiated sample of zirconium oxide containing 90 $\pm$ 3 ppm of hafnium is shown.

36 (AECL-2252) γ-RAY DOSIMETRY WITH p-i-n JUNCTION COUNTERS.

Jones A. (Atomic Energy of Canada Ltd., Chalk River [Ontario]).

Feb. 1965. 17 p. Dep.; $0.50 (AECL).

A manufacturing process was developed for low cost p-i-n junction counters, having 5 and 100 mm^2 junctions with intrinsic layer thickness of 1 mm. The performance of 20 samples as γ-ray dosimeters and the performance stability over a period of 19 months are described. In addition, suitable techniques and circuits to permit the application of these detectors to γ-ray dosimetry are discussed.

37 (INR-584/II/PS) BEAT-FREQUENCY METHOD FOR THE CAPACITANCE MEASUREMENT OF SEMICONDUCTOR NUCLEAR- PARTICLE DETECTORS.

Przyborski W. (Institute of Nuclear Research, Warsaw (Poland)).

Dec. 1964. 15 p. CFSTI.

Capacitance effects in semiconductor nuclear particle detectors, the principle of capacitance measurement methods, and the apparatus constructed are discussed briefly. Voltage-capacitance characteristics for the surface-barrier, thermal-diffused, and Li-ion-drifted detectors are presented.

38 SEMICONDUCTOR DETECTORS AS COUNTERS FOR A MAGNETIC BETA SPECTROMETER.

Walthard B., Schellenberg L., Huber O. (Universität Freiburg i. B.).

Helv. Phys. Acta, 38: 299-327(May 15, 1965)(In German).

Some general properties of commercially available Si-detectors are discussed. The problem of optimal preamplifiers in order to obtain best coincidence-resolution is then considered. With the assumption of exponential rise of the detector-pulse the optimal time-constants of the amplifier were found to be 2 to 10 times longer than that of the detector. Finally some coincidence-arrangements are described.

39 COLLECTION TIME AND EQUIVALENT CIRCUIT OF SURFACE BARRIER SEMICONDUCTOR DETECTORS.

Fabri G., Svelto V. (Laboratori CISE, Milan).

Nucl. Instr. Methods, 35: 83-7 (1965).

The rise time of silicon surface-barrier detector pulses was measured under excitation by alpha particles. Such a measurement made it possible to check both the collection time of charge carriers in the depletion region and the equivalent circuit of the detector. The measurements were made by comparing, at the output of a fast amplifying chain, the waveforms due, respectively, to alpha particles and to artificial pulses obtained by injecting a calibrated charge ($\delta(t)$-current pulse) into the detector. The measured parameter T turns out to be equal to $T = \tau + R_s C_0 + R_e C_0$, where τ is the collection time, C_0 the depletion layer capacity, R_s the bulk resistance due to the undepleted material, and R_e a series resistance. It was experimentally verified that T, according to the theory, is a linear function of $V^{-1/2}$, where V is the detector bias.

40 ON THE INFORMATION AVAILABLE FROM THE RISE-TIME OF THE CHARGE PULSE SUPPLIED BY SEMICONDUCTOR PARTICLE DETECTORS.

Quaranta A. Alberigi (Università, Bologna), Casadei G., Martini M., Ottaviani G., Zanarini G.

Nucl. Instr. Methods, 35: 93-9 (1965).

It is shown that by measuring the collection time of the charge released in the depletion layer of a solid-state radiation detector, some information can be obtained about the ionizing particle impact angle or about its range in the depletion layer. Several criteria are also given for selecting the detectors suitable to obtain the above mentioned information.

41 POSSIBLE IMPROVEMENT OF SIGNAL-TO-NOISE RATIO BY CORRELATION IN AN EXPERIMENT ON PARTICLE IDENTIFICATION.

Escudie B., Chery R. (Institut de Physique Nucléaire, Lyon).

Nucl. Instr. Methods, 35: 105-8 (1965). (In French).

A technique for improving the signal-to-noise ratio in particle identification by energy losses in semiconductor detectors is analyzed.

42 MEASUREMENT OF PARAMETERS AND THEIR INFLUENCE ON RESOLUTION ON PREAMPLIFIERS USED WITH SEMICONDUCTOR PARTICLE DETECTORS.

Leventhal E. A. (Philips Labs., New York).

Nucl. Instr. Methods, 35: 325-7 (Aug. 1965).

A condition that relates an optimum preamplifier capacitance to the detector capacitance is derived; the intercept and initial slope of the resolution vs external capacitance curve are expressed in terms of the parameters of the preamplifier input tube. A method for determining tube parameters is also described.

43 A Ge(Li) GAMMA RAY SPECTROMETER.

Fox R. J., Williams I. R., Toth K. S. (Oak Ridge National Lab., Tenn.).

Nucl. Instr. Methods, 35: 331-3 (Aug. 1965). (ORNL-P-1314).

A gamma- and x-ray spectrometer is described in which a lithium-drifted germanium crystal immersed in liquid nitrogen is used. Photopeak detection efficiency curves obtained for Ge(Li) and Na I(Tl) crystals using x and gamma sources are included, together with ^{207}Bi gamma calibration spectra obtained with both types of crystals. Photon spectra obtained from gadolinium isotopes using Ge(Li) detectors demonstrate the use of the detector both in the conventional manner and as a sum spectrometer.

44 A dE/dx-E-T PARTICLE IDENTIFICATION SYSTEM.

Parkinson E. R., Bodansky D. (Univ. of Washington, Seattle).

Nucl. Instr. Methods, 35: 347-9 (Aug. 1965).

A particle identification system is described in which the energy-loss and time-of-flight methods are combined.

45 (EURAEC-1384) SOLID STATE NEUTRON DETECTOR.

Final Report No. 2, October 1, 1963-September 30, 1964.

Contract 099-63-10-RDB. 64 p. (EUR 2347) Dep.(mn); $3.00(cy), 2(mn) CFSTI.

Work Performed under United States-Euratom Joint Research and Development Program.

The response to α particles of an americium and polonium source of SiC particle detectors upon reactor irradiation is studied. The change of the pulse-height, the I-V characteristics, the capacity vs. reverse bias, the short-circuit photocurrent and the open-circuit photovoltage upon reactor irradiation (BR1) were measured. Annealing studies were performed to 650°C. By comparing the calculated and the experimentally determined pulse-heights a relation is obtained between the lifetime of the charge-carriers and the fast neutron flux. Although the observations are too scanty to be decisive they seem to point to a simple radiation damage mechanism. Assuming that one kind of recombination center is formed, that the number of recombination centers is proportional to the fast neutron flux and that the Fermi-level is not displaced upon irradiation. The term δ was calculated from the relation $\tau_j = [1/\delta\varphi + 1/\tau_0)]$. For detector CEN-4, which was irradiated at 80°C, δ is found to be 10^{-4} cm^2 sec^{-1}. For detector CEN-6, which was irradiated at 250°C, $\delta = 10^{-5}$ n_f^{-1} cm^2 sec^{-1}. The smaller value for detector CEN-6 may indicate that a simultaneous annealing of a part of the primary defects along with their formation upon irradiation occurs at 250°C in agreement with the observations. Heating to 650°C has no further effect. From the assumption that 100 recombination centers are formed per fast neutron per cm follows that for $\delta = 10^{-4}$ n_f^{-1} cm^2 sec^{-1} the capture cross-section for recombination of charge-carriers is 10^{-13} cm^2. For $\delta = 10^{-5}$ n_f^{-1} cm^2 sec^{-1} the charge collection-efficiency of a properly designed SiC particle detector will reduce to 10%, which is about equivalent to the noise-level, at 10^{15} nvt.

46 PREPARATION, CHARACTERISTICS, AND APPLICATIONS OF HIGH-VOLTAGE SILICON SURFACE-BARRIER DETECTORS.

Ernest D. Klema (Northwestern Univ., Evanston, Ill.).

IEEE (Inst. Elec. Electron, Engrs.), Trans. Nucl. Sci., NS-12: 288-90 (Feb. 1965).

Surface-barrier detectors were fabricated from high-resistivity (up to 20,000 ohm-cm) n-type silicon by a technique which allows them to be operated at large reverse-bias voltages without guard rings. Protons of 17-Mev energy obtained from (d,p) reactions at the Argonne National Laboratory Tandem Van de Graaff accelerator were stopped with a reverse bias of 700 v on a detector made of 20,000 ohm-cm material. The detector area is 28 mm^2, and it was cooled by means of a thermoelectric device. Under these conditions, the measured energy resolution is 29 kev for the protons, and the leakage current is 0.1 μamp. This detector operates satisfactorily at reverse biases up to 1800 v. At this voltage, its measured energy resolution for 1-Mev electrons is 35 kev at room temperature, and its leakage current is 1.12 μamp. Special precautions required when the detectors are used at accelerators are discussed. The methods used to form the inversion layers of these detectors and to protect their edges are discussed in some detail since it is necessary that the reverse bias be withstood with both low noise and low leakage current to obtain good energy resolution. The characteristics of some of these detectors were observed for a period of two years, and conditions necessary for their stability with time are given. The detectors were also tested in a vacuum of 2×10^{-6} mm of Hg for a period of several months and were found to be stable under these conditions. Satisfactory techniques were developed and used to fabricate detectors as small as 2 mm and as large as 2.7 cm in diameter.

47 NEW RESULTS ON THE RECTIFYING PROCESS IN SURFACE BARRIER COUNTERS.

P. Siffert and A. Coche (Centre de Recherches Nucléaires, Strasbourg).

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: 284-7 (Feb. 1965).

In order to understand the rectifying process involved in silicon surface-barrier particle counters, the usual gold contact was substituted with various metals. The results obtained from this substitution with twenty different metals are given. Results concerning the formation of the rectifying process for the case of gold-silicon diodes are presented. In particular, the resistivity of silicon and the thickness of the gold film were considered.

48 A LITHIUM DRIFTED GERMANIUM SURFACE BARRIER DETECTOR.

H. DeLyser (Solid State Radiations, Inc., Los Angeles), F. P. Ziemba, and W. R. Van Antwerp.

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: 265-74 (Feb. 1965).

The fabrication procedure and some properties of thin-window lithium-compensated germanium nuclear-particle detectors are described. Their response to various nuclear particles is illustrated with typical spectra. In addition, some data on collection times in germanium and silicon detectors are presented, along with a description of experiments concerning the relative energies to form an electron-hole pair in silicon and germanium at liquid-nitrogen temperature. Finally, the relative response of germanium and silicon detectors to fast neutrons is compared.

49 LARGE GERMANIUM LITHIUM-DRIFT p-i-n DIODES FOR GAMMA-RAY SPECTROSCOPY.

A. J. Tavendale (Atomic Energy of Canada Ltd., Chalk River, Ont.).

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci. NS-12: 255-64 (Feb. 1965).

Lithium-drifted germanium p-i-n diodes with depletion depths up to 11 mm and an active volume 6 cm^3 were fabricated from 10 ohm-cm, gallium-doped material using a high-power drift method. The diodes were immersed in chloroform and drifted at ohmic dissipation power levels in the range 50 to 100 w at 30 to 50 v d-c drift bias. Diodes were electrothermally stabilized during drift by the boiling action of the chloroform. Peak power levels of up to 250 w at 200 v bias were obtained at the

commencement of the chloroform drift, but were reduced to within the range given above following a rapid increase in leakage current during the first few hours of drift. Diode temperatures were estimated at 10 to 20°C above the chloroform boiling point. Drift times were typically 500 to 700 hr for depletion depths of 8 and 10 mm respectively. Seven diodes with depletion depths of 6 to 11 mm were operated as gamma spectrometers in vacuum (10^{-6} mm Hg) at liquid N_2 temperatures (77°K) with bias up to 1200 v and leakage current $\sim 10^{-9}$ amp. Some typical spectral response characteristics are given for diodes used as photoelectric gamma spectrometers, and the effect of carrier trapping on energy resolution is demonstrated. Resolutions of 3.5 and 8.0 kev on the full-energy peaks of 122- and 1333-kev gamma rays were obtained from a device of average performance (5 $cm^2 \times$ 7 mm depletion depth). The intrinsic full-energy peak efficiency of a 4.0 cm^3 diode was measured at 1% at 1000-kev gamma energy. A diode of "open-ended" coaxial construction, partially drifted to an active volume of 16.5 cm^3, was tested as a gamma detector. The advantages of this structure are discussed.

50 UTILIZATION OF WEB SILICON FOR POSITION-SENSITIVE DETECTORS.

E. J. Ludwig (Rutgers Univ., New Brunswick, N. J.), W. B. Gibson, and J. S. Hood.

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: 247-54 (Feb. 1965).

Position-sensitive, surface-barrier detectors were made with web silicon, a hyper-pure silicon in ribbon form.. Several characteristics of this material are especially suited for position detectors, long lengths, flexibility and high surface lifetimes. In addition, the structural stability, thickness uniformity, and thin cross sections make this material attractive for standard or position-sensitive dE/dx detectors. Counters with active areas of 2-3.5 cm × 2-4 mm were tested with 5.5-Mev alpha particles yielding spectra sensitive in position to less than 1%. A region of twin planes is exhibited within the material by changes in the slope of the plots of detector capacitance and leakage current as functions of reverse bias. The effect of the twin planes on the carrier collection efficiency was investigated with several samples and found to be significant in certain cases. These results are discussed in terms of carrier lifetimes.

51 (ORNL-TM-1055) OPTIMIZATION OF SEMICONDUCTOR PREAMPLIFIERS FOR USE WITH SEMICONDUCTOR RADIATION DETECTORS.

Theron Vaughn Blalock (Oak Ridge National Lab., Tenn.).

Feb. 23, 1965. Contract [W-7405-eng-26]. 252 p. Dep.(mn); $6.00(cy), 4(mn) CFSTI.

The input and filter sections of the nucleonic preamplifier, which determine the noise line width and the pulse shape, are considered. A literature survey of theoretical physical operation and noise characteristics of field-effect transistors is presented. A noise theory based on a power-law doping profile is developed. Design considerations for optimum input-section performance are presented. Expressions for pulse response and noise power spectral density are derived. Pulse geometry and signal-to-noise ratios of various filter sections are considered. Experimental results are presented and correlated with the design theory.

52 (INR-583/II/PL) SIMPLE CRYOSTAT FOR COOLING OF NUCLEAR RADIATION SEMICONDUCTOR DETECTORS.

W. Przyborski (Institute of Nuclear Research, Warsaw (Poland)).

Dec. 1964 . 8 p. Dep.

The design of a simple cryostat for nuclear radiation semiconductor detectors applications at low temperatures is described. In this cryostat, a sample temperature of about 90°K can be achieved, using ¼ liter of liquid nitrogen only, and 1 liter suffices to maintain this temperature for 5 to 7 hours. The appropriate cooling time is 20 min, and 5 to 7 min is required to warm up the previously cooled sample to the room temperature.

53 GAS DENSITY MEASURING APPARATUS USEFUL AS ALTIMETER.

James Montgomery McKenzie (North American Philips Co., Inc.).

U. S. Patent 3,173,004. Mar. 9, 1965. Filed July 17, 1961.

The gas density measuring apparatus described consists of a source of heavy charged particles for injecting particles into a sample of the gas whose density is to be measured, a semiconductor radiation detector positioned to receive and detect the particles after passage through the gas sample and to generate a signal representative of the energy attenuation of the particles, and means for utilizing the signal to determine the density of the gas. The preferred particles are α particles from Am^{241}. The device is applicable in a gas density range of about 1.0 to 0.1 mg/cm^2, which corresponds to an altitude of 6000 to 60000 ft.

54 A CRYOSTAT FOR SEMI-CONDUCTOR GAMMA RAY DETECTORS.

C. Chasman and R. A. Ristinen (Brookhaven National Lab., Upton, N. Y.).

Nucl. Instr. Methods, 34: 250-2 (May 1965). (BNL-8692).

Cryostats for lithium-drifted germanium gamma detectors were designed and constructed using routine machine shop practices. These holders feature liquid nitrogen replenishment cycles of up to three weeks and activated charcoal sorption pumping which eliminates the need for external vacuum pumps. Low rates of lquid nitrogen consumption were attained by using thin walled stainless steel com-

ponents in heat leakage paths, by utilizing commercially available super-insulated Dewars and by maintaining a sufficiently high vacuum.

55 PERFORMANCE OF A Au-Si SURFACE BARRIER DIODE AS A BETA RAY DETECTOR.

PART II.

D. R. Brundrit and S. K. Sen (Univ. of Manitoba, Winnipeg, Can.).

Nucl. Instr. Methods, 34: 225-8 (May 1965).

A study was made of the variation of the peak absorption efficiency of a Au-Si surface barrier detector with energy and depletion depth using monoenergetic beams of electrons and positrons. The results differ from those of previous work, in the sense that this work shows a continuous decrease of peak efficiency with electron energy mainly because of scattering out of the detector. A slight difference between electron and positron detection was observed. The positron curve shows a tail on the high energy side due to Compton scattering of the positron annihilation gamma rays.

56 ENERGY DEPENDENCE OF PULSE HEIGHT DEFECT WITH FISSION FRAGMENTS IN A SILICON SURFACE BARRIER DETECTOR.

H. Kobayashi, A. Nakamoto, and M. Hosoe (St. Paul's Univ. Rikkyo Daigaku, Yokosuka, Japan).

Nucl. Industr. Methods, 34: 222-4 (May 1965).

Pulse height defect of a surface barrier detector for fission fragments was estimated for each energy respectively. The pulse height defect was obtained from comparison between an integrated curve of a fragment energy spectrum after prompt neutron emission and an integrated curve measured by the surface barrier detector. A discontinuity of pulse height defect was found between the heavy and the light fragment groups. For the heavy fragment group, the pulse height defect has linear relation with fragment energy. While, for the light fragment group, the pulse height defect increases drastically at the high energy region and no linear relation was observed.

57 PROGRESS IN THE APPLICATION OF SEMICONDUCTOR DETECTORS TO NUCLEAR PHYSICS EXPERIMENTS.

H. M. Mann (Argonne National Lab., Ill.).

IEEE (Inst. Elec. Electron. Engrs.), Trans. Nucl. Sci., NS-12: No. 2, 88-98 (Apr. 1965).

The selection of a detector for a particular experiment is briefly discussed, together with experiments in which phosphorus-diffused silicon detectors and lithium-drifted germanium detectors were used. The performance and areas of applicability of these detectors are considered.

58 (TID-21844) CALIBRATION OF A SILICON SURFACE-BARRIER DETECTOR TO READ NEUTRON DOSE INDEPENDENT OF INCIDENT NEUTRON ENERGY.

(Thesis).

Alfred John Ahlquist (Washington Univ., Seattle).

1965. 42 p. Dep.(mn); $2.00(cy), 1(mn) CFSTI.

A Si surface-barrier detector with a LiF foil was calibrated for reading neutron doses independently of both the neutron energy and the associated gamma radiation. The 10-inch polyethylene sphere, used to moderate the neutrons, was found to give a response similar to the inverse of the Radiation Protection Guide curve. The sensitivity and lifetime of the detector are discussed.

59 (NP-14875) TESTS ON A p-n JUNCTION SEMICONDUCTOR RADIATION DETECTOR AND A LOW NOISE AMPLIFIER SYSTEM.

M. De Carolis, G. Hannestad, and L. Svansson (European Company for the Chemical Processing of Irradiated Fuels, Mol (Belgium)).

Sept. 1964. 36 p. (ETR-168). Dep.(mn); $2.00(cy), 1(mn) CFSTI.

A series of measurements was taken on two surface barrier semiconductor detectors, a charge sensitive preamplifier, and a low noise amplifier assembly. The purpose of these tests was to find the efficiency of all the equipment and the difference existing between two detectors of different resistivity, and to investigate the optimum conditions for the electronic equipment. A short summary is given on how a semiconductor detector works with its amplifier system.

60 (KFK-257) SCHNELLER VORVERSTÄRKER 100 K-EKP.

(The Fast preamplifier 100 K-EKP).

Joachim Kind (Kernforschungszentrum, Karlsruhe (West Germany). Institut für Experimentelle Kernphysik).

Nov. 1964. 9 p. Dep.(mn).

The characteristics, circuit, and performance of a fast preamplifier that can be used for fast signals from semiconductor detectors are reported.

61 (CLOR/IBJ-II-33) COUNTING-RATES REPRODUCIBILITY AND ACCURACY IN MEASURING ALPHA ACTIVITY WITH Si(Au) SURFACE-BARRIER DETECTORS.

J. Roman, M. Slapa, and J. Chwaszczewska (Centralne Laboratorium Ochrony Radiologicznej, Warsaw (Poland)).

1964, 33 p. Dep.

The behavior of the silicon surface-barrier detectors, under ordinary laboratory conditions, in measuring alpha activity was investigated. The operating characteristics taken both

with voltage and with charge-sensitive preamplifiers are given. It was investigated, whether any counting errors can be stated in addition to the statistical fluctuations theoretically expected, when measuring alpha acivity with an accuracy of 0.3%. Also the drift of counting rates in long-term operation was examined. The effects of changes in temperature, fluctuations of detector bias, exposure during storage to daylight, and rapid changes in counting rates were considered. The results obtained show that the discussed detectors are well suited for low-level counting, where long-term stability is required. The high accuracy and reproducibility of counting rates make them promising in absolute measuring methods. The useful life time of the detectors is limited by the radiation damage in the silicon. The changes in the operating characteristics were studied and relevant results are presented.

62 NUCLEAR RADIATION MEASURING SYSTEM UTILIZING A RADIO RECEIVER.

Robert M. Kiehn.

U. S. Patent 3,160,750. Dec. 8, 1964. Filed Dec. 8, 1964.

A radiation ratemeter device is patented for use with an ordinary AM radio receiver to enable radiation intensity to be indicated by the frequency scale on the radio receiver when the tuning knob is turned to such a position that a certain tell-tale tone signal is produced. The device employs a radiation-sensing cell, such as a CdS photocell screened from light, of high resistance at low radiation intensity and whose resistance is inversely proportional to radiation intensity. A semiconductor, variable capacitance, junction diode and connections are provided for varying the voltage across the diode in response to changes in resistance of the sensing cell. A tuned oscillator circuit generates an r-f carrier whose frequency is determined by the capacitance of the diode; and a tone modulator system, which may include at least most of the oscillator circuit, produces a tone-modulated signal having a frequency in the range of 550 to 1700 kc.

63 COUNTER DIODES AND COUNTER TRANSISTORS.

Werner Czulius (Siemens-Schuckertwerke AG, Erlangen, Ger.).

P. 216-44 of["Vortrag auf der Halbleiter-Tagung in Saarbrucken am 5. IV. 1962, Erschienen in Festkorperprobleme Band 2."] Verlag Vieweg, 1963 (In German).

A bibliographic review is given of the most important properties and applications of counter diodes and counter transistors.

64 A LOW NOISE CHARGE SENSITIVE AMPLIFIER FOR USE WITH SOLID STATE RADIATION DETECTORS.

S. Z. R. Hashmi (Univ. of Texas, Austin).

Indian J. Pure Appl. Phys., 3: 107-9 (Mar. 1965).

Circuit details and noise characteristics of an improved charge-sensitive amplifier using the 8058 Nuvistor tubes, are described. The amplifier employs negative charge feedback in order to keep the output amplitude essentially independent of the value of the detector capacitance. A noise line width of nearly 5 kv is obtainable for best overall performance.

65 THE QUENCHING BY A MAGNETIC FIELD OF ENHANCED PULSES IN A SILICON RADIATION DETECTOR.

Hubert P. Yockey and Norman A. Baily (Hughes Research Labs., Malibu, Calif.).

Appl. Phys. Letters, 6: 163-4 (Apr. 15, 1965).

The effects of an applied magnetic field on multiplication phenomena in a Si semiconductor detector were studied using a n-p-n structure made by evaporating Al on both sides of a p-type Si wafer. Alpha particles from a ^{212}Po-^{212}Bi source were allowed to fall alternately on the positively and negatively biased barrier surfaces. With a magnetic field transverse to the applied electric field, the larger effect was observed for particles entering the negatively biased surface. This observation and observations with a parallel magnetic field are consistent with a dependence of the degree of multiplication on the path length of electrons in the device.

66 THE MEASUREMENT OF FAST NEUTRON SPECTRA AT HIGH REACTOR POWERS.

F. Boreli, N. Berovic, M. Aleksic, and V. Lazarevic.

Bull. Boris Kidrich Inst. Nucl. Sci., 14: 255-8 (Oct. 1963).

The fast neutron spectrum ranging from 1 to 6 Mev at the exit aperture of the horizontal channel B of the RA reactor was measured at 2 Mw, using a simple semiconductor counter telescope.

67 RESULTS OF THE TELSTAR RADIATION EXPERIMENTS.

W. L. Brown, J. D. Gabbe, and W. Rosenzstig (Bell Telephone Labs., Inc., Murray Hill, N. J.).

Bell System Tech. J., 42: 1505-9 (July 1963).

Results are given of the Telstar experiments measuring energy, time, and space distributions of electrons and protons, using Si p-n junction detectors, and of the integral radiation exposure of the satellite calculated from these distributions. Connections of the charged-particle distributions with nuclear explosions are discussed. Radiation damage to the semiconductor detectors, the solar power plant, and solar cells and damage transistors is reported and compared with that predicted on the basis of orbital integral radiation exposures.

68 THE SPACECRAFT RADIATION EXPERIMENTS.

N. L. Brown, T. M. Buck, L. V. Medford, E. W. Thomas, H. K. Gummel, G. L. Miller, and F. M. Smits (Bell Telephone Labs., Inc., Murray Hill, N. J.).

Bell System Tech. J. 42: 899-941 (July 1963).

Radiation experiments on the Telstar spacecraft were designed to measure the distribution in energy, position, and time of electrons and protons geomagnetically trapped in the Van Allen belts, thus characterizing the radiation environment of the satellite and providing an understanding of mechanisms responsible for particle injection into, and less from, the belts. Some experiments also measured directly the integral radiation damage on semiconductors protected by different thicknesses of shielding. An experiment measuring the orientation of the satellite with respect to the sun is also included. A correspondence was established between the radiation damage in the solar-cell supply, the solar cells and transistors of the radiation experiment, and the distribution of particles responsible for the damage. All parts of the experiment performed as expected, and the particle detectors, continuing satisfactory operation after several months in space.

69 CHARGE COLLECTION EFFICIENCY.

Frank Keywell.

20 p. (CONF-641210-5).

From American Physical Society Meeting, Berkeley, Calif.

A method is outlined for obtaining a first-order estimate of the back collection efficiency in a solid-state detector from pulse height vs bias voltage data.

70 TRUDY PYATOI NAUCHNO-TEKHNICHESKOI KONFERENTSII PO YADERNOI RADIOELEKTRONIKE.

18-23 DEK. 1961. (Reports of the Fifth Scientific-Technical Conference on Nuclear Radioelectronics, Dec. 18-23, 1961. Vol. Radiation Detectors).

V. K. Voitovetskii, ed. Moscow, Gosatomizdat, 1963. 144 p. (CONF-611201 (Vol. 3)).

Nineteen papers on radiation detectors are included. Spark chambers for particle track recordings, scintillation and semiconductor neutron detectors, and ionization detectors for fission particles are discussed. Neutron and γ spectrometers used for measuring the neutron time of flight and for separated gamma and neutron recordings are also discussed.

71 PREAMPLIFIERS FOR SEMICONDUCTOR CHARGED PARTICLE DETECTORS.

B. V. Fefilov.

Tr, 5-oi Pyatoi Nauchn.-Tekhn. Konf. po Yadern.

Radioelektronike, 1961, 39-43 (1962). (In Russian).

Specifications for semiconductor charged-particle detectors are discussed. A preamplifier circuit diagram for use with silicon detectors having a surface barrier is presented. The preamplifier input is on a cascade circuit, which ensures minimum noise. The best tubes for the circuit are 6S3P and 6S4P triodes . The signal is further amplified by a twin with 6Zh9P tubes and a large negative feedback. The preamplifier output is coordinated with cable RK-2 by a cathode follower on the 6S3P tube. The preamplifier amplification factor is 500. The output amplitude of the signal is stabilized when the detector bias and capacitance shift by a capacitance feedback through a small capacitor on a so-called charge amplifier. A circuit diagram is also given for a preamplifier for use with semiconductor detectors in a strong magnetic field. The best tubes here are the 6S6B and 6N16B. Because the electrodes are flat, when they are oriented perpendicularly to the lines of force of the magnetic field, the steepness of the anode current does not decrease more than 30% with an increase in the magnetic field from 0 to 12 kgauss. This preamplifier is built on the same circuit as the first. Since the circuit has only a few small parts, the total volume occupied is 50 cc or less. The overall amplification factor is 35.

72 MULTI-CHANNEL DIGITAL PROGRAM GENERATOR FOR SIMULATING CHARGED PARTICLE PENETRATION OF COUNTER TELESCOPES.

Richard Weissman (Univ. of Chicago).

Rev. Sci. Instr., 36: 683-9 (May 1965).

The simulation of charged-particle penetration in solid-state detectors was accomplished, using 2-μsec infrared light pulses. Infrared stimulators were incorporated in the design of cosmic-ray telescopes for space experiments, and a program generator was designed and built to provide programmed groups of stimulus pulses in which various coincidence and anticoincidence combinations can be set up in the detectors with a predetermined choice in each group of amplitude, repetition rate, and number of simulated events. The program generator and infrared pulsing circuits are described with consideration given to the logic design and circuitry employed. Other applications of the program generator are discussed, such as providing serial and parallel binary coded word groups, programmed sets of pulse trains, and/or time delays of fractions of a milli-second up to months in duration, control of or by computer data systems, and general purpose digital system testing.

73 APPLICATIONS OF GERMANIUM GAMMA-RAY DETECTORS.

David A. Shirley (Univ. of California, Berkeley).

Nucleonics, 23: No. 3, 62-6 (Mar. 1965). (UCRL-11865).

The performance of lithium-drifted germanium detectors in gamma spectrometry is discussed in relation to that of NaI(Tl) devices, showing the superior resolution and speed of the former. Applications of germanium detectors to gamma spectrum analysis; coincidence and angular-correlation measurements; Mössbauer spectroscopy; and studies of nuclear orientation, conversion coefficients, neutron-capture gamma rays, and meson (μ) x rays are then considered.

74 NUCLEAR INSTRUMENTATION MAKES TRIPLE PLAY.

H. McIntyre, D. R. Popoff, and C. Arthur Law.

Can. Controls Instr., 4: 32-40 (Jan.-Feb. 1965).

Descriptions of developments in nuclear instrumentation are presented. Industrial radiosotope performance, failsafe controls for irradiation plants, and semiconductor diodes for gamma detection are discussed.

75 P-I-N DIODES PINPOINT GAMMA RADIATION.

Can. Chem. Process., 49: 77-82 (Feb. 1965).

A specially-treated semiconductor promises to provide the key to better neutron activation analysis. Lithium-drifted germanium p-i-n diodes developed for gamma spectroscopy allow intrinsic efficiencies of 0.1 to 1.0% with resolutions that can be 10 times better than the sodium iodide spectrometer.

76 BF_3 COUNTERS. CONVENTIONAL FISSION CHAMBERS. SEMICONDUCTOR-FISSION CHAMBERS.

J.-L. Campan, J. Duchene, J.-P. Gourdon, and R. Schuttler (Centre d'Etudes Nucléaires, Saclay, France).

Bull. Inform. Sci. Tech. (Paris), No. 82, 1-7 (Apr. 1964). (In French) (EUR 2136.f).

The essential characteristics of ionization detectors for the measurement of in-pile neutrons available in industry or produced in the CEA laboratories are summarized together with the trends of detectors now being investigated.

77 THE INVESTIGATION OF THE BETA SENSITIVITY OF A SURFACE-BARRIER SEMICONDUCTOR DETECTOR.

Dezsoe Varga.

At. Kozlemen., 6: 143-9 (Dec. 1964). (In Hungarian).

The qualities of a surface barrier detector made of silicon and having the resistivity of 300 Ω cm, were investigated from the point of view of electron detection. The relative detection efficiency in the energy range 0-300 kev was determined.

78 CONTINUOUS CHANNEL ELECTRON MULTIPLIER OPERATED IN THE PULSE SATURATED MODE.

Schmidt K.C., Hendee C.F.

IEEE Transactions in Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 100-111.

Peaked pulse height distributions are obtained from curved channel electron multipliers at high gain levels. They are caused by a gain saturating mechanism which limits the instantaneous output current from the multiplier. Various limiting mechanisms are considered. Experimental and theoretical evidence strongly supports the hypothesis that space charge limiting is the major cause of gain saturation.

79 (UCRL-12245) LITHIUM-DRIFTED GERMANIUM DETECTORS FOR HIGH-RESOLUTION BETA- AND GAMMA-RAY SPECTROSCOPY.

D. C. Camp and G. A. Armantrout (Lawrence Radiation Lab., Univ. of California, Livermore).

Mar. 30, 1965. Contract W-7405-eng-48. 31 p. (CONF-650507-2). Dep.(mn); $2.00(cy), 1(mn) CFSTI.

From IAEA Symposium on Radioisotope Sample Measurement Techniques in Medecine and Biology, Vienna.

Two types of germanium detectors have been fabricated using the lithium-ion drift technique. Those of the first type have active volumes in excess of 6 cm^3 and are primarily intended for high-energy (>1.0 Mev) γ spectroscopy. Those of the second type are large area, low capacity, windowless detectors intended for very-high-resolution β and low-energy γ spectroscopy. Both types are operated in a vacuum at liquid nitrogen temperature (77°K). The large volume detectors have areas greater than 6 cm^2 with depletion depths in excess of 1 cm. The experimental resolution (FWHM) obtainable with these detectors is limited at low energies by the noise level of the preamplifier, while at high energies (>1 Mev) the limitation is due to amplifier instability. Typical resolutions are 3, 6, and 12 kev for 0.122, 1.333, and 5.0 Mev γ rays, respectively, while the photopeak efficiency ranges from approximately 75% at 122 kev to 1% at 1.333 Mev and 0.5% at 5 Mev. At 5 Mev the pair-peak efficiency is $\sim$5%. Typical low capacity detectors are slices (less than 5 mm thick) from the large volume detectors and have an area of 3 cm by 1 cm (the depletion depth). This gives a reduction in detector capacitance, which results in a significant improvement in the resolution compared to that obtained with the large volume detectors for a given preamplifier. At 0.122 and 1.333 Mev, resolutions of 1.9 and 4.1 kev respectively have been observed. Since these are essentially windowless detectors they make excellent small β spectrometers. A detailed evaluation of the properties and various applications of these two types of germanium detectors is discussed.

80 (UCRL-11946) MOUNTINGS AND HOUSINGS FOR LITHIUM-DRIFTED SILICON AND GERMANIUM DETECTORS.

C. Eugene Miner (Lawrence Radiation Lab., Univ. of California, Berkeley).

Feb. 24, 1965. Contract W-7405-eng-48, 41 p. Dep.; $2.00(cy), 1(mn) CFSTI.

A versatile cooling and housing design and several methods for mounting lithium-drifted silicon and germanium detectors are described. Since considerable care must be exercised to keep non-encapsulated germanium detectors in their best operating condition, greater emphasis is placed on mountings for germanium detectors than on mountings for silicon detectors. Developmental problems, materials, and methods of evacuating the housings are discussed in detail.

81 (AE-174) IMPROVEMENTS IN APPLIED GAMA-RAY SPECTROMETRY WITH GERMANIUM SEMICONDUCTOR DETECTOR.

D. Brune, J. Dubois, and S. Hellstroem (Aktiebolaget Atomenergi, Stockholm (Sweden)).

Jan. 1965. 17 p. Dep.(mn).

A germanium semiconductor detector is used in four cases of applied gamma spectrometry. In one case the weak activity contribution of ^{134}Cs in ^{137}Cs standard sources has been determined. The second case concerns the determination of ^{42}K in samples of biological origin containing strong ^{24}Na activities. In the third case the ^{94}Nb and ^{95}Nb activities from neutron-irradiated niobium foils used in the dosimetry of high neutron fluxes with long exposure times have been completely resolved, and it has been possible te determine the ratio of the two activities with a high degree of accuracy. Finally, a ^{95}Zr—^{95}Nb source has been analyzed in a similar way with respect to its radiochemical composition. The resolution obtained also made possible a determination of the branching ratio of the two gamma transitions in ^{95}Zr and the energies of the gamma transitions of both nuclides.

82 ON THE ACCURACY OF THE CALIBRATION TECHNIQUES USED WITH SEMICONDUCTORS.

F. E. Emery and T. A. Rabson (Rice Univ., Houston, Tex.).

Nucl. Instr. Methods, 34: 171-2 (Apr. 1965).

A fairly common technique used to calibrate amplifier chains used in semiconductor detector spectroscopy is to use a fast rise time mercury relay pulser. The signal is fed through a series capacitor to the input of the charge sensitive preamplifier. Accurate determinations of the pulse height may be made conveniently if a capacitor is charged for several time constants and then discharged. Two simple multiplicative errors were found in this technique and are discussed.

83 PRELIMINARY RESULTS ABOUT THE INFORMATION AVAILABLE FROM RISE-TIME OF THE PULSES SUPPLIED BY SEMICONDUCTOR DETECTORS.

A. Alberigi Quaranta, M. Martini, G. Ottaviani, and G. Zanarini (Istituto Nazionale di Fisica Nucleare, Bologna and Istituto di Fisica, Bologna).

Nucl. Instr. Methods, 34: 167-8 (Apr. 1965).

The possibility of obtaining information about the impact angle of ionizing particles on a semiconductor detector by means of a measurement of the pulse rise time is discussed. Experiments were performed with proton beams and the possibility of distinguishing, by a direct measurement of the pulse rise times, protons with different impact angles or protons from other charged particles of the same energy but with different ranges in the detector is confirmed.

84 INFLUENCE OF NON-CONSTANT CARRIER MOBILITY ON THE CHARGE TRANSPORT TIME IN SEMICONDUCTOR DETECTORS.

K. Falk, P. A. Tove, and M. Madakbas (Uppsala Univ.).

Nucl. Instr. Methods, 34: 157-9 (Apr. 1965).

The influence of non-constant carrier mobility on the charge transport time in semiconductor detectors was calculated. Two main conditions are considered: non-fully depleted detectors and fully depleted detectors, with applied overvoltage. Approximation formulas for the pulse rise time are given for special cases. It is found that the transport time calculated under the assumption of constant mobility is modified by an appreciable factor, under some conditions, especially when a high voltage is applied to low-resistivity diodes.

85 STUDIES OF BETA SPECTRA USING A SOLID STATE SPECTROMETER.

P. Charoenkwan (Univ. of California, Los Angeles).

Nucl. Instr. Methods, 34: 93-9 (Apr. 1965).

The lithium drifted detectors of different depletion depths were used as beta spectrometers studying beta spectra of both allowed and forbidden shapes. Distortions to the beta spectra are mainly due to the backscattering effect of the detectors. Corrections to this effect were performed by using the backscattering coefficient independent of the primary energy and by using a standard source as a reference. This technique gives very satisfactory results in the study of beta spectra of medium energy range.

86 THE MOBILITY OF HOT ELECTRONS AND THEIR INFLUENCE ON THE RISE TIME OF THE PULSES OF n-SILICON SEMICONDUCTOR COUNTERS.

O. Meyer and H. J. Langmann (Kernforschungszentrum, Karlsruhe, Germ.).

Nucl. Instr. Methods, 34: 77-8 (Apr. 1965). (In German).

The rise time of the pulses in semiconductor counters excited by alpha particles is calculated and compared with measurements on counters fabricated fo high resistance n-silicon. The calculation is effected including the strong dependence of the mobility of charge carriers on the high electric field in a semiconductor counter. The case of overvoltage on a fully depleted counter was taken into account, too. Calculated and measured rise times agreed reasonably well, using a fixed set of constants for all counters. For low electric field strengths of the order of 1000 v/cm the governing time constant is the plasma time. Its value for alpha particles was empirically determined to be 1.9×10^{-2} sec · v²/cm². For an average field strength the rise time is strongly influenced by integration of the pulses by the resistance of the counter base together with the input capacitance of the measuring equipment, provided the depletion layer is not extended up to the back contact. Only in a fully depleted counter the rise time is proportional to the transient time of the charge carriers. This transient time even in a not fully depleted

counter will depend on the electric field strength in as much as the mobility itself is field dependent. For field strengths of about 30,000 v/cm the transient time and thus the drift velocity are constant, the mobility therefore is inversely proportional to the field strength. The value determined for this maximum drift velocity v^{∞} for conduction electrons amounts to 7.4×10^6 cm/sec, and for defect electrons to 4.8×10^6 cm/sec.

87 (UCRL-11828 (p. 225-6)) SILICON RADIATION DETECTORS.

Robert P. Lothrop, Morris D. Roach, and Harry E. Smith

(Lawrence Radiation Lab., Univ. of California, Berkeley).

A fabrication process for diffused silicon devices is described in which control of surface states is effected by means of the gaseous ambient during the end of the final high-temperature diffusion. Progress in the fabrication of Li-drifted silicon devices is also summarized.

88 (NYO-3246-4) STUDY OF SURFACE CONTOURING AS APPLIED TO SEMICONDUCTOR RADIATION DETECTORS.

Semiannual Report, June 1964-January 1965.

Gerald C. Huth, James B. Trice, Robert J. Locker, and Russell A. McKinney (General Electric Co., King of Prussia, Pa. Space Sciences Lab.).

Contract AT(30-1)-3246. 63 p. Dep.(mn); $3.00(cy), 2(mn) CFSTI.

Studies are reported of semiconductor p-n junctions, utilizing geometrical surface-field control, and possessing sufficiently high values of internal electric field to cause carrier multiplication and thus pulse amplification. Specific topics studied include: the effect of directionality of response of the detector junction in the amplifying mode; the effects of variations in the base resistivity (and thus the field-distance relation); development of surface-field-controlled P + NN + devices; development of a tunnel-diode univibrator for use with amplifying detectors; and measurement and resolution of the 5.6-kev K α x ray from Mn produced by decay of ^{55}Fe.

89 (LA-DC-6397) A SEMICONDUCTOR ANTICOINCIDENCE DETECTOR SYSTEM.

Dale M. Holm and William Mort Sanders (Los Alamos Scientific Lab., Univ. of California, N. Mex.). [nd].

Contract [W-7405-eng-36]. 10 p. (CONF-641001-54). Dep.(mn); $1.00(cy), 1(mn) CFSTI.

From Symposium on Radiochemical Methods of Analysis, Salzburg, Austria.

An anticoincidence lithium-drifted germanium detector system is described. A block diagram of the circuitry is included. Features and applications of the detector are also discussed.

90 (UCRL-11828 (p. 197-9)) NONDESTRUCTIVE ACTIVATION ANALYSIS WITH LITHIUM-DRIFTED GERMANIUM DETECTORS.

S. G. Prussin, J. A. Harris, and J. M. Hollander (Lawrence Radiation Lab., Univ. of California, Berkeley).

In order to assess the potential of high-resolution Li-drifted Ge detectors for activation analysis, the concentrations of several trace metals (Na, Cu, Mn, and Ga) were determined in 99.9 and 99.999% pure Al. The gamma spectra of the irradiated 99.9% pure Al are compared with that obtained using a NaI(Tl) crystal.

91 (UCRL-11871) NUCLEAR STUDIES USING SEMICONDUCTOR DETECTORS (thesis).

Richard Barry Frankel (Lawrence Radiation Lab., Univ. of Califormia, Berkeley).

Jan. 5, 1964. Contract W-7405-eng-48. 159 p. Dep. (mn); $5.00(cy), 3(mn) CFSTI.

Germanium surface barrier detectors were used to measure the angular distribution of conversion electrons from the 255-kev isomeric transition in ^{137m}Ce for ^{137m}Ce nuclei aligned in the neodymium ethyl sulfate lattice. Direct comparison with the γ-ray angular distributions gave the particle parameters $(b_2)_K = 1.061(18)$, $(b_2)_L = 1.059(20)$. From the variation of the γ-ray anisotropy with temperature, the hyperfine coupling constant for ^{137m}Ce was determined to be $A = 0.0147(7)$ cm^{-1} using the 1957 temperature scale for this salt. The ^{137m}Ce was also aligned in cerium magnesium nitrate, and the variation of the 255-kev γ-ray anisotropy was studied as a function of temperature. Anomalies were shown to exist in the cerium magnesium nitrate temperature scale derived by Daniels and Robinson. A new temperature scale is proposed which goes down to 0.0019°K. To test the new scale, ^{144}Pm was aligned in cerium magnesium nitrate. The anisotropies of the 615- and 695-kev γ-rays were found to be attenuated, but confirmed the ^{137m}Ce results. The decay of ^{137m}Ce + ^{137g}Ce to ^{137}La was investigated with Ge(Li) γ-ray detectors, Si(Li) electron detectors, and nuclear alignment. Levels were found at 10, 446, 492, 708, 762, 781, 835, 925, 1004, and 1170 kev. Definite spin and parity assignments were 762 kev (11/2+), 835 kev (9/2+), and 1004 kev (11/2—). A spin of 5/2+ was tentatively assigned to the 446-kev level. The 11/2— state corresponds to a quasi-particle state predicted by Rho. The distribution of alpha particles from ^{263}Es oriented in neodymium ethyl sulfate was measured using germanium surface barrier detectors. The L = 4 wave in the ground state transition was found to be out of phase with the L = 0 and L = 2 waves. The L = 4 wave was found to have a larger amplitude and the L = 2 wave a smaller amplitude than predictions based on the Bohr, Froman, and Mottleson coupling relations. The relative amplitudes for the ground state transitions are $a_0 = 1$, $a_2 = 0.11$, and $a_4 = 0.016$.

92 FAST SINGLE-CHANNEL PULSE-HEIGHT ANALYZER.

Leonard M. Welter (Argonne National Lab., Ill.).

Rev. Sci. Instr., 36: 487-92 (Apr. 1965).

A circuit description and performance evaluation are presented for an analyzer capable of processing pulses with risetimes as fast as 7 nsec and widths as narrow as 10nsec. An integral nonlinearity of $\pm 0.15\%$ and a differential nonlinearity of $\pm 3.5\%$ were obtained over its dynamic range of 100 : 1. The maximum input repetition rate for the lower and upper level thresholds was 13 and 5 Mc, respectively, when using a 12 nsec input pulse width. The entire analyzer is mounted on a single-sided 11.4×17.8 cm printed circuit board.

93 LATEST DEVELOPMENTS IN SEMICONDUCTOR TYPE NUCLEAR RADIATION DETECTORS.

Ludwik Kowalski (Technical Univ., Warsaw).

Postepy Fiz., 15: 547-58(1964). (In Polish).

Developments in semiconductor type radiation detectors since the last review compiled by the authors in 1961 are reviewed. Only commercially available devices are covered. The detectors reviewed are lithium-drifted silicon diodes used especially for gamma radiation electrons, high-energy protons, and heavier particles; dE/dx-type detectors as thin as 50 microns; neutron detectors with a sensitive film of ^{10}B, ^{6}LiF, $^{235}U_3O_8S$, $^{238}U_3O_8S$, and $(CH_2)_n$; silicon semiconductor detectors with guard rings; and special arrays of detectors. Detector resolution is also covered.

94 A COMPTON-REJECTION GERMANIUM SPECTROMETER.

Y. Sever (Soreq Research Establishment, Yavne, Israel) and J. Lippert.

Nucl. Instr. Methods, 33: 347-8 (Mar. 1965).

When lithium-drifted germanium detectors are used for gamma spectrometry instead of NaI crystals, the advantage of higher resolution is much dampened by the height (relative to the photopeak) and sharpness of Compton edges. The danger of misinterpretation of a Compton edge as a photopeak in a composite spectrum is stronger in this case. A 1 $cm^2 \times 7$ mm germanium detector with a 5 mm thick lithium-drifted layer that was guarded by a 108 mm diameter NaI(Tl) well counter with wall thickness of 31 mm is described. The spectrum of ^{137}Cs with and without Compton rejection is illustrated.

95 INFLUENCE OF THE DEAD LAYER OF SEMICONDUCTOR DETECTORS ON THE PRECISION OF ENERGY MEASUREMENTS OF α PARTICLES.

G. Roux (Centre d'Etudes Nucléaires, Saclay, France).

Nucl. Instr. Methods, 33: 329-31 (Mar. 1965). (In French).

The influence of the dead layer of semiconductor detectors upon the shape of rays obtained by spectrometry of energy of α particles is studied theoretically. The calculated shape of the rays is given for the values of the ratio r/R_0 of the thickness of the dead layer r of the detector to the maximum range of the particles R_0 with range from 10^{-3} to 5×10^{-3} for silicon junction detectors and for different angles of collimation of the particle beam. An experimental spectrum obtained with a silicon junction detector (dead layer 0.55 μ) and a ^{210}Po α source (5.3 Mev) is in good agreement with the theoretical spectrum.

96 METHOD AND APPARATUS FOR THE PRODUCTION OF SEMICONDUCTOR LITHIUM-ION DRIFT DIODES.

Tavendale A. J. (Atomic Energy of Canada Ltd.).

Canadian Patent 752,583. Feb. 7, 1967.

A method is decribed for producing lithium-drifted germanium diodes. A thin layer of lithium is applied to one face of a slab of germanium crystal to form a P-N junction, followed by heating in a liquid such as chloroform, whose boiling point is 50-70°C. About 200 volts dc across the junction causes lithium ions to drift into the germanium to form a wide intrinsic layer of 5 mm thickness in ten days. Intermittent operation enhances the drifting process.

97 ON THE BEHAVIOUR OF HIGH RESISTIVITY Si SURFACE BARRIER DETECTORS.

C. Bussolati (Istituto di Fisica Sperimentale, Politecnico, Milan), M. Bertolaccini, and S. Cova.

Nucl. Instr. Methods, 33: 293-7 (Mar. 1965).

An investigation was performed on the behaviour of high resistivity (21 $k\Omega \cdot cm$) silicon surface barrier detectors in view of their application to electron spectroscopy. The detectors can develop depletion layers 1.3 mm thick and were used to detect ^{137}Cs and ^{113}Sn internal conversion electrons. Some anomalous effects, consisting in poor energy resolution and distortion of the spectra, were observed cooling the detectors ($T \cong 260°K$), with low bias voltage. The effects are probably due to inhomogeneities of Si that may cause nonuniform trapping of charge carriers in the detector; they can be reduced by increasing the bias and by collimating the beam of ionizing particles so as to work with only a small portion of the surface of the detector.

98 DOSIMETRY BY MEANS OF SOLID SUBSTANCES.

Jozsef Patko and Istvan Berta (Kossuth Lajos Tudomanyegyetem, Alkalmazott Fizikai Intezet, Debrecen, Hungary).

Magy. Radiol., 16: 303-12 (Oct. 1964). (In Hungarian).

The merits of various dosimeters are discussed in detail and particular attention is given to solid-state dosimeters. It is pointed out that for the ideal dosimeter, the optical changes in the irradiated substance should be independent of: the energy of the radiation, temperature, age of the dosimeter, and the dose being measured. Fading should be a minimum, and a criterion for stability is that, for dosimeters measuring doses from a few millirads to a few rads, measurements should be 10 to 20% accurate, whereas measurements from a few rads to a few thousand rads should have an accuracy of 2 to 5%. A table shows the dose ranges for various dosimeters now in use; they are divided into two groups, those which may be used many times and those which may be used only once. Dosimeters made of crystalline substances may be used over the range of 20 to 10^4 rad; glass, 10^4 to 16^6 rad (and possibly 10^3 to 10^9 rad); synthetic materials, 10^4 to 10^9 rad; tinted synthetics, 10^3 to 10^7 rad; activated glass, 10 to 10^5 rad; and anthracene 10^6 to 5×10^9 rad. Those for one time use are $CaSO_4$: Mn, 10^{-1} to 10^5 rad; CaF_2: Mn, 10^{-3} tot 3×10^5 rad; and LiF: Mn, 10^{-1} to 10^5 rad. The characteristics of photoluminescent dosimeters are as follows: silver-activated phophate glass ranges from 10 to 10^5 rad, the max dose rate for these is 50 rad/sec, and fading is slow; phosphate glass with high effective atomic number, 10 to 10^5 rad; phosphate glass with low effective atomic number, 10 to 10^5 rad; and silver-activitad boron - lithium glass, 5×10^{-2} to 5×10^3 rad. The characteristics of thermoluminescent dosimers are as follows: $CaSO_4$: Mn, ranges from 10^{-1} to 10^5 rad, fading is substantial; CaF_2: Mn, 1 to 10^5 rad, max dose rate 117 rad/sec, fading 10% in first hr; the same in a plastic cover, 10^{-3} to 3×10^5 rad; the same in a 1 by 12 mm tube, 10^{-2} to 3×10^5 rad, fading 16 hr, thereafter 1% daily, wavelength dependency of 7; and LiF: Al_2O_3, 10^{-1} to 10^5 rad, 4×10^3 rad/sec, fading at 50°C none in 24 hr, wavelength dependency of 1.3. The wavelength figures refer to the sensitivity factor between 1-Mev and 50-kev energy radiations. Semiconductor detectors and their relative ease of construction and light weight are also considered as dosimeter materials. It was concluded that, although the presently available dosimeters do not qualify as meeting all requirements, the photo- and thermoluminescent dosimeters are suitable for medical use and the CaS type for measuring dose rate.

99 (NP-14729) NEKOTORYE OSOBENNOSTI USILITELEI, PRIMENYAEMYKH PRI RABOTE S n-p DETEKTORAMI YADERNOGO IZLUCHENIYA.

(Some Properties of Amplifiers Used with Nuclear Radiation n-p Detectors).

Yu. P. Sel'dyakov (Gosudarstvennyi Komitet po Ispol'zovaniyu Atomnoi Energii SSSR).

1963. 14 p. Dep.(mn).

A review is given of the available data on calculations, and construction of low-noise tube amplifiers used with semi-conductor detectors. A design is also given of a preamplifier for the incoming section. The characteristics and performance of this preamplifier are compared with the ORTEC-101 model preamplifier.

100 (EURAEC-1215) SOLID-STATE NEUTRON DETECTOR.

Period Covered: July1-September 30, 1964. (Centre d'Etude de l'Energie Nucléaire, Mol (Belgium)).

Work Performed under United States - Euratom Joint Research and Development Program. Contract 099-63-10 RDB. 16 p. (R-2315). Dep.(mn): $1.00 (cy), 1(mn) CFSTI.

A SiC charged-particle detector is reactor-irradiated to a dose of 3.6×10^{15} nvt at 250°C. The pulse height decreased to such an extent that the peak to the α spectrum disappeared in the noise level. No annealing has been found upon heating at 500°C. At a temperature of 700°C, the detector became short circuited by diffusion of Zn into the SiC crystal. The Zn was found to come from one of the constituent parts of the encapsulation. Other detectors, where these parts are omitted, have been prepared. The pre-irradiated electrical and counting characteristics of the detectors are given.

101 (BNL-902) SOLAR CELL INTEGRATING DOSIMETER.

A. C. Muller, F. X. Rizzo, and L. Galanter (Brookhaven National Lab., Upton, N. Y.).

July 1964. Contract AT-30-2-GEN-16. 8 p. Dep.; $1.00 (cy), 1(mn) CFSTI.

When irradiated with ^{60}Co gamma rays, commercially available p-on-n silicon solar cells suffer a reproducible and predictable amount of radiation damage. Te resulting degradation in photoresponse is found to be proportional to this gamma-ray-induced radiation damage. By using a tungsten lamp as a calibrated light source with which to measure the resulting photodegradation, total doses of ^{60}Co gamma rays in the range of 10^4 to 10^8 rads may be determined, with an accuracy of $\pm 5\%$.

102 FLUCTUATIONS OF ENERGY LOSS IN SEMICONDUCTOR DETECTORS.

MacCabee H.D., Raju M.R., Tobias C.A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 176-179.

Significant fluctuations and broadening of the energy-loss spectrum are expected in certain cases of passage of charged particles through "thin" detectors. Experimental measurements of this phenomenon (by use of lithium-drifted silicon detectors) are in good agreement with the rigorous theory of Vavilov, as tabulated by Seltzer and Berger. *Escherichia coli* bacteria efforts are concerned with modifying procedures to reduce the overall time required for analysis. The analysis of powdered solids was investigated by the x-ray absorption-edge method with a rotating sample holder. Disposable one-piece polystyrene cells were fabricated for use in the analysis of radioactive solutions by the same method. Computer codes were written for determining the height of an x-ray absorption edge by extrapolation and for analyzing multicomponent alloys by x-ray fluorescence. Ru and Se were determined

at the 0.5-μg/ml level by atomic absorption with an air-H_2 flame and an end-fed absorption tube. Only 1 to 2 ng of sample is required; rare isotopes in concentration as low as 1 ppm can be measured. The isotopic composition of atmospheric Ne was measured by use of ^{20}Ne and ^{22}Ne standards of high isotopic and chemical purity; the composition (atom percent) is indicated to be: ^{20}Ne, 90.514 ± 0.031; ^{21}Ne, 0.266 ± 0.005; ^{22}Ne, 9.220 ± 0.029. Infrared spectroscopy was used to determine the effect of gamma de Graaf accelerator with ^{3}He particles; the potential usefulness of such procedures for activation analysis is being investigated.

103 (JINR-E-1898) METHOD OF INVESTIGATING ELASTIC pp-SCATTERING IN THE HIGH-ENERGY REGION WITH SEMICONDUCTOR DETECTORS.

Yu. K. Akimov, A. I. Kalinin, M. N. Khachaturyan, V. A. Nikitin, V. S. Pantuyev, A. I. Sidorov, and V. A. Sviridov (Joint Inst. for Nuclear Research, Dubna (USSR). Lab. of High Energy and Joint Inst. for Nuclear Research, Dubna (USSR). Lab. of Nuclear Problems).
1964, 5 p.

The energy spectrum of particles emerging at an angle of 87.7° from a thin $(CH_2)_n$ target bombarded with 10-Bev protons has been measured with a semiconductor detector. An obvious peak has been observed, which corresponds to recoil protons in elastic p-p scattering.

104 MEANINGFUL TESTING FOR RADIATION EFFECTS IN SEMICONDUCTOR DEVICES.

H. Schulman (Martin Co., Baltimore).

New York, Institute of Electrical and Electronics Engineers, 1964, Paper No. 64-499, 10 p., $1.00 (CONF-776-7).

From National Electronics Conference, Chicago, Oct. 1964.

The difficulties encountered in relating diverse radiation-experimental results, obtained in non-equivalent conditions, are considered. Included are questions relating to particle differences (e.g. neutrons, electrons, protons, and gammas), and, chiefly, the disparities in reactor neutron spectra. It was demonstrated that the use of bulk semiconductor materials as damage monitors (as distinct from dosimeters) achieves the desired relationships directly. The necessity of relating changes in device characteristics to modifications in material parameters is motivated by these considerations.

105 THE DEPLETION DEPTH OF LITHIUM-ION DRIFT DETECTORS AS A FUNCTION OF THE TIME, VOLTAGE AND THE DIFFUSION COEFFICIENT.

J. Takacs (Oxford Univ.).

Nucl. Instr. Methods, 33: 174-5 (Mar. 1, 1965).

The depletion depth (w) of lithium-ion drift detectors was calculated from the equation $w = [2\mu Vt/kT]$, where μ is the mobility, V is the drifting voltage, and t is the time . The mobility and the diffusion coefficient D are connected by Einstein's relation $D = (kT/e)\mu$. The results of the calculations are presented in the form of nomographs from which the depletion depth as a function of time can be read for different drift voltages and temperatures.

106 A BETA SPECTROMETER USING SOLID STATE DETECTORS.

J. Reynolds and B. Persson (Univ. of Lund, Sweden).

Nucl. Instr. Methods, 33: 77-83 (Mar. 1, 1965).

The construction and operation of a surface-barrier solid state beta spectrometer of approximately 4π aperture is described. Its properties were investigated by the use of electrons from internal conversion and beta decay. Corrections to the spectra measured are small, and methods for their evaluation are given.

107 A VERSATILE n-He^3 COINCIDENCE SYSTEM WITH IMPROVED He^3 RESOLUTION.

R. A. I. Bell, N. G. Chapman, and P. B. Johnson (Victoria Univ. of Wellington, N. Z.).

Nucl. Instr. Methods, 33: 13-18 (Mar. 1, 1965).

A versatile n-He^3 coincidence system for use with the D(d,n)^{3}He reaction is described. The use of a silicon surface barrier detector, with a thin nickel foil window has enabled complete resolution of the ^{3}He peak with consequent improved neutron flux determination. The angular distribution of the neutron beam tagged by the associated particle technique was investigated using a plastic scintillator as the neutron detector. This distribution is compared with the calculated angular spread of neutrons from a thick target.

108 A HYBRID PREAMPLIFIER FOR COOLED LITHIUM ION-DRIFTED SEMICONDUCTOR DETECTORS.

T. W. Nybakken and V. Vali (Boeing Scientific Research Labs., Seattle).

Nucl. Instr. Methods, 32: 121-4 (Jan. 1965).

The use of a cooled field-effect transistor as the input stage of a preamplifier for lithium-ion-drifted semiconductor detectors is discussed. A resolution of 0.98 kev fwhm Si was measured for zero external capacitance. As an example, the preamplifier was connected to a cooled detector, and a pulse-height analyzer spectrum was taken of the 6.5 kev x ray and 14.4 kev gamma ray of ^{57}Fe.

109 CONSTRUCTION AND PERFORMANCES OF SILICON LITHIUM DRIFTED DETECTORS.

G. Bertolini, F. Cappellani, and G. Restelli (EURATOM, Ispra, Italy).

Nucl. Instr. Methods, 32: 86-92 (Jan. 1965).

Some results obtained in the construction of silicon lithium-drifted detectors are presented. The applications to electron spectroscopy and performances of these detectors in the investigation of low-energy gamma-ray complex spectra are studied.

110 THE PULSE HEIGHT DEFECT IN SEMICONDUCTOR DETECTORS.

R. C. Axtmann and D. Kedem (Soreq Research Establishment, Yavne, Israel).

Nucl. Instr. Methods, 32: 70-7 (Jan. 1965). (IA-983).

Measurements of the pulse height defect in a silicon surface barrier detector, with fission fragments whose energies were degraded in air, show that the defect is approximately constant in the fragment energy range 25-100 Mev. The results contradict an earlier hypothesis that the defect is caused by recombination of electron-hole pairs in the dense plasma produced by the fragment at the beginning of its track. A coincidence arrangement permitted separate studies of the median light and median heavy fragments. At increased fields in the detector, pulse height distributions of the respective fragment groups became distorted toward greater pulse heights. This result is interpreted to mean that, rather than decreasing recombination, the increased field causes charge multiplication in the counter. The onset of the multiplication appears to be a function of the ionization density in the fragment track.

111 IMPROVED SPECTRUM EXPANDER FOR SEMICONDUCTOR DETECTOR SPECTROSCOPY.

M. Bertolaccini (Istituto Nazionale di Fisica Nucleare, Milan), C. Bussolati, and S. Cova.

Nucl. Instr. Methods, 32: 31-6 (Jan. 1965).

An instrument is described by which semiconductor detector spectroscopy can be performed employing a conventional amplification chain and multichannel PHA with an increase by a factor of 10 or more in the number of available equivalent channels, as far as resolution capability is concerned. The method of compensation by charge injection in the detector is employed: a waveform is adopted which calculations show to allow linear compensation of the voltage pulse maximum at the input of the PHA without overload in the amplification chain. Circuit design ensures the stability required by high resolution spectroscopy, pulse pile-up rejection, and a dead time smaller than that of a conventional PHA. Experimental results confirm the expected performance.

112 RECENT DEVELOPMENTS IN Li-DRIFTED DETECTORS.

I. L. Fowler (Atomic Energy of Canada Ltd., Chalk River, Ont.).

Can. Nucl. Technol., 4: 40-4 (1965).

A review is presented of Canadian efforts in the fabrication and further development of lithium-drifted p-i-n semiconductor detectors of spectrometer use. Emphasis is on gamme spectroscopy.

113 (UCRL-13106) RESEARCH AND DEVELOPMENT ON FABRICATION OF PIN AND LID DETECTORS AND THE DRY RUN INTERFACE SYSTEM.

Final Report.

F. P. Ziemba (Solid State Radiations, Int., Los Angeles). Aug. 31, 1963. For California. Univ., Livermore.

Lawrence Radiation Lab. Contract [W-7405-eng-48]. 86 p. Dep.; $3.00 (OTS).

The design, fabrication, and performance of two types of semiconductor detectors suitable for field use are presented. The first type is based on the lithium ion drift technique having a sensitive depth between 1 mm and 1 cm and active areas between 0.04 and 1.0 cm^2. The second type is the PIN detector having a sensitive depth of 250 μ and an active area between 0.04 and 1.0 cm^2. Detectors fabricated using the LID approach are designed primarily for high sensitivity, and the detectors fabricated using the PIN structure are designed primarily for speed. The performance of the detectors for high intensity gamma radiation and the dry run apparatus that was designed for the testing of the static and dynamic characteristics of these detectors under field conditions are described.

114 (NP-14721) O PRIMENENII POLUPROVODNIKOVYKH DETEKTOROV YADERNYKHIZLUCHENII V SERIINOI APPARATURE.

(The Use of Semiconductor Nuclear-Radiation Detectors in Mass-Produced Instruments).

V. V. Matveev and Yu. P. Sel'dyakov (U.S.S.R. Sovet Ministrov. Gosudarstvennyi Komitet po Ispol'zovaniyu Atomnoi Energii).

[1962]. 12 p. Dep.(mn).

Studies of semiconductor nuclear radiation detectors indicated the highest resolution with 5.5-Mev to 13-kev α particles and 660- to 6.5-kev electrons. The design of the spectrometer and electronic equipment used for amplification and development of the obtained pulses are described.

115 SEMICONDUCTOR JUNCTION DEVICE FOR MONITORING RADIOACTIVITY IN A WELL LOGGING SONDE.

John T. Dewan (Well Surveying Corp.).

U. S. Patent 3,158,743. Nov. 24, 1964, Filed Feb. 23, 1961.

The radioactivity well logging apparatus described consists of a pressure-resistant housing adapted to be lowered through a borehole. The housing contains a neutron

source and a radiant energy detector. The radiant energy detector is a junction-type semiconductor elongated in a direction transverse to its junction and supported with its elongated dimension extending radially of the housing. Means are coupled with the detector for deriving indications primarily representative of radiant energy incident upon the semiconductor in the radial direction. The semiconductor detector requires minimum space and minimum electrical circuitry, and use of the radial direction reduces borehole size effects.

116 THE ROLE OF PARTICLE CHANNELLING IN DETECTOR SYSTEMS.

Gibson W.M.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 162-175.

The orientation dependence of the energy loss rates of energetic protons and alpha particles in thin silicon crystals was first reported at the last Semiconductor and Scintillation Counter Symposium two years ago. Since that time the effect has been extensively and systematically studied in several laboratories. Particle channeling, as the effect is now called, can be manifest as anomalous energy loss rate, anomalous range, anomalous charge production, anomalous radiation damage, anomalous scattering or anomalous reaction yield. These phenomena can affect appreciably the results obtained from the use of crystalline detectors for charged particles and can also affect general nuclear and atomic scattering measurements independent of the type of detector used. It is important therefore that the nuclear experimentalist be aware of the nature and causes of particle channeling and be familiar with the techniques to test for, eliminate or in some cases use the effect in his measurements.

117 BEHAVIOR OF SOLID DETECTORS IN A FLUX OF RADIATION.

R. Schuttler, B. Girault, J. Lebailly, J. P. Noel, and S. Passe (Centre d'Etudes Nucléaires , Fontenay-aux-Roses, France).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 127-53 (1964). (In French).

The manner in which radiations perturb the functioning of a solid detector is studied. It is shown that, independently of the destructive effects, transitory perturbations, at least as interference, can distort the measurements. The action of the radiation was shown in two fashions: the first classical by the variation of the collection yield (connected to the recombination velocity and the mobility) and the other corresponding to the transitory variation of the internal geometry of the detector.

118 METHOD OF FABRICATING SURFACE BARRIER.

R. J. Fox (U. S. Atomic Energy Commission).

U. S. Patent 3,163,915. Jan. 5, 1965.

An invention relating to the fabrication of surface barrier detectors is described which will produce uniform units having improved geometry on a routine basis, by using a diglycidal ether of bisphenol A with ethylene diamine as a curing catalyst and an amine type hardener.

119 SEMICONDUCTOR DETECTORS FOR NUCLEAR MEDICINE AND BIOLOGY.

Stephen S. Friedland, Henry S. Katzenstein, and Michael R. Zatzick (Solid State Radiations Inc., Los Angeles).

Nucleonics, 23: No. 2, 56-61 (Feb. 1965).

Applications of semiconductor detectors in nuclear biomedicine for detecting radioisotopes *in vivo* and in uptake studies are discussed. Resolution, noise, dynamic range, and sensitivity are discussed for phosphorus-diffused-junction detectors, surface-barrier detectors, and lithium-drifted detectors. Uses for radioactive assay, *in vivo* tracer detection, brain probes, gastrointestinal probes, alpha probes, circulation probes, and dosimetry are described.

120 A CRYOSTAT FOR GERMANIUM DETECTORS.

J. Lippert (Atomenergikommissionen, Riso, Denmark).

Nucl. Instr. Methods, 32: 360 (Feb. 1965).

A cryostat was developed for cooling germanium solid state detectors to liquid nitrogen temperature. When in use the cryostat is placed on top of a standard 5-liter Dewar bottle with liquid nitrogen and maintains the liquid nitrogen temperature for 50 to 60 hours.

121 ON A NEW FAST CHARGE-SENSITIVE PREAMPLIFIER.

A. Alberigi Quaranta, M. Martini, G. Ottaviani, and G. Zanarini (Università, Bologna).

Nucl. Instr. Methods, 32: 352 (Feb. 1965).

A prototype charge-sensitive preamplifier that works satisfactorily for pulse repetition rates up to 5 Mc is described. The conversion gain is 75 mv/Mev, and the noise is 35 kev (fwhm) at 1 pF detector capacitance.

122 AN INTERNAL CONVERSION COEFFICIENT SPECTROMETER UTILIZING SEMICONDUCTOR DETECTORS.

H. T. Easterday, A. J. Haverfield, and J. M. Hollander (Univ. of California, Berkeley).

Nucl. Instr. Methods, 32: 333-8 (Feb. 1965). (UCRL-11524).

A description is given of a device that was designed for the measurement of internal conversion coefficients by simultaneous observation of electron and gamma spectra with lithium-drifted silicon and germanium detectors,

respectively. Calibration of the device was made by use of several well-known internal conversion coefficients (^{203}Hg, ^{198}Au, ^{137}Cs, ^{207}Bi, and ^{109}Cd sources). Dependence of the efficiency of the germanium detector for full-energy absorption of gamma rays was determined. Application of the method to the determination of conversion coefficients of the 191-kev transition from ^{197}Pt decay and of the 346-kev transition from ^{197m}Pt decay is described. The following results are obtained: ^{197}Pt: 191-kev transition, $\epsilon_K = 0.69 \pm 0.07$, $K/L = 5.2 \pm 0.6$, and ^{197m}Pt: 346-kev transition, $\epsilon_K = 3.9 \pm 0.4$, $K/L = 1.8 \pm 02$.

123 APPLICATIONS OF DETECTORS IN LOW ENERGY NUCLEAR PHYSICS.

Donovan P.F.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 21-33.

This review paper discusses new applications of detectors in low energy nuclear physics and emphasizes semiconductor particle detectors where new development have had an outstanding influence on the nuclear physics which can be done. The paper includes an account of: new limits of detector resolution; a new method for measurement of gamma ray lifetimes; gamma-gamma angular correlation studies with multiple scintillation detectors; kinematic energy shift correction with radial position sensitive detectors; an improved particle identification system with multiple detectors; and the application of germanium to measurements of long-range charged particles . The paper also discusses present state-of-the-art limitations and possibilities in areas of particular importance to nuclear physics.

124 TECHNIQUES FOR THE FABRICATION OF LITHIUM DRIFTED GERMANIUM GAMMA DETECTORS.

W. L. Hansen and B. V. Jarrett (Univ. of Calfornia, Berkeley).

Nucl. Instr. Methods, 31: 301-6 (Dec. 11, 1964). (UCRL-11589).

Two pulse generators utilizing the negative resistance of zener diodes in a relaxation circuit are described. It is shown that the near randomness and average rates to 10^7 pulses per second make these pulses especially suitable for testing nuclear electrons.

125 DEVELOPMENT AND FIRST APPLICATIONS OF A SEMICONDUCTOR DETECTION APPARATUS DESIGNED FOR MEDICAL AND BIOLOGICAL RESEARCH.

R. V. Rechenmann and J. G. Swart.

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 357-69 (1964). (In French).

A semiconductor detection device, using Si-base surface barriers, was constructed to test its utility in medical and biological research. The properties of the device were reported. The first applications were to the study of the translocation of elements in oat seedlings. The tracers ^{45}Ca and ^{22}Na were used. The semiconductor detector gave a true picture of the phenomenon: increase of the activity at the point measured, maximum, decrease to a plateau. A G-M counter measuring the same migration showed the effects of the slow increase of γ intensity around the counters.

126 RADIATION DETECTORS IN HIGH ENERGY PHYSICS.

Piroue P.A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 1-8.

Spark chambers, scintillation and Cerenkov detectors are used extensively in high energy physics experiments. The potential usefulness of semiconductor detectors is being investigated. There is a need for detectors which will identify very high energy particles. The various types of spark chambers are briefly reviewed, including narrow gap, wide gap and filmless chambers. Applications of scintillation detectors are discussed, together with remarks on light pipes, localization of particles by time-of-flight, use of multiparameter pulse height analysis, hodoscopes and on-line computers. The use of Cerenkov counters is summarized. Several new types of detectors are considered which may be suitable for identification of particles of very high energy, hundreds of BeV, including transition radiation detectors and semiconductor devices.

127 A SEMICONDUCTOR PROTON RECOIL TELESCOPE FOR NEUTRON SPECTRA AND FLUX DETERMINATION.

P. H. White (Atomic Weapons Research Establishment, Aldersmaston, Berks, Eng.).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 341-9 (1964).

Two silicon surface-barrier detectors were used to construct a proton recoil telescope for the measurement of neutron spectra and neutron flux in the energy range 3.5 to 14 Mev. Measurements made with the telescope were described and its performance was compared critically with a proton recoil telescope of conventional design. The factors affecting the resolution, accuracy, and energy range of the counter system were discussed. It was indicated that a telescope made with semiconductor crystals can, by careful design, be more versatile than one made with a proportional counter and CsI crystal.

128 EXAMINATION OF THE POSSIBILITIES OF DIRECT METHODS OF SPECTRAL ANALYSIS OF INTERMEDIARY AND FAST NEUTRONS.

C. Beets, Ph. Colle, H. Deckers, G. Gierts, and S. De Leeuw (CEN, Mol, Belg.).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 317-40 (1964). (In French).

The areas of validity of the spectral analysis of isotropic neutron populations were analyzed for ionographic-emulsion, proportional-counter, and junction-detector techniques in the case of (n,p) scattering and the $^{6}Li(n,t)^{4}He$ reaction.

129 ^{6}LIF SANDWICH SPECTROMETER MEASUREMENTS.

J. Moritz (Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt mbH, Geesthacht, Ger.).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 311-16 (1964).

Silicon surface-barrier detectors, having a LiF layer of 96% enriched ^{6}Li between them, are used. The sensitivity of the spectrometer is $\sim 10^{-6}$ for n in the Mev region with LiF layers ~ 1 μ thick. Data are given for fast neutron spectra (1.0—6 Mev) measurements. Variations of the beam caused by polyethylene containing B and by graphite are shown.

130 ANNULAR DETECTOR FOR SPECTROMETRY AT 180 DEGREES.

Gilbert Lemaitre.

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 307-10 (1964). (In French).

The construction and characteristics of a surface-barrier annular detector of monocrystalline Si of the n type are described.

131 STUDY OF THE LOW-TEMPERATURE BEHAVIOR OF A LITHIUM-COMPENSATED SILICON JUNCTION.

J. Heughebaert, G. Lemaitre, J. Oostens, and L. Van Gerven (Laboratoire des Hautes Energies, Brussels).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 303-6 (1964). (In French).

The response of a Li-compensated Si junction having a surface of 20 mm^2 and 2.5 mm thickness to a ^{207}Bi source was investigated at the temperature of liquid air and below. A resolution of 25 kev was obtained at the temperature of liquid air. On a progressive lowering of the temperature to 58°K, no significant change was detected in the pulse spectra. But at the temperature of liquid hydrogen, the response became faulty. Reheating restored the response of the junction.

132 USE OF DOPED SILICON JUNCTIONS IN HIGH-ENERGY PHYSICS.

G. B. Collins, J. Menes, and J. Oostens (Brookhaven National Lab., Upton, N. Y.).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 293-301 (1964). (In French).

A 4.76-mm thick Li-doped Si crystal detector was tested in a beam of particles from the proton synchrotron. The beam, by the action of 2 magnets, furnished e, mesons (π) and (μ), p, and d of different momenta. The characteristics of the beam were determined by calibrating the magnets by the floating wire method to establish the trajectory of the charged particles in the magnetic field, then fixing other points from trajectory curves obtained by inserting increasing thicknesses of absorber in the beam and observing the disappearance of transmitted particles. The detector, in a Styrofoam box cooled by a rod which dipped into liquid N, was then placed in the path of the beam. A multichannel analyzer gave the pulse-height spectrum which showed peaks for the d, p, and particles of minimum ionization. The specific ionization value for each could be calculated from the position of the peaks. Plotting the number of the channel corresponding to the peak maximum against the specific ionization gave a straight line. The width of the peaks at mid-height showed an indeterminacy of $\pm$ 10% on the ionization value of an individual particle.

133 CHARACTERISTICS OF THE ELECTRONIC EQUIPMENT USED WITH SEMICONDUCTOR DETECTORS AT THE REACTOR STATION GEESTHACHT.

H. J. Tauffenbach (Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt mbH, Geesthacht, Ger.).

Mem. Soc. Roy. Sci. Liège, 10: No. 2, 285-91 (1964).

Two charge-sensitive preamplifiers for work with semiconductor detectors are described. One preamplifier follows a classical design. The other is a transistorized version for spectrometry of fast neutrons with LiF sandwich spectrometers. The circuit diagrams and noise contributions of the preamplifiers are given.

134 A SOLID STATE DETECTOR TELESCOPE.

W. Mausberg and E. Roesle (Institut für Kernphysik, Frankfurt am Main).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 277-83 (1964).

A detector telescope using only solid state detectors, some dE/dx and one E, and used to measure differential cross sections and angular distributions of the protons emitted by the reaction $^{28}Si(n,p)^{28}Al$ is described. The differences in energy loss, the pulse-height analysis of energies lost, and the efficiency of directional discrimination vs proton energy are shown. Distinctions can be made between opposite particle directions with the telescope.

135 ON THE USE OF SEMICONDUCTOR COUNTERS IN THE INVESTIGATION OF RESONANCE REACTIONS.

P. M. Endt (Rijksuniversiteit, Utrecht).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 245-54 (1964).

The possibilities and limitations of semiconductor counters for the detection of protons and α particles, produced in reactions showing a resonant character, are discussed. The discussion is limited to the investigation of nuclides in the $2s$-$1d$ shell at bombarding energies below 3 Mev. The ground state transitions of (p,α) and (α,p) reactions and the elastic scattering of protons or α particles are considered. Studies being made on $^{22}Ne(p,p)^{22}Ne$, $^{23}Na(p,\alpha)$, $^{27}Al(p,\alpha)$, $^{31}P(p,\alpha)$, $^{19}F(\alpha,p)$, and $^{31}P(\alpha,p)$ reactions are discussed.

136 PULSE HEIGHT DEFECT OF SURFACE BARRIER DETECTORS FOR FISSION FRAGMENTS.

A. J. Deruytter (SCK-CEN, Mol, Belg.).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 231-43 (1964).

The pulse-height defect of large Au-Si surface-barrier detectors for fission fragments was evaluated. The average pulse height of the difference spectrum ($E_L - E_H$) was used as an absolute energy point. With this calibration the pulse-height defects of the average light and heavy fragment pulses and of the average sum pulse were determined. These measurements were made for the thermal neutron induced fission of ^{235}U. Also α particles from ^{234}U and from a Th source were used for calibration, and the resulting pulse-height defects for fission fragments were compared with the values obtained by the method previously described. The calibration of a detector by comparison of the measured pulse-height distribution to a standard fission fragment energy spectrum was shown for the thermal neutron induced fission of ^{235}U. The different parts of the pulse-height defect, i.e., window effect and true pulse-height defect of the junction, were discussed. The influence on the pulse-height defect of the supplementary absorption in the backing of two kinds of 4π targets made by electro-spraying and by evaporation was illustrated.

137 TRANSISTORIZED PREAMPLIFIERS USED AT THE LABORATOIRE DE PHYSIQUE NUCLEAIRE D'ORSAY WITH SILICON JUNCTION DETECTORS.

Guy Corbe (Faculté des Sciences, Orsay, France).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 221.9 (1964). (In French).

Two types of transistorized preamplifiers were used with Si junction detectors, one with a resolution close to 15 kev and large dynamic capacity and the other with inferior characteristics but making possible a high counting rate and pulse durations less than 2×10^{-7} sec. The characteristics, design, and performance of each of these preamplifiers are described.

138 SHAPING OF p-i-n DETECTOR PULSES BY RC NETWORKS.

C. A. J. Ammerlaan (Inst. for Nuclear Physics Research, Amsterdam).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 211-20 (1964).

The results of pulse shape calculations for particles incident perpendicularly to the p-type surface of a lithium-drifted junction detector are presented. The nonlinearities introduced by shaping these pulses with a single RC integrator followed by a single RC differentiator are determined. The time constants of the networks are equal and have the same order of magnitude as the pulse rise time.

139 MEASUREMENT APPARATUS FOR ALPHA SPECTROMETRY.

R. Allemand and J. L. Lecomte.

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 201-9 (1964). (In French).

The characteristics and performance of a measurement circuit adapted to semiconductor junction detectors (particularly in the area of α spectrometry) were studied. The transistorized measurement apparatus consists of a low-noise preamplifier and an amplifier stage. The theoretical aspects of the background noise in two versions of the preamplifier (the first with ordinary transistors and the second with transistors with field effect as input stage) were investigated.

140 JUNCTIVE-BARRIER DETECTORS.

G. Vallois (CEN, Saclay, France).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 105-13 (1964). (In French).

The performance of energy loss detectors formed on the same platelet of Si by four large surface barriers and separated from each other by 80 microns was tested. The independence of each junction (possible influence by one junction on the other), extension of the sensitive zones, and variation of the resolution at the boundary of the zones separating the junctions was investigated. It was concluded that each junction was practically independent. The dead times were so narrow that they could not be shown. There was constant resolution over the entire surfacce of the junction.

141 COLLOQUE SUR L'UTILISATION DES DETECTEURS A SEMI-CONDUCTEURS EN PHYSIQUE NUCLEAIRE, UNIVERSITE DE LIEGE, 16-17-18 SEPTEMBRE 1963.

(Conference on the Utilization of Semiconductor Detectors in Nuclear Physics, Liège, Belgium, September 16-18, 1963).

L. Winand (ed.).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 1-371 (1964). (CONF-630904).

Seperate abstracts are prepared for 27 of the 28 papers presented. An abstract of one paper previously appeared in NSA (18:41788).

142 SURFACE-BARRIER NUCLEAR RADIATION DETECTORS WITH FAST RESPONSE.

P. Siffert, H. Rougeot, and A. Coche (Centre de Recherches Nucléaires, Strasbourg).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 119-26 (1964). (In French).

Because of the utilization of surface-barrier detectors in fast electronic circuits, the form of the pulses (produced by ^{210}Po α particles) at the output of these devices was studied and the optimum conditions for a rapid response were determined. The electronic apparatus for pulse observation made it possible to measure rise times of less than 1 nsec when the signal amplitude was more than 2 mv. By the selection of a suitable thickness of the platelet constituting the diode and of the polarization applied, it was possible to attain rise times of less than 2 nsec even when the resistivity of the Si base exceeded $10^4\Omega$-cm.

143 SILICON RADIATION DETECTORS AND SOME SIMPLE APPLICATIONS.

Williams I. R. (Oak Ridge National Lab., Tenn. Wantage Radiation Lab., Eng.).

Phys. Educ., 2: 94-9 (Mar. 1967). (ORNL-P-2376).

The semiconductor detector of ionizing radiations is rapidly becoming standard equipment in nuclear physics research experiments. The devices have many advantages the most important of which is that they can be used in spectrometers. The elementary physics of their operation is outlined, together with the techniques involved in their use. Details are also given of some student laboratory experiments that were performed with silicon detectors in order to demonstrate certain aspects of nuclear and solid-state physics.

144 DETECTION OF NUCLEAR RADIATION WITH THE AID OF LITHIUM-COMPENSATED DIODES, WITHOUT INPUT WINDOW.

P. Siffert, H. Rougeot, and A. Coche (Centre de Recherches Nucléaires, Strasbourg).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 95-104 (1964). (In French).

Beginning with the classical techniques for the fabrication of lithium-compensated diodes, an apparatus, whose input window is equivalent to 30 kev or less (for 5-Mev α particles) was perfected by developing a surface-barrier diode on compensated silicon. The electric characteristics and the time stability, as well as the possibilities for the particles, electrons, and γ radiation, were indicated.

145 LARGE GOLD-SILICON SURFACE BARRIER DETECTORS FOR FISSION EXPERIMENTS.

A. J. Deruytter, J. A. Moore, and I. G. Schroeder (Columbia Univ., New York and Brookhaven National Lab., Upton, N. Y.).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 83-93 (1964).

Large gold-silicon surface-barrier detectors were constructed for the detection of fission fragments and energetic α particles (30 Mev). In the construction techniques, emphasis was put on the large surface, resolution, and sturdy construction. Careful surface treatment of the silicon wafer proved to be important for the final resolution. The use of delicate wires to make contact to the inversion layer was avoided. To illustrate the performance of the detectors, single fragment kinetic energy spectra and sum spectra (E_1+E_2) were shown for the fission of ^{235}U with thermal neutrons. The performance for α-particle detection was also illustrated.

146 SURFACE-BARRIER DETECTORS FOR NUCLEAR RADIATION.

A. Coche (Faculté des Sciences, Strasbourg).

Mém. Soc. Roy. Sci. Liège, 10: No. 2, 23-52 (1964). (In French).

The procedures for the preparation of improved Si and Ge surface-barrier detectors and their performance and characteristics are discussed.

147 (UCRL-13128) PART I. FABRICATION PROCESS FOR HIGH-VOLTAGE PIN DETECTORS. PART II. APPENDIX. RESEARCH AND DEVELOPMENT ON FABRICATION OF PIN AND LID DETECTORS AND THE DRY RUN INTERFACE SYSTEM.

(Solid State Radiations, Inc., Los Angeles).

Sept. 1, 1964. For California. Univ., Livermore. Lawrence Radiation Lab.

Contract W-7405-eng-48. 113 p. Dep.(mn); $4.00(cy), 3(mn) OTS.

Process specifications are given for the various operations involved in the manufacture of PIN gamma-transient detectors using boron-doped p-type silicon. Development work on the fabrication of lithium-ion-drift detectors for high sensitivity and of PIN detectors for high speed is reported. A dry run system for field testing detectors with simulated gamma-ray bursts is described, and some test results are given.

148 (TID-21446) DEVELOPMENT OF A HIGH-SENSITIVE FAST NEUTRON DOSIMETER.

Quarterly Report No. 6, August 1 - October 31, 1964. B. H. Chase, R. R. F. Speers, J. M. Swartz, and M. O. Thurston (Phylatron Corp., Columbus, Ohio).

Contract AT(11-1)-1226. 5 p. Dep.(mn); $1.00(cy), 1(mn) OTS.

Diode processing studies were continued; plating of nickel (+boron) onto silicon and simultaneous diffusion of boron and phosphorus onto silicon were attempted. A comparison was made of the performance of different readout circuits.

149 (NP-14473) REALISATION DE DETECTEURS A JONCTION DE GRANDE EPAISSEUR PAR LE PROCEDE DE LA MIGRATION DES IONS Li^+ (ION DRIFT) (thèse):

(Utilization of Junction Detectors of Great Thickness by the Method of Migration of Li^+ Ions (Ion Drift) (thesis)). Gaston Bruge (Paris. Université).

Aug. 2, 1963. 58 p. Dep.(mn).

The development of junction detectors capable of detecting heavy ions of average energy produced by the Saclay cyclotron was investigated. The theory of semiconductor detectors and a simplified theory of the processes of ion migrations were summarized. The different methods available for the fabrication of semiconductor detectors and their testing were reviewed. Impurities were important in the fabrication of this type of detector as the impurities delay the thermal diffusion and migration of Li. Impurities trap temporarily and definitively the charges produced by the passage of a charged particle, affecting the amplitude and rise time of the pulses. It was concluded that the impurity content in the initial materials was an essential factor in the successful fabrication of this type of junction. The conditions of cleaning, thermal diffusion, and development of contacts were also of great importance.

150 (PR-P-63) PHYSICS DIVISION PROGRESS REPORT, JULY 1 TO SEPTEMBER 30, 1964.

(Atomic Energy of Canada Ltd., Chalk River, Ont.). 60 p. (AECL-2108). Dep.; $1.50 (AECL).

Progress is reported in each of the fields: nuclear physics, general physics, neutron physics, and theoretical physics. Among the topics treated are pulse-shape discrimination, nuclear lifetime measurement, detectors and spectrometers, space physics, nuclear models, computation, etc.

151 REDUCING CHARGE-SENSITIVE-AMPLIFIER SENSITIVITY TO DETECTOR CAPACITANCE VARIATIONS.

Goldsworthy, W. W. (Univ. of California, Berkeley).

Nucl. Instrum. Methods, 52: 343-4(1967). (UCRL-17403).

A method for reducing the sensitivity of charge-sensitive preamplifiers to detector capacitance variations is described. This method is directly applicable to many existing charge-sensitive preamplifiers with only minor modifications.

152 PREAMPLIFIER FOR SEMICONDUCTOR DETECTORS FOR CHARGED PARTICLES.

B. V. Fefilov (Joint Inst. for Nuclear Research, [Dubna, USSR]).

Pribory i Tekhn. Eksperim., No. 5, 121-2 (Sept. - Oct. 1964). (In Russian).

The design of a charge-sensitive preamplifier tube is described. A triode 6C3P is used as the input tube. The noise line width is not > 12 kev with the external capacitance at the entrance of 100 nF (integration and differentiation time constants are 0.5 to 0.8 μsec, respectively).

153 FAST-ACTING SEMICONDUCTOR SCHEME FOR MULTIPLE COINCIDENCES.

A. F. Dunaitsev (Joint Inst. for Nuclear Research, [Dubna, USSR]).

Pribory i Tekhn. Eksperim., No. 5, 119-20 (Sept. - Oct. 1964). (In Russian).

Descriptions are given of a transistorized bridge-type multiple-coincidence scheme. The resolving time for a charged meson beam is $\sim$2 nsec.

154 MULTICHANNEL SCHEME FOR COINCIDENCES-ANTICOINCIDENCES OF NANOSECOND RANGE IN SEMICONDUCTORS.

I. F. Kolpakov (Joint Inst. for Nuclear Research, [Dubna, USSR]).

Pribory i Tekhn. Eksperim., No. 5, 99-102 (Sept. - Oct. 1964). (In Russian).

A 4-channel coincidence scheme with one-anticoincidence channel operating on the principle of current interference at a tunnel diode, with an inlet pulse former to the transistor is described. Tests with fast scintillation counters operating with α sources with 1 M cable indicated the resolving time of 10 nsec for coincidences and 7 nsec for anticoincidences at a resolving curve decrement of 5 and 3 nsec for coincidences and anticoincidences respectively. The scheme selectivity coefficient is $\sim$10, the anticoincidence efficiency is $\sim 10^{-3}$, and the dead time is 30 nsec. The time characteristics do not vary at temperatures up to 50°C. The amplitude range of incoming pulses is 0.15 to 8 v. High-frequency diffusion triodes with maximum frequency of 700 Mc, D 10 diodes, and a p-germanium tunnel diode with maximum current of 10 ma are utilized in the scheme.

155 "A WINDOW" IN SEMICONDUCTOR SPECTROMETER FOR CHARGED PARTICLES.

A. K. Mednikov, N. I. Sroikin, and A. A. Babushkin (Kazakh State Univ., Alma-ata, SSR).

Pribory i Tekhn. Eksperim., No. 5, 87-92 (Sept. - Oct. 1964). (In Russian).

Descriptions are given of a silicon surface-barrier nuclear emission detector coated with 0.15 to 3.80 and 0.37×1.20 mg/cm^2 films of Au and Al, respectively. The influence of the coating on the amplitude resolution of the detector was found. The energy losses in thin layers of the substance, in particular in Au, was determined by the surface-barrier semiconductor detector during the α-particle passage. The mean excitation energy of Au is 900 ev.

156 (PPAD-529-E) PREPARATION AND PERFORMANCE OF A HOMOGENEOUS SILICON MINIMUM-IONIZING PARTICLE DETECTOR.

H. Blumenfeld and F. P. Pandolfi (Princeton-Pennsylvania Accelerator, Princeton, N. J.).

Oct. 29, 1964. Contract AT(30-1)-2137. 14 p. (CONF-799-11). Dep.(mn); $1.00(cy), 1(mn) OTS.

From 11th Annual Nuclear Science Symposium, Philadelphia, Oct. 1964.

A homogeneous high-resistivity silicon crystal detector was developed for minimum-ionizing particles in a hydrogen bubble chamber. The detector is operated at liquid nitrogen temperature, and the resistivity is raised close to the intrinsic level by gamma irradiation. The performance of the detector was studied using beta and cosmic ray tests.

157 (AE-162) A NEEDLE-TYPE p-i-n JUNCTION SEMICONDUCTOR DETECTOR FOR IN-VIVO MEASUREMENT OF BETA TRACER ACTIVITY.

A. Lauber and B. Rosencrantz (Aktiebolaget Atomenergi, Stockholm).

1964. 18 p. Dep.(mn).

A miniature detector probe was developed for *in vivo* detection of beta tracer activity. A lithium-drifted p-i-n semiconductor detector shaped as a cylinder 0.9 mm in diameter and 3 mm long acts as the sensing element. The detector is encased in a stainless steel tube 50 mm long, fastened to a holder fitted with a miniature coaxial contact. The free end of the tube has a syringe-like, entirely tight tip. The steel tube has an outer diameter of 1.4 mm except for 10 mm at the free end where the outer diameter is 1.1 mm corresponding to a wall thickness of 0.05 mm. The detector is placed in the 1.1 mm part of the tube. The construction and the properties of the probe are described.

158 P-N JUNCTION SEMICONDUCTOR RADIATION DETECTOR.

Junji Shimizu, Kyoichi Miyashita, Mamoru Takada, and Yoshiyuki Sugawa (Mitsubishi Electric Corp., Hyogo Prefecture, Japan).

Mitsubishi Denki Lab. Rept., 4: 495-503 (Oct. 1963).

Semiconductor radiation detector of the p-n junction type is an attractive detector having many outstanding features. Using a 5,000 Ω-cm p-type silicon crystal, many detectors of the same size (4×4.5 mm) are manufactured and tested. The best energy resolution obtained is 0.7% for 5.3-Mev α particles. Measurable upper energy limit of the α particles is tested by scattered α particles from carbon nuclei. The measured limit is 23 Mev, but it may be expansible up to 28 Mev using a detector applicable 200 v bias. As for the optimum energy resolution and charge collection efficiency, two types of detectors having an opposite inclination for the applied bias were found. Measurement of internal conversion electron of ^{57}Co was attempted but two peaks corresponding to 115 and 129 kev were not separated. Detection of thermal neutrons is possible using a boron converter.

159 STEADY-STATE RESPONSE OF SILICON RADIATION DETECTORS OF THE DIFFUSED p-n JUNCTION TYPE TO X RAYS. I. PHOTOVOLTAIC MODE OF OPERATION.

Karl Scharf and Julian H. Sparrow.

J. Res. Natl. Bur. Std., 68A: 683-701 (Nov.-Dec. 1964).

A relation is derived for the photocurrent produced by x rays in silicon radiation detector cells of the p-n junction type, giving the dependence of the generated photocurrent on exposure rate, photon energy, and electrical and geometrical parameters of the silicon wafer. Silicon radiation detector cells operated as photovoltaic cells are found to be more sensitive to x rays than silicon solar cells previously investigated, open-circuit voltages being several hundred times larger than those measured in solar cells. The short-circuit current produced by x rays increases with increasing temperature by about 0.3 percent per °C at 25°C cell temperature. Due to the high zero voltage junction resistance of silicon radiation detector cells, the temperature dependence of the photovoltaic output current increases with increasing load resistance at a smaller rate than that observed in silicon solar cells. The energy dependence of the short-circuit current produced by x rays, measured over a wide range of radiation qualities, is shown to be in good qualitative agreement with calculated values.

160 (NYO-3246-3) PROTON AND ELECTRON IRRADIATIONS OF CONTOURED SEMICONDUCTOR RADIATION DETECTORS.

J. B. Trice, G. C. Huth, H. E. Bergeson, and R. A. McKinney (General Electric Co. Missile and Space Div., Valley Forge Space Technology Center, King of Prussia, Penna.).

(1964). Contract AT(30-1)-3308. 45 p. Dep. (mn); $2.00(cy), 1(mn) OTS.

Irradiations of surface contoured silicon semiconductor detectors with monoenergetic beams of low energy electrons (45 kev) and protons from 100 kev to 3.0 Mev are described. Sperior noise characteristics, energy resolution, stability, and freedom of these detectors from surface breakdown (the most common difficulty with solid state detectors) are discussed in terms of fundamental electrical properties. Two specific classes of detectors are described. The first of these is a window detector in a shallow-cone geometry oriented so that low energy particles from above are incident over a large fraction of the lateral surface. The response of this detector to low energy protons and electrons is described. The second detector described is the proportional solid state detector the operation of which depends on the attainment of very high bulk electric fields. Its response to protons up to 3.0 Mev is described.

161 (GPI-57) PROGRESS ON A FAST-DRIFT METHOD FOR MAKING LITHIUM-ION-DRIFT GERMANIUM p-i-n GAMMA-RAY SPECTROMETERS.

A. J. Tavendale and I. L. Fowler (Atomic Energy of Canada Ltd. Chalk River Nuclear Labs., Chalk River, Ont.).

Apr. 1964. Revised and Re-issued Nov. 1964. 10 p. (AECL-2110). Dep.; $0.50 (AECL).

A fast boiling-liquid method, used to drift large-volume (6 cm^3), deep-depletion-layer (up to 11 mm), p-i-n germanium diodes for use as high-resolution gamma spectrometers is described. The method is about five times as fast as that obtained in an air-drift apparatus.

162 SOME RECENT APPLICATIONS OF SCINTILLATION AND SOLID STATE COUNTERS IN CHEMISTRY.

Sayre E. V.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 18-20.

The high resolution obtainable with semiconductor radiation detectors has extended the scope of neutron activation analysis. Illustrations are nondestructive analysis of archeological artifacts, meteorites and terrestrial rocks. A quite different new technique is the counting of tracks produced by massive, energetic particles in glasses and crystals, which has been used, for example, to date ancient uranium containing glasses. The use of scintillation and proportional counters, amplitude selection, coincidence and anticoincidence techniques, and the Mossbauer effect are discussed for various applications from x-ray crystallography to the detection of neutrino induced reactions. The anisotropic behavior or channeling in silicon detectors has opened a nex field of research on the effect of crystal orientation on energy loss of penetrating particles.

163 (EURAEC-1113) SOLID-STATE NEUTRON DETECTOR.

Quarterly Report No. 3, April 1 - June 30, 1964 (Centre d'Etude de l'Energie Nucléaire, Mol, Belgium).

Work Performed under United States - Euratom Joint Research and Development Program.

Contract 099-63-10-RDB. 13 p. (R-2295) Dep.(mn); $1.00(cy), 1(mn) OTS.

A SiC diode, irradiated at 250°C, was lost because of failure of the irradiation facility. The results of some measurements before irradiation are given. After the construction of a new furnace, a first irradiation up to 1.2×10^{15} nvt of a second SiC diode was carried out at 250°C. The results do not show any annealing while the pulse height decreased by 25%.

164 SPECTRAL CHARACTERISTICS OF SEMICONDUCTOR DETECTORS FOR PULSED X RADIATION.

A. A. Egorov, A. A. Lukashov, and E. V. Nitochkina.

Zh. Tekhn. Fiz., 34: 2038-43 (Nov. 1964). (In Russian).

Some characteristics of Ge and Si semiconductor radiation detectors for x radiation pulses on the order of 10^{-7} sec were studied. The short-circuit current of the detectors under these conditions is proportional to the radiation intensity, and the spectral characteristic in the quantum energy range from 30 to 600 kev is proportional to $\mu\epsilon$.

165 SILICON SURFACE BARRIER DETECTOR.

Seiichiro Gotoh and Zinzaburo Takagi (Nippon Atomic Industry Group Co., Japan).

J. Nucl. Sci. Technol. (Tokyo), 1: 311-15 (Nov. 1964).

A method was established for producing silicon surface-barrier detectors with an energy resolution of 0.7% for 5.3-Mev alpha particles and with long-term stability. The fabricated detector was found to have a depletion layer as thick as 200 μ and a surface layer with an energy loss of less than 15 kev for 5.3-Mev alpha particles. The detector was found to be stable for at least 2 to 3 months.

166 A RADIOGRAPHIC INSPECTION DEVICE USING SOLID-STATE p-i-n JUNCTION DETECTORS.

N. A. Baily, G. D. Robertson, and F. W. Cleary (Hughes Research Labs., Malibu, Calif.).

Intern. J. Appl. Radiation Isotopes, 15: 523-8 (Sept. 1964).

The use of p-i-n junctions as the sensitive elements of dynamic radiographic inspection systems was investigated. The feasibility of doing this was established for both steady-state and pulsed radiation sources. The resolution obtained using a differential system was excellent for beam intensities delivering an exposure of at least 2 mr at the surface of the detectors in a time period short compared to the decay characteristics of the circuitry. At this radiation level, signal-to-noise ratios of approximately 15:1 without amplification were obtained for defects representing 2% change in flux level. Scanning rates of 6 to 12 in./min. should be possible. Large area scanning may be accomplished through the use of mosaics made up of a large number of junctions.

167 LITHIUM-DRIFTED SILICON JUNCTION DETECTORS.

Sakae Nishiu, Takashi Nakakado, Yasuyuki Nakayama, and Sakae Shimizu.

Bull. Inst. Chem. Res., Kyoto Univ., 42: 319-37 (Sept. 1964).

Details of the procedure for preparation of Li-ion-drifted silicon detectors are described. Various characteristics of the detectors prepared were examined by use of nuclear radiations including electrons, alpha particles, and gamma rays. Special attention was given to the detector response for incident electrons using conversion electrons from some nuclides and mono-energetic electrons obtained by a beta spectrometer at room and liquid-nitrogen tempera-

tures. The p-i-n junction detectors prepared exhibited their extreme usefulness for measuring beta rays from very weak sources. It may be emphasized that in some aspects the use of the semiconductor detector of such a type for beta spectroscopy seems to be advantageous compared with the usual magnetic spectrometer, although some essential properties remain to be improved. For gamma spectroscopy the detector showed its usefulness when it was used at lower temperature, especially by its excellent energy selection for incident photons compared with the crystal scintillation detector. The radiation damage and spontaneous deterioration of the detector were also studied. As a cause responsible for the deterioration, the redistribution of lithium atoms in silicon with the lapse of time after the Li-ion drifting process was examined in some details. Measurements of nuclear radiations performed with the p-i-n junction detector are also discussed.

168 (BNL-8633) THE ENERGY LOSS BY CHARGED PARTICLES IN SILICON AS A FUNCTION OF TRACK ORIENTATION.

H. E. Wegner, C. Erginsoy (Brookhaven National Lab., Upton, N. Y.); and W. M. Gibson (Bell Telephone Labs., Inc., Murray Hill, N. J.).

[1964]. Contract AT-30-2-GEN-16. 12 p. (CONF-799-6). Dep.(mn); $1.00(cy), 1(mn) OTS.

From 11th Annual Nuclear Science Symposium, Philadelphia, Oct. 1964.

It is important to know the orientation of the crystal axis of silicon semiconductor detectors when they are used for the detection of energetic charged particles in stacked arrays and the particles are expected to traverse all of the detectors. It has been observed that particles that pass through the crystal along the directions of crystal planes or axes lose less energy than those in other directions. This anomalous energy loss spoils the response characteristics of the detector. Various experiments have demonstrated that the penetrating particles tend to move along crystal planes or axes by a process of correlated multiple-coulomb scattering. The experimental evidence for these anomalous characteristics will be reviewed and the degrading effects on the discrimination ability of mass-discrimination detector-systems will be shown. Mass distribution curves were taken for protons, deuterons, and tritons, as well as ^{3}He and alpha particles in the 20 to 40 Mev region with a thin silicon ΔE detector oriented with the (111), (110), and other axis parallel to the penetrating particle direction. The mass separation is appreciably improved when the crystal is oriented so that the direction of the penetrating particles is well away from any of the major crystal planes or axes.

169 SOME KINETIC PHENOMENA IN IMPURE IONIC SEMICONDUCTORS.

Plavitu C.N.

Physica Status Solidi, Vol. 16, No. 1, 1966, p. 69-78.

A criterion is given for finding the regions where one of the various scattering mechanisms is dominant. The phonon drag contribution to some of the kinetic coefficients is only slightly modified when ionized impurity scattering is taken into account.

170 STUDIES OF THE RESPONSE SPEED OF SILICON SURFACE BARRIER DETECTORS, WHEN IRRADIATED WITH DIFFERENT PARTICLES.

Meyer H.

IEEE Transactions on Nuclear Science, Vol. N8-13, No. 3, June 1966, p. 180-188.

The rise time of produced surface barrier detectors for α-particles, fission fragments and conversion electrons was measured with and without over-voltage and compared with calculations. The detectors were produced from n-type silicon with resistivities in the range, 250Ω cm to 9000Ω cm.

The best rise times, τ (0-63 %), obtained up to now are $\approx$ 0.8 ns for alphas (^{241}Am) and 1.4 ns for fission fragments (^{252}Cf) at high fields (system rise time, $\tau \approx 0.6$ ns included). The contribution of the plasma time, τp, due to the erosion of the ionisation tracks with their high carrier density by the field was studied in some more detail. τ_p vs. E_m (effective field), derived from the rise time measurements, seems to be a relatively pure exponential dependence, $\tau_p \propto k\ E_m^{-n}$, for a given detector at fields greater than 500 V/cm ($0.7 < n < 1.3$). "k" is a constant, dependent on particle type.

With fission fragments from ^{252}Cf the time jitter of correlated fragments in selected energy ranges was feasured by irradiating two detectors in a wide angle (sandwich counter).

A minimum jitter (F.W.H.M.) of 90 ps was reached for threshold detection. Zero crossing circuitry was also used for time detection to have an idea of the probable pulse shape jitter from fragments irradiating a detector under different angles.

(Different orientation of the particle track with respect to the field).

Such jitter seems to exist, also at relativety high fields.

171 GAMMA-RAY SPECTROSCOPY ON 155-DAY Lu^{177} USING LITHIUM-DRIFTED GERMANIUM COUNTERS.

J. Blok and D. A. Shirley (Univ. of California, Berkeley).

Phys. Letters, 13: 232-4 (Dec. 1, 1964). (UCRL-11644).

Lithium drifted germanium gamma detectors were used to study the spectrum from the decay of the isomer of ^{177}Lu. The presence of the 426-kev gamma ray was detected, thus establishing the 19/2 member of the 7/2$^-$[514] band.

172 (CEA-R-2408) CONTRIBUTION A L'ETUDE DU PROCESSUS DE LA FISSION THERMIQUE DE L'URANIUM 235.

(Contribution to the Study of the Thermal Fission Process for Uranium 235). Mostafa Chahrtache (France, Commissariat à l'Energie Atomique. Centre d'Etudes Nucléaires, Saclay). 1964. 86 p. Dep. (mn).

Thesis submitted to Université, Paris.

The distribution of the masses of the fragments produced by the disintegration of ^{236}U formed when ^{235}U captures a thermal neutron was studied. The experimental method chosen consists in the simultaneous measurement — using p-n silicon junction detectors — of the energies of the two fragments emitted in coincidence. This measurement is first made by a conditioned analysis of the energy of one of the fragments and then by a two-dimensional analysis of the energies of the two fragments. Systematic results are obtained concerning the distribution of the masses for different values of the total kinetic energy. The five structures appearing both for the mass distributions and for the energies of the fragments are studied and discussed. Generally speaking, the results are in agreement with those obtained by the time-of-flight method.

173 SOLID-STATE CHARGED PARTICLE DETECTORS.

Niels J. Hansen.

Progr. Nucl. Energy, Ser. IX, 4: 1-72 (1964). New York, The Macmillan Company, $4.25.

Information is included on solid-state theory, formation of the charge-depleted region, interaction of charged particles with matter, charge collection and the charge collection time, amplifier configurations and pulse rise time, energy resolution, and applications of junction and drifted detectors to nuclear spectroscopy, 55 references are included.

174 SPECTRUM STABILIZATION WITH VARIABLE REACTANCE GAIN CONTROL.

P.K. Patwardhan (Atomic Energy of Canada Ltd., Chalk River, Ont.).

Nucl. Instr. Methods, 31: 169-72 (Dec. 1, 1964).

This paper describes a novel and simple method of spectrum stabilization effected by "overall" gain control employing variable capacitance p-n junction diodes. The stabilizing peak is referenced directly from the analyzer store. Digital windows set on the stabilizing peak sense the magnitude of the spectrum shift and generate an analog signal of appropriate polarity and amplitude. This is applied as a reverse bias to a variable capacitance diode causing the effective feedback capacitance of a charge sensitive amplifier to change. This holds the spectrum in a fixed position. The high gamma-ray resolution (0.1 to 0.2% fwhm at 6 Mev) obtainable with the lithium-drifted germanium detectors call for an amplifier stability of 1 part in 10,000. At lower gamma energies the amplifier noise contributes primarily to the line width, while at higher energies, where the amplifier noise contribution is negligible, gain drifts of the order of 0.1 to 0.01%, cause line broadening. The system is capable of efficiently correcting these orders of drifts. Typical resolutions obtained with the stabilizer are 6.3 kev (fwhm) for 2.614 Mev gamma rays from a Th(B+G+C″) source and 4.15 kev for 1.333 Mev ^{60}Co gamma rays.

175 SEMI-CONDUCTOR PROBE FOR INVESTIGATING ACCELERATOR BEAM PULSES.

H.E. Conzett, L. B. Robinson, and R. N. Burger (Univ. of California, Berkeley).

Nucl. Instr. Methods, 31: 109-11 (Dec. 1, 1964). (UCRL-11492).

An instrument which makes possible the investigation of individual beam pulses from a cyclotron is described. It utilizes a fully depleted diffused-silicon junction detector of 100 to 200 microns thickness. The detector characteristics of fast charge collection time ($\sim$1 nsec) and of inherent amplification are important in this application. Examples of the detector system response to beams from the Berkeley sector-focused cyclotron are presented.

176 A COMPTON SPECTROMETER WITH A P-N JUNCTION PARTICLE DETECTOR.

H. Aiginger (Atom-institut der Österreichischen Hochschulen, Vienna).

Atomkernenergie, 9: 355-8 (Sept.-Oct. 1964). (In German).

An experiment was carried out to study replacing the scintillation counter normally used for the detection of the Compton electrons by a p-n semiconductor detector. The high resolution of these detectors for conversion electrons and the sharply defined Compton edges of γ spectra attained with these detectors offered the probability of an improvement in resolution. The experiment showed an improvement of 7% in a usual Compton spectrometer to 3.2% in this arrangement. In evaluating this improvement it is necessary to know the contribution of amplifier noise to line width and the resolution of the detector for monoenergetic electrons. The measurement of both is described.

177 SEMICONDUCTOR DETECTOR SPECTROSCOPY OF THE NUCLEAR REACTIONS O^{16} + d, O^{18} + p.

Georges Amsel (Ecole Normale Supérieure, Paris).

Ann. Phys. (Paris) (13), 9: 297-344 (May-June 1964). (In French).

Semiconductor detectors were used to study the reactions $^{16}O+d$ and $^{18}O+p$. The principles of semiconductor detectors, and their fabrication, characteristics, resolution, stability, and experimental utilization are reviewed. The preparation of the oxygen targets by anodic oxidation on Al and the performance of the Al_2O_3 films (nonmetallized and metallized) are reported. The experimental techniques and the results obtained are discussed in some detail. The theoretical interpretation of the data showed the validity of the Breit-Wigner R matrix theory in the excitation region at 9 Mev in ^{18}F for the emission of alpha particles. The existence of selection rules of isotopic spin in the same excitation region for ^{18}F and ^{19}F was confirmed. The theory of (d, p) stripping at proton emission energies of the order of 1 Mev was verified.

178 A SOLID STATE NEEDLE DETECTOR FOR THE DETERMINATION OF REGIONAL BLOODFLOW IN THE BRAIN AND KIDNEY BY THE ^{85}Kr CLEARANCE METHOD.

Appelgren, K. L.; Lewis, D. H.; Haeggendal, E. (Sahlgrenska Sjukhuset, Goteborg, Sweden).

Scand. J. Clin. Lab. Invest., 17: 511-12 (1965).

A new type of needle detector for β radiation was developed for use with ^{85}Kr in the determination of the regional blood-flow of an organ by the clearance of the

inert gas from the tissue. A small solid state needle detector can be inserted directly into the tissue which is sensitive almost exclusively to β radioactivity from a small area of tissue around the detector. The new detector is a needle-type lithium-drifted p-i-n junction semiconductor detector shaped as a cylinder 0.9 mm in diameter and 2.5 mm long. It is encased in a stainless tube 50 mm long with an OD 1.4 mm except for 10 mm in the free end of the tube where the OD is 1.1 mm, corresponding to a wall thickness of 0.05 mm. The sensing element is placed in the 1.1 mm part of the tube. The free tip of the needle is sealed by No. 1 Hivac epoxy inert to the tissue. The detector is operated with a bias voltage 20-40 v. The signal from the detector is amplified by a low-noise charge-sensitive, preamplifier and recorded via a conventional discriminator unit on a ratemeter-scaler unit. With ^{85}Kr the detector gave a measured ratio of γ to total activity which was 10% of the theoretical ratio which is 0.4%. That is, the detector works practically as a β detector with a good β: γ ratio for ^{85}Kr.

179 (LAL-1102) UTILISATION DES DETECTEURS A SEMICONDUCTEUR AUPRES D'UN ACCELERATEUR A HAUTE ENERGIE. I. ETUDE EXPERIMENTALE D'UN DETECTEUR A SEMICONDUCTEUR AUPRES DE L'ACCELERATEUR LINEAIRE. II. AMPLIFICATEUR A FORT DEBIT D'IMPULSIONS POUR DETECTEUR A SEMICONDUCTEUR.

(Utilization of Semiconductor Detectors with a High-Energy Accelerator. I. Experimental Study of a Semiconductor Detector With the [Orsay] Linear Accelerator). Amsel, G.; Benaksas, D.; Zajde, C. (II. High-Pulse-Rate Amplifier for a Semiconductor Detector). Bosshard, R. (Laboratoire de l'Accelerateur Linéaire, Univ. de Paris, Orsay (France)). Mar. 1965. 87 p. Dep. mn.

The special techniques required for the use of semiconductor detectors near a beam of high energy electrons are studied and their advantages discussed. An amplifier is described with capabilities of handling very high counting rates without pile up. The amplifier has a 6 ns risetime; pulses can be clipped down to 10 ns. Gain is 300 and noise levels in the range of 30 Kev (F.W.H.M. for silicon) are achieved. α particle pulses in presence of 10^8 counts per second due to protons from an electrostatic accelerator were correctly measured. Operation with pulsed accelerators yields satisfactory background reduction. The structure of the amplifier is given in detail. Pile up problems are discussed both in pulsed and continuous operation. The noise characteristics are studied, taking into account the effect of amplifier and detector risetimes and clipping time.

180 ENERGY FOR ELECTRON-HOLE PAIR GENERATION IN SILICON BY ELECTRONS AND α PARTICLES.

C. Bussolati (Istituto di Fisica del Politecnico, Milan), A. Fiorentini, and G. Fabri.

Phys. Rev., 136: A1756-8 (Dec. 14. 1964).

The difference of response of Si semiconductor detectors to α particles and electrons was tested. The mean energy required for electron-hole pair generation by electrons was found to be different from that for α particles. These values are, respectively, $\varepsilon_\infty = 3.79 \pm 0.01$ and $\varepsilon_\infty = 3.61 \pm 0.01$ at a temperature of 300°K for electrons (365 kev) and α's (5.477 Mev).

181 ON THE TIME RESOLUTION OF CHARGED PARTICLE SEMICONDUCTOR DETECTORS.

I. A. Baranov, M. V. Blinov, and N. M. Kazarinov.

Izv. Akad. Nauk SSSR, Ser. Fiz., 28: 1257-8 (July 1964). (In Russian).

182 (LA-DC-6500) TRANSIENT RESPONSE OF SOLID-STATE DETECTORS.

A. Hemmendinger, M.G. Silbert, and A. Moat (Los Alamos Scientific Lab., N. Mex.).

[1964]. Contract W-7405-eng-36. 8 p. (CONF-799-3). Dep. (mn); $1.00 (cy), 1 (mn) OTS.

From 11th Annual Nuclear Science Symposium, Philadelphia, Oct. 1964.

The response of a solid state detector to large bursts of ionizing particles was investigated for the purpose of determining detectors suitable for recording accurately the sizes and shapes of rapidly changing ionizing flux. Basic design details for a gamma detector with response proportional to the incident energy flux are given.

183 (CRGP-1182) LOW-NOISE, CHARGE-SENSITIVE, VACUUM TUBE PREAMPLIFIER FOR SEMICONDUCTOR DETECTORS.

A. J. Tavendale (Atomic Energy of Canada Ltd., Chalk River, Ont.).

Sept. 1964, 11 p. (AECL-2071). Dep.; $0.50 (AECL).

The design and performance of a low-noise, charge-sensitive vacuum tube preamplifier for semiconductor detectors are described. The preamplifier has a noise figure of 1.8 kev FWHM-germanium equivalent or 270 rms electron-hole pairs at zero load capacitance. The slope of the noise versus input load capacitance characteristic is 0.04 kev FWHM-germanium equivalent per picofarad.

184 (AED-C-06-10) INSTRUMENTS AND MEASURING TECHNIQUES IN NUCLEAR PHYSICS.

Series C: Bibliographies. K. Debertin, comp. (Johann-Wolfgang-Goethe-Universität, Frankfurt am Main. Institut für Kernphysik).

May 1964. 185 p. Dep. (mn).

A total of 642 titles is included for methods and instruments used in radiation detection and measurement. Author, patent-number, report-number, and subject indexes are included. The majority of the references have been announced in NSA.

185 (PAN-347) ELASTIC SCATTERING OF 24.7-Mev ALPHA PARTICLES.

A. Budzanowski, K. Grotowski, S. Micek, H. Niewodniczanski, J. Sliz, A. Strzalkowski, and H. Wojciechowski

(Polish Academy of Sciences, Inst. of Nuclear Physics, Krakow). May 1964. 48 p. Dep.

The differential cross sections for the elastic scattering of 24.7-Mev alpha particles on O, Mg, Al, Si, Ca, Mn, Co, Ni, Cu, Ge, Zr, Ag, In, Sn, Hf, W, Au, Bi, and U nuclei were measured by means of a semiconductor detector in a wide range of angles. The behavior of the angular distribution curves for different mass numbers is discussed.

186 (PR-P-62) PHYSICS DIVISION PROGRESS REPORT, APRIL 1 TO JUNE 30, 1964.

(Atomic Energy of Canada Ltd. Chalk River Nuclear Labs., Chalk River, Ont.). 59 p. (AECL-2044). Dep.; $1.50 (AECL).

Two high-resolution techniques were developed to study the closely spaced energy levels above 9 Mev excitation in ^{20}Ne. Using one method, γ rays from the reaction $^{19}F(d,n\gamma)^{20}Ne$ are studied in a good-resolution Li-drifted Ge spectrometer as a function of the deuteron beam energy. A pulse shape discrimination, which rejected many of the pulses from electrons passing through the walls of the γ-ray detector, was used and gave a peak to background improvement of about a factor of two.

187 DEVICES FOR THE DETECTION OF ENERGETIC PARTICLES.

J. A. Newth (Imperial Coll. of Science and Tech., London). Rept. Progr. Phys., 27: 93-159 (1964).

A brief survey of some of the problems of high-energy particle physics is followed by a discussion of the properties of particle accelerators and the production and handling of beams of particles. The performance of four main types of particle detectors — scintillation and Cherenkov counters, bubble and spark chambers — is then described in some detail. A number of different detectors that are less common and important are briefly described. The capabilities and limitations of the different types if instruments are emphasized. 90 references.

188 SEMICONDUCTOR RADIATION DETECTORS.

Hisanobu Kobayashi. Radioisotopes (Tokyo), 13: 323-8 (July 1964). (In Japanese).

The theory and characteristics of semiconductor radiation detectors are reviewed. The singular properties examined include the energy distribution, linearity of the output wave height with respect to the energy of the incoming particle, and the pulse build-up time. The operating characteristics of pulse ionization chambers, proportional counters, G-M tubes, scintillation counters and semiconductor detectors are compared, describing in detail three types of semiconductor detectors: the surface barrier, p-n junction, and p-i-n junction types.

189 SIGNIFICANT PROGRESS FOR GAMMA SPECTROSCOPY : LITHIUM DRIFTED GERMANIUM COUNTERS.

M. Roemer and H. Schneider (Universität, Giessen, Ger.). Kerntechnik, 6: 421 (Sept. 1964). (In German).

Performance of lithium-drifted germanium counters in gamma spectroscopy is discussed. Results are compared with NaI(Tl) scintillation counters for ^{60}Co gamma spectra.

190 (UCRL-3307(Rev.2) LAWRENCE RADIATION LABORATORY COUNTING HANDBOOK.

(California. Univ., Berkeley. Lawrence Radiation Lab.). June 5, 1964. Contract W-7405-eng-48. 185 p. Dep. (mn); $5.00 (cy), 4 (mn) OTS.

A compilation is presented of operational techniques and performance specifications on counting equipment. The counting notes are written from the viewpoint of the user. The equipment covered includes amplifiers, cables, coaxial components, coincidence systems, discriminators, amplitude analysis components, photomultipliers, scintillators, scalers, readout equipment, waveform generators, and power generators.

191 (PAN-516/II) POVERKHNOSTNO-BAR' ERNYE KREMNIEVYE DETEKTORY TIPA dE/dx.

(dE/dx Surface-Barrier Silicon Detectors).

T. Krogul'ski, Ya. Khvashchevska, and M. Yaskula (Polish Academy of Sciences. Inst. of Nuclear Research, Warsaw).

Apr. 1964. 13 p. Dep.(mn).

The detectors obtained had thicknesses 70, 50, 40, 30, and 25 μ, the active area 1 to 1.5 cm^2 while their barrier could be broadened over the whole geometrical detector thickness. The detectors were studied by means of natural polonium and thorium α sources and by means of 24-Mev α particles and 12.7-Mev protons obtained from a cyclotron.

192 (NP-14332) IMPROVED SOLID-STATE RADIATION DETECTOR.

Final Report. M. S. Shaikh, R. R. Ferber, E. L. Keller, and P. R. Malmberg (Westinghouse Electric Corp. Semiconductor Div., Youngwood, Penna. and Westinghouse Electric Corp. Research Labs., Pittsburgh).

Apr. 22, 1963. Contract OCD-OS-62-70. 151 p.

An investigation of silicon diode structures as solid-state gamma radiation detectors, and recommendations for their utilization in OCD instrumentation are presented. The efforts are divided into five categories: (1). Theoretical studies and a mathematical analysis of gamma response for the determination of optimum detector parameters. This work was carried out using an IBM 7094 computer. (2). Setting up diode production and evaluation facilities. This includes instrumentation for diode evaluation, gamma source preparation, diode diffusion and alloying furnaces, special vacuum evaporator facilities, lithium ion drift-

ing apparatus and power supply. (3). Development of diode formation processes including diffusion, alloying, ion drift, and combinations of processes. (4). Fabrication and evaluation of diode structures, contacting, and encapsulations. (5). Development of transistorized instrument electronics, i.e., ultralow noise preamplifier, amplifier, response compensation circuit, and metering circuit design.

193 (HW-81746 (p.5.46-53)) EXPERIMENTAL METHOD FOR MEASUREMENT OF NEUTRON DOSE.

G. F. Garlick (General Electric Co. Hanford Atomic Products Operation, Richland, Wash.).

A technique was investigated for the measurement of neutron dose and dose rates over a wide energy range. The objective was to achieve a composite response corresponding to that established by the National Committee on Radiation Protection (NCRP). Further, it was desired that the developed instrument be compact for direct personal use and also be applicable for use in general area neutron monitoring. The experimental multiple-detector neutron dosemeter showed promise in providing a measurement of neutron dose and dose rates over an energy range from thermal to 10 Mev. A composite sensor system using three solid state junction diodes as thermal, intermediate, and fast neutron energy detectors was developed. Response over the thermal to low kev range is provided by a ^{6}LiF cover over a diode plus a 3-in. diameter hydrogenous moderator. The intermediate range, from a low kev value to several hundred kev, is monitored by a ^{103} Rh foil covered diode plus a cadmium cover and suitable moderation. The fast neutron portion of the spectrum is measured through the use of a ^{238}U foil over the third diode. During the experimental tests, appropriate weighting functions were applied electronically by line-operated instrumentation to the signals from the three detectors. The composite response curve was determined through measurements with neutron sources, a Van de Graaff accelerator, and through specific calculations. Results indicated that a neutron dose of less than 1 mrem could be measured.

194 TECHNIQUE AND APPARATUS FOR DETERMINING THE RESPONSE OF SCINTILLATORS AND SEMICONDUCTORS TO LOW-ENERGY X-RAY EXCITATION.

Aitken D. W., Marcum A. I., Zulliger H. R. (Stanford Univ., Calif.).

IEEE (Inst. Elec. Electron. Eng.). Trans. Nucl. Sci., NS-13: No. 1, 287-96 (Feb. 1966).

Some apparatus and techniques that are being developed in order to investigate the response of scintillators and semiconductors to x-ray excitation are described. Examples of the signal-averaging technique are shown using the highly attenuated output of a precision pulse generator as the signal source. A discussion of the intended applications of the apparatus is presented.

195 ON THE MAXIMUM RESOLVING POWER OF SEMICONDUCTOR DETECTORS.

Alkhazov G. D., Vorb'ev A. A., Komar A. P. (Ioffe Inst. of Physics and Tech., Leningrad).

Izv. Akad. Nauk SSSR, Ser. Fiz., 29: 1227-32 (July 1965). (In Russian).

The ratio of the mean square deviation of the number of electron-hole pairs produced in a semiconductor charged-particle detector to the Fano coefficient is calculated for Si and Ge detectors, using the Fano method and assuming that the ionization process is correctly described by the Shockley model. The error in the calculations is estimated to be 30%. The calculated Fano coefficient for Ge is in agreement with previous experimental values; that for Si is much smaller than experimental values. It is concluded that close to maximum resolution is being achieved with Ge detectors, but that Si detectors can be further improved and are capable of considerably higher resolution than Ge detectors. A temperature dependence of the Fano coefficient is also found.

196 RADIATION DETECTOR AND DISCRIMINATOR UTILIZING A SEMICONDUCTOR SOLID STATE DETECTOR.

Allenden, Dennis; Boddy, Keith; Freck, David Vernon; Hunt, Stanley Ernest (Associated Electrical Industries Ltd.).

U. S. Patent 3,209,151. Sept. 28, 1965. Priority date Sept. 18, 1961, Great Britain.

An apparatus for detecting radiation in gases includes a semiconductor solid state detector, means for exposing a strip of material to the radiation, means for moving the irradiated strip into operative relation with the detector, means for producing an electric pulse output from the detector, and means for analyzing the pulse output to determine the nature of the radiation. The analyzing means is made up of a number of filters each passing a pulse of a different pulse height band, selector switching means for rendering a required filter operative, and means for varying the length of time during which the strip of material is exposed to the radiation. The apparatus is particularly applicable to detecting Pu-239, U-235, and U-238 in the air.

197 DETECTION OF THE REACTION $^{28}Si(n,p)^{28}Al$ IN SILICON SEMICONDUCTOR DETECTORS AT NEUTRON ENERGIES OF 14 Mev.

Andersson-Lindstroem G., Zausig B. (Institut für Experimentalphysik, Hamburg).

Ann. Physik (7), 15: 287-93 (1965). (In German).

The use of very thick surface-barrier detectors (1 mm deep) in the investigation of neutron-induced nuclear reactions in Si was described. Whereas earlier works in the neutron energy range around 14 Mev were limited

to the study of the Si(n,α) reaction, the (n,p) reactions were also observed. A difference method for the separation of the (n,α) and (n,p) spectra was given and the initial results were reported. The pattern of the effective cross section was measured in the region from 13.5 to 14.4 Mev. The results were discussed.

198 SILICON SURFACE-BARRIER DETECTORS; FABRICATION, TEST METHODS, PROPERTIES, AND SOME APPLICATIONS.

Andersson-Lindstroem G., Zausig B. (I. Institut für Experimentalphysik, Hamburg).

Nucl. Instrum. Methods, 40: 276-90 (Mar. 1966).

Investigations were performed on fabrication methods for silicon surface barrier detectors and their correlated properties. The resulting technique currently applied is presented. The method is based on the use of high resistivity silicon material (10000—30000 Ω · cm). Some special tests and results for several properties are given in detail and examples of applications in nuclear experiments are described.

199 SIMULTANEOUS MEASUREMENTS OF FLIGHT TIMES AND ENERGIES OF FISSION FRAGMENTS.

Andritsopoulos G., Cornell T., Rodgers A. L. (Atomic Weapons Research Establishment, Aldermaston, Eng.).

pp. 481-9 of STI/PUB/101 (Vol. 1).

An alternative way of measuring the prompt neutron emission is described. Fragment time-of-flight apparatus is mounted in an evacuated tube that passes laterally through the thermal column of the 5-Mw research reactor HERALD. A centrally positioned thin source produces 3×10^5 fissions s^{-1}. Fragments travel distances of 180 and 300 cm respectively to the terminal detectors, and in passing through a VYNS film, positioned 180 cm from the source along the longer flight path, eject electrons that are used to form a reference time-signal. Essentially the times of flight of both fission fragments are measured simultaneously with the kinetic energy of one of the pair. This is achieved by using a surface barrier counter for the 300-cm detector. The difficulty of maintaining good timing and energy resolutions simultaneously is overcome by routing the pulse to the charge sensitive preamplifier through a delay line amplifier from which a fast timing pulse is derived. The collected data enables the fragment mass to be determined both before and after prompt neutrons have been emitted. Hence the experiment provides a means, for studying the behavior of neutron emission from individual fragments. The experimental uncertainties are those associated with the measurement of small differences, and an appraisal is made of the errors and calibrations that enter into the measurements. Of particular importance, the response of the surface barrier counter to fission fragments is obtained directly from the collected data from events in which the neutron emission is low. These calibrations are used in the measurements of post-neutron mass.

200 (JINR-P-2487) PRIMENENIE ELEKTROFOTOGRAFII DLYA IZMERENIYA CHUVSTVITEL'NOI OBLASTI GERMANIEVYKH p-i-n- DETEKTOROV.

(Application of Electrophotography for Measurements of Sensitive Region of Germanium p-i-n Detectors).

Antonov A. S., Yuskeselieva L. G. (Joint Inst. for Nuclear Research, Dubna (USSR). Lab. of Nuclear Problems).

1965. 10 p. Dep. mn.

The width of the sensitive region in germanium pin detectors is determined by developing the p-n-junction with dry and liquid electrophotographic developers.

201 ANTICOINCIDENCE SPECTROMETERS FOR NUCLEAR REACTION STUDIES.

Arnell S. E., Hasselgren A. (Chalmers Univ. of Techn., Goeteborg).

Arkiv Fys., 30: 397-409 (1965).

An anticoincidence spectrometer was constructed, in which the main detector consists of a 5 in. diameter by 6 in. long NaI crystal enveloped by a large cylinder of NE 102 A plastic scintillator. The intended use of the spectrometer is to simplify the response of the NaI crystal to high energy gamma radiation resulting from nuclear capture reactions without greatly reducing the detector efficiency. The behavior of the arrangement was tested with some (p,γ) reactions. The other type of anticoincidence spectrometer consists of a 2 mm thick Ge(Li) detector surrounded by the plastic scintillator. The intended use of this arrangement is to simplify the response of the Ge(Li) detector to low energy gammas by reducing the Compton distribution. The arrangement was tested with radioactive sources.

202 (EUR 2494.d) ABSCHIRMUNGSEXPERIMENTE AM FORSCHUNGSREAKTOR GEESTHACHT—JAHRESBERICHT 1964.

(Shielding Experiments at the Reactor Station Geesthacht — Annual Report, 1964).

Bagge E., Fischer E. (Gesellschaft für Kernenergieverwertung in Schiffbau und Schiffahrt m.b.H., Hamburg [West Germany]).

1965. 175 p. Dep. mn.

The experimental rigs ESTAKOS, ESTAGROP I and ESTAGROP II were used for several tests. The ESTAKOS group carried out various tests to check the measuring accuracy as well as measuring the radiation field on 5 shield arrays and determining the effective relaxation values of a number of materials. A start was made on tests to verify the accuracy with which ESTAKOS measuring results can be used to predict the measuring results obtained on other experimental devices. In Pool IV of the FRG (ESTAGROP I) the temperature rise resulting from radiation absorption in a 5 cm steel plate was investigated. It was shown that the temperature increase was everywhere proportional to the gamma dose-rate, the

neutrons playing only a small part in the heating effect. On conclusion of these tests, the first experiments were carried out on shield penetrations. Studies were made on gamma-permeability at a penetration in a 20 cm-thick iron slab and at an S-shaped penetration in concrete. The measurements provided basic data for the design of the main steam duct penetration in the secondary shielding of the research ship. Shielding tests were performed with layered shielding assemblies for the purpose of defining the optimum shielding design for mobile reactors. It proved possible to deal with 12 different shielding setups. A start was made on the first shielding experiments in the large irradiation-channel of the FRS (ESTAGROP II). The radiation field was measured in a water-filled irradiation space (thermal, epithermal and fast neutron flux and gamma dose-rate). The work aimed at the elaboration of measuring devices covered basically the further development of a recoil proton spectrometer and tests intended to provide data concerning the possibility of using semiconductor spectrometers for neutron spectrometry in shielding rigs. Indications are given of the difficulties arising as a result of interference reactions in the silicon of the semiconductor diodes. The theoretical group performed rough calculations for shield penetrations while continuing its work connected with the setting-up of comparative calculations for the experiments with flat assemblies. The computation programs MENDIP-65, COGA, and SHIGA made it possible to estimate group constants from microscopic data. A new method for radiation shielding optimization was devised with which layered shields including their material components, in flat, cylindrical and spherosymmetrical geometry, can be optimized. Furthermore, new mathematical methods were evolved in connection with neutron transport theory.

203 (UR-875-117) CHARGED PARTICLE COUNTING SYSTEM, WITH PARTICLE SEPARATION BY dE/dx MEASUREMENT.

Bahnsen A., West R. W. (Rochester Univ., N. Y. Dept. of Physics and Astronomy).

Jan. 1, 1966. Contract AT(30-1)-875. 18 p. Dep. mn. CFSTI $1.00 cy. $0.50 mn.

A counter and electronic system designed for the purpose of identifying charged particles is described. It consists of a proportional dE/dx counter-solid state E counter telescope, a pulse multiplier and additional electronics to store the energy spectra of protons and deuterons in separate parts of a 400-channel analyzer. This system was used in an investigation of the $^{12}C(d,p)$ reaction near 4 Mev.

204 (SAN-549-1) RESEARCH AND DEVELOPMENT ON SINGLE-CRYSTAL HIGH RESISTIVITY CADMIUM TELLURIDE FOR USE AS A GAMMA RAY SPECTROMETER.

Annual Report.

Baily N. A. (Hughes Research Labs., Malibu, Calif.)

June 1965. Contract AT(04-3)-549. 43 p. Dep. mn. CFSTI $2.00 cy, $0.50 mn.

Methods of preparing single crystals of CdTe were studied, as well as the properties of such crystals. Methods of preparing CdTe junctions were also investigated, and the characteristics of several diodes were measured. The response of the diodes to radiation was also studied.

205 THE RESPONSE OF P-I-N JUNCTIONS TO BETA RAYS. II. COUNT RATE VERSUS SURFACE ABSORBED DOSE RATE FOR ^{32}P AND ^{204}Tl.

Baily N. A., Hilbert J.W. (Hughes Research Labs., Malibu, Calif.).

Phys. Med. Biol., 11: 75-81 (Jan. 1966).

The use of lithium-drifted silicon p-i-n junctions as pulse counters for β dosimetry was investigated using the β particles emitted by ^{32}P and ^{204}Tl. The counting rate is directly compared with the surface absorbed dose rate as measured at the polystyrene electrode of a thin window extrapolation chamber. The rate of change of the detector response is compared with the rate of change of absorbed dose rate as a function of source-to-detector distance, source geometry and detector area. It was found that the ratio of these quantities remains constant after a certain minimum source-to-detector distance is achieved. In all cases investigated this distance did not exceed 10 cm. The absolute sensitivity of these devices is such that dose rates as low as 0.1 mrad/hr can be measured.

206 ON THE PREPARATION OF LITHIUM-DRIFTED Ge COUNTER DIODES.

Baldinger E., Matile G. (Univ., Basel).

Z. Angew. Math. Phys., 16: 822-6 (1965). (In German).

The lithium-compensated Ge counters are used for the detection of γ rays because of their excellent resolution power. The fabrication of these counters and their characteristics are described.

207 (ORNL-3908, pp 90-9) ATOMIC AND MOLECULAR CROSS SECTIONS.

Barnett C. F., Griffin D. A., Krause M. O., Ray J. A. (Oak Ridge National Lab., Tenn.).

Measurements were made to confirm the existence of stable electronic excited states of H_3, similar to those found in H and H_2. Capture into repulsive levels of H_3 dominates the electron capture process, but the capture into all levels is an order of magnitude less than expected. The parameters influencing the charge-transfer conversion of monoenergetic protons into energy-dispersed neutral particle beams were investigated. A 50-kev proton beam was passed through an argon gas cell composed of 11 insulated electrodes arranged to provide a linear decelerating field. Application of a 40-kv retarding field resulted in a nearly flat energy distribution with a 40% conversion efficiency of incident protons to neutrals. Fifty-kiloelectron-volt H_2^+ particles incident on the gas cell exhibited 45% conversion. Engineering modifications have decreased the measured noise width of the silicon surface barrier for measuring low-energy protons. A minimum noise width of 2.75 kev was obtained. The pulse spectrum of

6-kev protons was resolvable with the present geometry. Resolvable pulse spectra were also obtained for 10-kev He^+ and 15-kev N^+ ions. The fast time response of a barium titanate crystal was determined for a pulsed 300-kev H^0 beam. At low power levels (10^{-4} w/cm) the shape of the output signal pulse from the crystal was differentiated; however, as the input power increased, the time response of the crystal was the same as that of the beam.

208 MULTIPLE SPECTROMETER CONTROL BY COMPUTER.

Beaucage D. R., Kelley M. A., Ophir D., Rankowitz S., Spinrad R. J., Van Norton R. (Brookhaven National Lab., Upton, N. Y.).

Nucl. Instrum. Methods, 40: 26-44 (Feb. 1966). (BNL-9275).

A computer system whose function is to simultaneously operate, control and monitor nine neutron and x-ray spectrometers is described. The spectrometer equipment and the local control station characteristics are presented. The programmed control of the apparatus details asynchronous and synchronous control tasks. A time sharing supervisory system allows semi-automatic and fully automatic operation of the equipment and offers a library of mutually-used computer programs. Communication with the system is through a console typewriter and a complete record of experiment operation is printed.

209 PHOTOGRAPHIC, GLASS OR THERMOLUMINESCENCE DOSIMETRY.

Becker K. (Nuclear Research Establishment, Jülich, Ger.).

30 p. (CONF-650616-15). ORINS.

From Health Physics Society Annual Meeting, Los Angeles.

An attempt is made to compare advantages and disadvantages of "classical" photographic and modern solid-state detectors. Both advanced thermoluminescent detectors (TLD), in particular LiF and similar materials, and more recent radiophotoluminescent glasses are superior to photographic systems with regard to reliability and accuracy of the dose indication, sensitivity, dose range, energy and directional dependence of sensitivity, fading and "fogging" stability, reusability, fast and cheap evaluation, etc. LiF seems to be superior for certain radiobiological and medical purposes because of its flat response. For routine and accident (military or civil defense) personnel dosimetry, however, a properly designed glass badge gives more information and is a remeasurable "document" of the exposure similar to the photographic film because the radiation effect is integrated in spite of an unlimited number of interval measurements. As an example of a possible next generation personnel dosimeter proposals for a multiglass badge are briefly described. It is capable of giving instant information about the gamma and beta dose, the average gamma energy and the presence of neutrons. Fast neutrons can be measured by automatic counting of the number of fission fragment tracks in glass or other nonphotographic nuclear track detectors. Some practical aspects of this system are discussed.

210 MEASUREMENT OF HIGH-ENERGY γ-RAYS WITH Ge(Li) DETECTORS.

Berg R. E., Kashy E. (Michigan State Univ., East Lansing).

Nucl. Instrum. Methods, 39: 169-72 (Jan. 1966).

A method of measuring the energy of high-energy gamma rays is described. Parallel capacitors are used as an effective energy multiplier of a pulser signal to compare unknown high-energy gamma rays to known low-energy standards. This method has also provided an effective tool for measuring the linearity of the energy response of Ge(Li) detectors. This response is found to be linear to better than $\pm 0.03\%$ in the range 662 to 2614 kev and better than $\pm 0.1\%$ up to 6 Mev. As an example of this capacitor multiplying method the energy of the gamma ray from the 3^- excited level of ^{16}O is measured to be 6127.8 ± 1.2 kev.

211 RADIATION-INDUCED NOISE IN SEMICONDUCTOR COUNTERS.

Bertin A., Gondi P., Scandola G. (Univ., Bologna).

Nuovo Cimento, (10), 41B: 198-207 (Feb. 11, 1966).

The effects of electromagnetic radiations of various energies, ranging from 7 to $\sim 10^6$ ev, on silicon surface-barrier detectors were examined. Induced shot noise resulted; the noise amount, for equal induced currents, increases with the number of electron-hole pairs per primary electron, with departures from the law of proportionality that depend on the root mean square deviations specific of each radiation. The most energetical photons give rise to exceptionally high rms deviations whose origin was considered by examining the thickness and bias voltage effects.

212 (EUR 2580.e) LITHIUM DRIFTED SEMICONDUCTOR DETECTORS IN NUCLEAR SPECTROSCOPY.

Bertolini G., Cappellani F., Fumagalli W., Henuset M., Restelli G. (European Atomic Energy Community, Ispra (Italy), Joint Nuclear Research Center).

Aug. 31, 1965. 10 p. Dep. mn.

Results obtained in beta and gamma spectroscopy, together with short details on the construction of silicon and germanium Li-drifted detectors are presented.

213 THE DEGENERATE SEMICONDUCTOR THIN FILMS. I - THE FERMI ENERGY.

Bezak V.

The Journal of Physics and Chemistry of Solids, Vol. 27, No. 5, May 1966, p. 815-820.

A formula is derived for the electronic Fermi energy of the strongly degenerate monocrystalline n-type semiconductor thin films. If a set of these films, having equal concentration of conduction electrons, is borne in mind,

then the dependence of the Fermi energy (related to the conduction band bottom) upon the film thickness is shown to have a tendency to oscillate, provided that no Tamm levels are present in the forbidden gap. The n-type InSb films are discussed in connection with the topic of this paper.

214 THE DEGENERATE SEMICONDUCTOR THIN FILMS. II - THE LONGITUDINAL ELECTRICAL CONDUCTIVITY.

Bezak V.

The Journal of Physics and Chemistry of Solids, Vol. 27, No. 5, May 1966, p. 821-834.

A quantum theory of the longitudinal electrical conductivity of the mono-crystalline strongly degenerate semiconductor thin films is developed under some simplifying assumptions (no surface states are assumed, the effective mass of the carriers, as well as their relaxation time, are taken isotropic, constant and independent of the film thickness, the external electrical field is assumed so small that the Ohm's law may be in force, etc.). The n-type InSb films with donor concentrations 10^{13}-10^{16} cm^3 may represent objects being most interesting in regard to the topic of the paper. In order to formulate a suitable boundary condition for the diffuse scattering of the conduction electrons on the film surface, the Wigner representation of the one-electron density matrix is taken into account. When the film thicknesses are comparable with (or smaller than) the mean interelectronic distance, then only the values of the longitudinal electrical conductivity are found seriously enough different from those obtained in frame of the semi-classical theory having been presented for metallic films by Fuchs.

215 OPTIMUM ENERGY RESOLUTION OF SEMICONDUCTOR RADIATION DETECTORS WITH PREAMPLIFIERS USING TUBES, FIELD-EFFECT TRANSISTORS, AND BIPOLAR TRANSISTORS.

Bilger H. R. (Oklahoma State Univ., Stillwater).

Nucl. Instrum. Methods, 40: 54-60 (Feb. 1966).

A uniform treatment of tubes, field-effect transistors (FET's) and bipolar transistors (transistors) in first stages in nuclear-detector preamplifiers is given by introducing equivalent circuits with suitable noise sources. Optimizing the system detector-preamplifier with respect to energy-resolution, it is feasible to obtain a rms-fluctuation of 90 electron-hole pairs with electrometer-type tubes or FET's, whereas with transistors it is feasible to achieve 900 pairs. These values correspond to $\Delta E_{fwhm,Ge} = 0.6$ kev and $\Delta E_{fwhm,Ge} = 6$ kev.

216 HIGH-RESOLUTION PHOTON SPECTROMETRY WITH LITHIUM-DRIFTED GERMANIUM DETECTORS.

Bilger H. R., Sherman I. S. (Argonne National Lab., Ill.).

Phys. Lett., 20: 513-16 (Mar. 15, 1966).

Line-widths of 850 ev (f.w.h.m.) were obtained for γ rays below 100 kev with new field-effect transistors in the preamplifier used with germanium detectors. The "doublet" of ^{133}Ba (cascade γ rays from ^{133}Cs) at 80 kev, which consists of two lines 1.5 kev apart, was partially resolved.

217 NEW POSSIBILITIES OF SILICON p-n JUNCTIONS IN NUCLEAR PARTICLE DETECTORS.

Blanc D. (Faculté des Sciences, Toulouse), Casanovas J., Chapuis A.-M., Soudain G.

Nucl. Instrum. Methods, 37: 90-2 (Nov. 1965). (In French).

By measuring the number of electric charges produced through ionization in a silicon surface-barrier p-n junction, it is possible to evaluate the absorbed dose of each type of particles in a complex beam of α, β, and γ rays and to be aware of the collection share of each such radiations. The detector and the results obtained with α, β, and γ sources of various energies are described.

218 A VERSATILE VACUUM CHAMBER FOR SEMICONDUCTOR BETA AND GAMMA DETECTORS.

Benvenuti A., Blasi P., Maurenzing P., Sona P. (Univ., Florence).

Nucl. Instrum. Methods, 37: 168-70 (Nov. 1965).

The vacuum chamber described has the following features: capability of simultaneous use of several semiconductor detectors, and a scintillation detector, in the chamber; provision for source replacement and movement under vacuum; and provision for rapid insertion of sources into the chamber. The chamber is a cubical enclosure 28 cm on a side, designed for operating at 10 μ Torr and 78°K.

219 USE OF SURFACE-BARRIER SILICON DETECTORS FOR MEASURING FAST PARTICLE SPECTRA.

Bogdanov G. F., Maksimenko B. P.

At. Energ. (USSR), 19: 449 (Nov. 1965). (In Russian).

Silicon surface-barrier detectors were used to measure the spectra of plasma ions and charge-exchange neutrals with energies of 10 to 200 kev. Calibration of the detectors using 28- to 70-kev protons indicated their response was linear. A sample spectrum of atoms and molecules from the Ogra device is presented and discussed.

220 APPLICATION OF HIGH-RESOLUTION SEMICONDUCTOR DETECTORS IN X-RAY EMISSION SPECTROGRAPHY.

Bowmon Harry R., Hyde Earl K., Thompson Stanley G., Jared Richard C. (Univ. of California, Berkeley).

Science, 151: 562-8 (Feb. 4, 1966). (UCRL-16485).

Solid-state devices developed primarily for nuclear gamma spectroscopy have many potential uses in x-ray analysis. Experiments are described which demonstrate their performance.

221 METHODISCHES ÜBER HOCHENERGIE-EXPERIMENTE AN SCHWEREN KERNEN UNTER BENUTZUNG VON GLIMMER ALS DETEKTOR.

Brandt R.

Nukleonik, Band 8, Heft 4, 1966, z. 235-239.

Es wird gezeigt, dass 18-GeV-Protonen keine ätzbaren Spuren im Glimmer hinterlassen. Solange $<10^{13}$p/cm^2 durch eine Glimmerfolie treten, werden durch die Wechselwirkung mit Verunreinigungen im Glimmer vernachlässigbar wenig ätzbare Spuren (A>30) erzeugt. Es wird eine Glimmer-Päckchen-("sandwich")-Methode entwickelt, in der eine sehr dünne Metallschicht (etwa 10 μgr/cm^2 Uran auf 200 μgr/cm^2 Aluminium) zwischen zwei Glimmerfolien gepresst wird. Dieses Päckchen wird bestrahlt und wie üblich werden die Teilchenspuren mit Fluss-Säure herausgeätzt. Danach sieht man unter einem gewöhnlichen optischen Mikroskop einzelne Spuren, die von Spallationsereignissen herrühren. Weiter beobachtet man einander räumlich zugeordnet 2 Spuren, die von einem Spaltereignis herkommen. Gelegentlich sieht man drei einander zugeordnete Spuren, deren Ursprung möglicherweise eine echte Kerndreifachspaltung ist. Diese Glimmerpäckchenmethode ist geeignet, die Spaltwirkungsquerschnitte als Funktion der Energie und Masse genauer als bisher zu bestimmen.

222 DETECTORS IN BIOLOGY AND MEDICINE.

Dunham Ch. L.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 9-17.

Detector applications are discussed for three fundamental areas of Biology and Medicine: Radiobiology, Photobiology and Nuclear Medicine. The detectors discussed include photomultiplier tubes, image intensifier tubes, scintillators, semiconductors and spark chambers. Examples of biomedical work in progress are given which have been made possible by the development of adequate detectors. The biological and medical significance of the work is discussed and some needed detector advances are pointed out.

223 IMPROVEMENTS IN APPLIED GAMMA-RAY SPECTROMETRY BY GERMANIUM SEMICONDUCTOR DETECTOR.

Brune D., Dubois J., Hellstroem S. (Aktiebolaget Atomenergi Studsvik, Sweden).

Nukleonik, 7: 484-8 (Oct. 1965).

A germanium semiconductor detector was used in the investigation in four cases of applied gamma-ray spectrometry. In one case the weak activity contribution of ^{134}Cs to ^{137}Cs standard sources was determined. The second case concerns the determination of ^{42}K in samples of biological origin containing strong ^{24}Na activities. In the third case the ^{94}Nb and ^{95}Nb activities from neutron irradiated niobium foils used in the dosimetry of high neutron fluxes with long exposure times were completely resolved, and it was possible to determine the ratio of the two activities with a high degree of accuracy. Finally, a ^{95}Zr—^{95}Nb source was analyzed in a similar way with respect to its radiochemical composition The resolution obtained also made possible a determination of the branching ratio of the two gamma-transitions in ^{95}Zr and the energies of the gamma-transitions of both nuclides.

224 THE EFFECT OF HIGH-ENERGY PROTONS ON SEMICONDUCTOR DETECTORS OF NUCLEAR RADIATION. II. DIFFUSION-DRIFT DETECTORS.

Brykina L. S., Vasilev V. S., Golovin B. M., Landsman A. P., Osipenko B. P., Fedoseeva O. P.

Kosm. Issled., 3: 499-502 (May-June 1965). (In Russian).

Eighteen silicon n-i-p detectors with 0.3-mm sensitive films and four with 2-mm layers were subjected to proton bombardment of 2×10^9 to 8×10^9 protons/cm^2-sec with a maximum dose of 5×10^{13} protons/cm^2. With the 0.3-mm type, investigation was made of detector output pulse height, reverse current, energy resolution, and detector capacitance as a function of the radiation dose. The results show that the immunity of the diffusion drift detectors is approximately equal to that of the surface barrier type; i.e., no substantial deterioration of parameters was observed for doses as high as 10^{12} protons/cm^2. With the 2-mm type, the changes in the electrical structure were determined by measuring the detector photoresponse before and after bombardment. It was found that after a dose of 8×10^{12} protons/cm^2 the sensitive area of the detector was reduced, becoming practically negligible after a dose of 5×10^{13} protons/cm^2.

225 COMPARISON OF BURNUP DETERMINATIONS BY MEANS OF MONITOR-ACTIVATION AND GAMMA SPECTROSCOPY FOR AN MTR ELEMENT.

Buba L., Hick H., Rumpold K. (Oesterreichische Studiengesellschaft für Atomenergie GmbH, Vienna).

Atomkernenergie, 11: 167-72 (Mar. - Apr. 1966). (In German).

A semiconductor Compton spectrometer was developed which allows nondestructive burnup determination of fuel elements. To test the reliability of such a measurement a partial fuel element of the ASTRA-reactor was prepared with monitor wires and irradiated. After irradiation the monitor wires were removed remotely and their activity measured. By neutron-physical evaluation the fuel-element burnup could be calculated. Then the burnup of the fuel element was determined by means of a Compton spectrometer too. The two results of 37.6 mg and 36.1 mg for the amount of ^{235}U consumed agree very well. The error of a burnup determination with the semiconductor Compton spectrometer should therefore be $\sigma \leqslant 15\%$.

226 (CLOR-39/D) ALPHA CONTAMINATION LOCATOR WITH JUNCTION RADIATION DETECTOR.

Bukowiecki B. (Centralne Laboratorium Ochrony Radiologicznej, Warsaw [Poland]).

1965. 5 p. Dep. mn.

An alpha contamination locator with semiconductor radiation detector is developed. The alpha contamination locator is designed as a small, portable instrument that provides a precise location of alpha contamination. Electronic circuits provide an audible acoustic signal for every alpha particle that loses, within the detector sensitive volume, at least 600 kev of its energy. The instrument works with or without an extension of about 50 cm, according to the conditions of the measurements actually performed.

227 (CLOR-44/D) OPTYMALIZACJA SPEKTROMETRYCZNYCH STOPNI WEJSCIOWYCH NA TRANZYSTORACH TYPU F.E.T. WSPOLPRACUJACYCH Z POLPRZEWODNIKOWYMI DETEKTORAMI PROMIENIOWANIA JADROWEGO.

(Considerations on the Optimalization of F.E.T. Spectrometer Stages Working with Semiconductor Radiation Detector).

Bukowiecki B., Katkiewicz W. (Centralne Laboratorium Ochrony Radiologicznej, Warsaw [Poland]).

1965. 21 p. Dep.

Some problems in the design of low-noise preamplifiers for use with solid-state detectors are discussed, and the performance and optimization of some amplifier-detector combinations are described. Some experimental results on preamplifiers using specific transistors are included.

228 GERMANIUM COMPENSATION BY Li-DRIFT IN BOILING LIQUIDS FOR p-i-n-DIODE CONSTRUCTION.

Cappellani F., Fumagalli W., Restelli G. (C.C.R., Euratom, Ispra, Italy).

Nucl. Instrum. Methods, 37: 354-6 (Nov. 1965).

The fabrication of lithium-drifted germanium p-i-n diodes having compensated volumes as high as 4 cc is reported. The lithium drifting process is carried out in boiling liquids in order to provide temperature control and heat removal. The liquids studied include pentane, hexane, o-xylene, chloroform, methanol, acetone, and petroleum spirits.

229 FAST NEUTRON BOMBARDMENT OF A LITHIUM-DRIFTED GERMANIUM GAMMA-RAY DETECTOR.

Chasman C., Jones K. W., Ristinen R. A. (Brookhaven National Lab., Upton, N. Y.).

Nucl. Instrum. Methods, 37: 1-8 (Nov. 1965). (BNL-9157).

Pulse height spectra from a lithium-drifted germanium gamma-ray detector bombarded with monoenergetic neutrons are measured at neutron energies of 1.2, 2.2, 4.7, and 16.3 Mev. Gamma rays from inelastic neutron scattering in the counter and the counter cryostat are identified. An EO conversion electron line from the decay of the 691-kev first excited state in ^{72}Ge is very prominent, and at neutron energies of 4.7 and 16.3 Mev charged particle groups from neutron-induced reactions in the germanium appear. A discussion of the application of germanium gamma detectors to the study of (n,n'γ) reactions is presented. The setector is irradiated with a total fast neutron flux of approximately 10^{11} neutrons/cm^2 and shows no deterioration of resolution.

230 (NAA-SR-11762) DEVELOPMENT OF A SOLID-STATE NEUTRON DETECTOR FOR SNAP-10A.

Chesavage A. (Atomics International, Canoga Park, Calif.).

Mar. 25, 1966. Contract AT(11-1)-Gen-8. 40 p. (Dep. mn. CFSTI $2.00 cy, $0.50 mn.

Electronic devices, primarily semiconductors, degrade in a nuclear radiation environment. In a reactor environment most of the damage is due to fast neutrons. The lithium hydride shield on SNAP 10A was designed to attenuate the fast neutron exposure at the instrument compartment to a tolerable level. To evaluate shield effectiveness fast neutron detectors were developed. Eight detectors were installed in the SNAP 10A FS-4 flight system. The development and in-flight data of these detectors are discussed.

231 LITHIUM-DRIFTED DETECTORS FOR BETA- AND GAMMA-SPECTROMETRY.

Chwaszczewska Janina; Dakowski Miroslaw; Przyborski Wincenty; Sowinski Mieczyslaw (Inst. of Nuclear Research, Swierk, Poland).

Nukleonika, 10: 251-4 (1965).

The performance of lithium-drifted β and γ-semiconductor spectrometers is described. Lithium-drifted silicon diodes prepared on the basis of the Pell method made possible the construction of β-particle detectors with thin window and very good characteristics. The depletion layer thickness is 2.8 mm and active area — 160 mm^2. For gamma spectroscopy, the lithium-drifting process was carried out on p-type gallium-doped germanium samples of 5 Ω/cm resistivity and about 100 μsec life time minority carriers. A compensated region 1.5 mm thick was obtained. Beta and gamma spectra for ^{207}Bi are illustrated.

232 A SEMICONDUCTOR SYSTEM FOR CHARGED PARTICLES IDENTIFICATION.

Chwaszczewska J., Freindl L., Karcz W., Pryzyborski W., Slapa M.

Report No. 444/PL. Institute of Nuclear Physics, Cracow, January 1966.

A system consisting of two semiconductor counters of types "dE/dx" and "E" was built to separate particles from nuclear reaction. The properties of this system were checked by detection of products of reaction induced by 24.8 MeV alpha particles and 12.4 MeV deuterons on Au, C and Ca nuclei.

233 SEMICONDUCTOR NUCLEAR RADIATION DETECTORS AND THEIR APPLICATIONS.

Chwaszczewska Janina, Dakowski Miroslaw, Przyborski Wincenty, Sowinski Mieczyslaw.

Przeglad Elektron., 6: 174-9 (Apr. 1965). (In Polish).

The advantages of semiconductor radiation detectors are briefly discussed, and the state of the art of semiconductor-detector design and fabrication in Poland is outlined. Surface-barrier detectors have been constructed with gold layers of 40-100 micrograms/cm^2 thickness, with areas of 4 mm^2 to 2 cm^2 for single detectors and up to 14 cm^2 for a mosaic of detectors, and with a resolution of 16 Kev for 8.776 Mev alphas (using a single 12 mm^2 detector). Sensitive layers of 400-500 microns have been achieved. Also, dE/dx type detectors have been built with thicknesses of 25 to 70 microns. Surface barrier diodes with guard rings have made depths of 1.2 to 1.5 mm. The guard ring reduces the leakage current on the sensitive inner gold conductor and thereby allows the use of higher voltages across the sensitive layer. For thicknesses above 1 mm, lithium drifted germanium detectors have been constructed. Thicknesses of 3 mm have been obtained. The demands placed on the electronic circuitry required to obtain high resolution information from the millivolt-level signals produced by these semiconductor type devices are descussed.

234 (RT/EL(65)7) RIVELATORI A SEMICONDUTTORE DEL TIPO A BARRIERA SUPERFICIALE.

(Semiconductor Detectors of the Surface Barrier Type).

Coiante D., Michalowicz J., Parisi Presicce L., Spoglia U. (Comitato Nazionale per l'Energia Nucleare, Rome, Italy). Sept. 1965. 17 p. Dep. mn.

A method of making semiconductor surface barrier particle detectors and their epoxy resin encapsulation is described. The electrical and radiation testing results of devices are presented.

235 THE USE OF A LITHIUM DRIFTED GERMANIUM DETECTOR TO OBSERVE THE DE-EXCITATION GAMMA RAYS PRODUCED BY THE INELASTIC SCATTERING OF 2.9 Mev NEUTRONS BY COBALT AND COPPER.

Christie D. R., Daniels J. M., Felsteiner J. (Univ. of Toronto).

Nucl. Instrum. Methods, 37: 165-7 (Nov. 1965).

Gamma spectra from inelastic scattering of 2.9-Mev neutrons by ^{59}Co, ^{63}Cu, and ^{65}Cu are measured, and energy-level and gamma-decay schemes for these nuclides are inferred from the data. The design of the lithium-drifted germanium detector used in the measurements is described.

236 SEMICONDUCTOR DETECTORS OF NUCLEAR RADIATION.

Coche A. (Centre of Nuclear Research, Strasbourg).

Ind. At., 9: 61-9 (1965). (In French).

The principal characteristics of diodes with a n-p linkage and with surface barriers and their essential uses are examined. Next the principle of the method is given for compensating a material of the P type by the migration of lithium, and lastly the properties of n-1-p diodes of silicon and of germanium are studied, as well as their applications, with special attention to gamma spectrometry.

237 (N-65-19766) BASIC RESEARCH IN SEMICONDUCTOR DETECTOR-DOSIMETER CHARACTERISTICS, AS APPLIED TO THE PROBLEMS OF WHOLE BODY DOSIMETRY.

Informal Progress Report.

Crawford George W. (Southern Methodist Univ., Dallas, Tex.).

Feb. 1965. 3 p. (NASA-CR-57300). CFSTI $1.00 cy. $0.50 mn.

A family of lithium-drifted silicon semiconductor detectors for measuring the stopping power of protons and proton absorption is reported. Stopping power measurements were made for protons of 5 to 187 Mev in metals, plastics and tissue. A program for calculation of the linear stopping power was completed, tested, and incorporated into a Monte Carlo transport program which permits Coulomb interaction with both orbital electrons and the nuclei. Also, the Monte Carlo program was written to permit calculation of the depth-dose distribution in skin, muscle, and fat.

238 SURFACE POTENTIAL MEASUREMENTS OF LITHIUM DRIFTED GERMANIUM DIODES.

Davies D. E., Webb P. P.

15 p. (CONF-651001-25). ORAU, Gmelin, AED-CONF-65-293-28.

From IEEE Nuclear Science Symposium, San Francisco.

A potential probe was built to measure the distribution of potential on the etched surfaces of lithium-drifted Ge diodes. A vibrating condenser proble was used. Initial measurements with the probe confirmed a theoretical model proposed by McIntyre to explain previously observed unusual behavior of some lithium-drifted diodes. The probe was also used to determine the effect of various surface treatments designed to produce Ge diodes having high breakdown voltages and low leakage currents. It was found that a two-stage etch was frequently very useful

in achieving a low-leakage diode at 77°K. For surfaces exhibiting strong n-type characteristics, dipping in H_2O_2 and washing in warm distilled water had the effect of moving the potential drop toward the front surface, but neither process was controllable. Efforts to obtain reproducible results were hampered by lack of uniformity of the crystal supplied by the manufacturer.

239 (NASA-CR-69479) SEMI-ANNUAL STATUS REPORT, MARCH-AUGUST 1965.

CASPER K. J.

Western Reserve University, Cleveland, Ohio.

The research covered by this status report can be divided into the following topics: (1) Studies of the fundamental response of semiconductor detectors to charged particles. (2) Fabrication techniques for lithium surface barrier silicon detectors. (3) Compilation of the computer program for the analysis of beta decay spectra. (4) Operation of a superconducting magnet in conjunction with solid state detectors as a novel and unique beta ray spectrometer. (5) Direct observation of the internal Compton effect with the superconducting magnet beta ray spectrometer. (6) Studies of high Z semiconductors for improved gamma ray detection.

240 SEMICONDUCTOR-TYPE NUCLEAR RADIATION DETECTORS AND SPECTROMETERS. PART I.

Deme Sandor, Csakany Antal (Central Inst. for Physics Research, Budapest).

Magyar Fiz. Foly., 13: 273-307 (1965). (In Hungarian).

Semiconductor detectors have excellent energy resolution, linearity, and small size. The thickness of the barrier layer can be easily adjusted, allowing discrimination between radiations of different penetrating power. The sensitive surface is smaller than that of scintillation counters; this defect can be overcome by using several detectors in parallel. The principle of operation involves production of electron-vacancy pairs by charged particles. Fabrication methods are described, reviewing detectors with surface-barrier layers, diffusion-barrier layers, and Li-ion drifting. The magnitude, shape, and duration of the signal are examined in detail. Factors affecting the operation of the instruments, such as radiation damage, environment, and high vacuum, are studied; high magnetic fields have only a slight effect. Applications are discussed. 66 references.

241 (AD-620434) THE CONSTRUCTION OF A LITHIUM DRIFTED GERMANIUM SOLID STATE DETECTOR SYSTEM WITH SPECIAL ATTENTION TO ^{105}Ag AND ^{192}Ir [Thesis].

Dessert Robert Allen (Ohio State Univ., Columbus).

1965. Contract AF33(608)-1095. 72 p. CFSTI $3.00 cy, $0.75 mn.

A relatively inexpensive cryostat was constructed for operation of Li-drifted Ge gamma detectors at pressures below 0.0000001 mm of Hg and at 77°K. Fundamental data were obtained on a Li-drifted Ge detector, including relative counting efficiency, resolution and peak-to-total ratio. The spectra of ^{192}Ir and ^{105}Ag were investigated using the solid-state detector. A technique of segmentation and expansion of energy subgroups with a multichannel analyzer is proposed as a means to provide more points in a given peak of a spectrum taken on the detector.

242 RADIATION ABSORPTION AND CHARGE SEPARATION IN SEMICONDUCTOR COUNTERS.

de Vries H. (Universität, Marburg, Ger.).

Ann. Phys., 16: 41-69 (1965). (In German).

The spatial expansion of the trace of increased electron-vacancy pair concentrations, which occur in the absorption of heavy charged particles in a crystal counter, and the time pattern of their origin, can be determined through the discussion of the various slowing-down processes. The electric properties of the particle track and the process of charge separation were investigated. The representation by Brown on successive plasma decomposition through the electric field was extended to include the electrostatic effect in the particle track. A quantitative comparison was carried out between the charge separation through the electric field and the charge separation through the "normal" diffusion processes assumed by Northrop and Simpson. In the treatment of charge separation it is proved that the diffusion process in a particle track can be described by a differential equation of the second order. According to the solution of this equation the time pattern of the diffusion process goes through two successive stages. The first rapid stage of the diffusion process can be described with the process of a particle slowing down to a common process in which a range of increased electron-vacancy pair concentration is given as a particle trace. This length expansion is given by the range of the projected particles whose diameter was determined from the semiconductor properties (diffusion constant and collision time) of the crystal. Discrepancies between these and previous results are discussed.

243 (BNL-948, pp 704-17) TECHNICAL DEVELOPMENTS [IN HARDWARE].

Donovan Paul F. (Bell Telephone Labs. [Murray Hill, N. J.]).

Some advances in semiconductor detectors are discussed together with some problems with these detectors. A particle identification system and servo-stabilized analog-to-digital converters are also briefly considered as well as the use of computers in experiments in low-energy nuclear physics.

244 SOLID BODY DOSIMETRY IN RADIOTHERAPY.

Drexler Günter, Scharmann Arthur (Univ., Erlangen-Nürnberg).

Radiologe, 4: 262-7 (Aug. 1964). (In German).

The physical principles of the thermoluminescence dosimeter, the radiophotoluminescence dosimeter, and the semiconductor dosimeter are described. The suitability of these types of dosimeters for use in clinical dosimetry is discussed. Doses within the range of 1 to 1000 R can be measured with thermoluminescent dosimeters. One disadvantage of thermoluminescent methods is their varying sensitivity and the energy dependence of the LiF crystals, and the shift of the "glow peaks". The crystals are easy to purify. For *in vivo* studies the crystals can be sterilized. CaF_2 with Mn is sometimes used as a substitute for LiF. However, this is 10 times as energy dependent, although it has greater sensitivity. Photoluminiscent dosimeters, or fluorods, are suitable for measurement of 2 R or more of hard or ultrahard irradiation, and should be in or near to the beam. Measurements can be made with $\pm 2\%$ accuracy at doses of about 200 R. The glass rods must be heat treated before use. The energy dependence of CdS crystals limits their accurate use to measurements of irradiation of known energy. Comparison of isodose measurements made with CdS crystals, Ag phosphate glass, and LiF with ionization chamber mesasurements indicate that hard radiation measurements are in close agreement. However, for conventional irradiation thermoluminescence dosimetry with LiF is the only one that should be used.

245 THE INFLUENCE OF THE CONTACT SURFACE ON EFFICIENCY OF SILICON COUNTERS FOR FISSION FRAGMENTS.

Dyachenko P. P., Kuzminov B. D., Chukichev M. V.

Prib. Tekn. Eksp., No. 5, 85-8 (Sept.-Oct. 1965). (In Russian).

In the results of the investigation of two sets of surface-barrier counters with different condition of the surface, it was found that the presence of craters on the counter surface is a basic cause for the appearance of "tails" in the amplitude distribution of the pulses, created by fission fragments, and hampers the attainment of information from fragments with low yield.

246 (MLM-1268) MOUND LABORATORY PROGRESS REPORT FOR JUNE 1965.

Eichelberger J. F., Grove G. R., Jones L. V. (Mound Lab., Miamisburg, Ohio).

June 21, 1965. Contract AT (33-1)-Gen-53. 37 p. Dep. mn. CFSTI $2.00 cy, $0.50 mn.

Developments are reported for studies on: uranium-234 recovery; measurement of 2.3-kev isomeric state in lead-205; *semiconductor radiation detectors;* hydrolysis of plutonyl ions; plutonium-238 alpha sources; neutron spectrometry; increase in neutron yields; carbon isotope separation; stable gaseous isotopes; thermal diffusion research; helium vapor pressure thermometry; controlled-potential coulometric determination of uranium in uranyl acetylacetonate salts; emission spectroscopy; and calorimetry.

247 A PREAMPLIFIER WITH 0.7 kev RESOLUTION FOR SEMICONDUCTOR RADIATION DETECTORS.

Elad E. (Univ. of California, Berkeley).

Nucl. Instrum. Methods, 37: 327-9 (Nov. 1965). (UCRL-16390).

A low-noise preamplifier, utilizing a field-effect transistor in its input stage, is described. The preamplifier (pulse generator resolution 0.7 kev fwhm) is designed from the viewpoint of optimization of the signal-to-noise ratio. In use with a semiconductor radiation detector, the preamplifier yields 1.1 kev resolution.

248 TEMPERATURE DEPENDENCE OF AVERAGE ENERGY PER PAIR IN SEMICONDUCTOR DETECTORS.

Emery F.E., Rabson T.A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 1, February 1966, p. 48-52.

An accurate measurement of the average energy lost by charged particles per hole-electron pair produced in semiconductor detectors as a function of temperature is desirable in view of the recently noted response of detectors at low temperature. A simple model for the value of ϵ, the average energy per hole-electron pair, was proposed by Shockley in 1960. This model has been extended in the present work to predict temperature effects upon. Silicon and germanium lithium-drifted counters were designed and built for detecting 1 Mev electrons and/or 5.5 Mev alphas over a temperature range of 4°K to 300°K. Techniques and the necessary equipment to measure the charged produced from a single idident ionizing particle within 0.4% were developed. Data were taken for silicon and germanium detectors for temperature ranging from 20°K to 300°K. These data only qualitatively agree with the simple model. The evidence points to an additional effect over the ones invoked by Shockley. The room temperature values of for the silicon lithium-drifted counters observed in the present experiment agree with those for silicon surface barrier detectors which were recently published.

249 AVERAGE ENERGY EXPENDED PER IONIZED ELECTRON-HOLE PAIR IN SILICON AND GERMANIUM AS A FUNCTION OF TEMPERATURE.

Emery F. E., Rabson T.A. (Rice Univ., Houston, Tex.).

Phys. Rev., 140: A2089-93 (Dec. 13, 1965).

Measurements were made over a range of temperature of the amount of ionization produced by the passage of ionizing radiation through the junction of Ge and Si Li-drifted solid-state detectors. These data are presented in the form of the average energy per hole-electron pair. A simple model for the value of ϵ, the average energy per hole-electron pair, was proposed by Shockley in 1960. This model was extended to predict temperature effects upon ϵ. Silicon and Ge Li-drifted counters were designed

for detecting 1-Mev electrons and/or 5.5-Mev alphas over a temperature range of 4 to 300°K. The techniques and necessary equipment were designed to enable the measurement of the charge detected from a single incident ionizing particle with a probable error less than 0.4%. Data were taken on Si and Ge detectors for temperatures ranging from 20 to 200°K. The data only qualitatively agree with the simple model. The evidence points to additional effects besides those considered by Shockley. The room temperature values of ϵ for the Si Li-drifted counters agree with those for silicon surface barriers which were recently published.

250 SCATTERING CHAMBER FOR USE WITH SOLID-STATE DETECTORS.

Erramuspe H. J., Seifert A. M. (Columbia Univ., New York).

Nucl. Instrum. Methods, 40: 155-6 (Feb. 1966).

A scattering chamber is described, which was specifically designed to work with solid state detectors mounted internally in a tandem assembly or in multiple arrays. The size of the chamber, which is of simple design, permits working with a large range of solid angles and the rotation assembly covers practically the whole angular range. A vertical cross-sectional view of the chamber, target assembly, exit and entrance pipes and top view, and a ball-bearing-holder diagram are shown. The maximum absolute angular error was estimated to be 0.2, the relative error being 0.1 for a typical polyethylene experiment using the Pupin Columbia University Cyclotron with a proton beam under 15 Mev.

251 EXPERIMENTS WITH GERMANIUM γ SPECTROMETERS IN THE CHALK RIVER LABORATORY.

Ewan G. T.

Izv. Akad. Nauk SSSR, Ser. Fiz., 29: 1054-69 (July 1965). (In Russian).

The properties of the Li-drifted p-i-n Ge detectors are summarized, including their design and layout, resolution for gamma rays of various energies, efficiency, resolving time, and response to high-energy gammas. The performance of these detectors in recording the gamma decay scheme of ^{134}Cs, in measuring internal conversion coefficients, in determining high-energy levels in deformed even-even nuclei, in measuring the gamma spectrum from the $^{19}F(d,n\gamma)^{20}Ne$ reaction, and in measuring the lifetime of nuclear states by the recoil-nucleus method is described.

252 STUDY OF SEMICONDUCTOR SURFACE BARRIER DETECTORS AT 4.2 deg K.

Fabjan C. W., Kenawy M., Rauch H. (Oesterreichische Hochschule, Vienna).

Z. Phys., 188: 378-84(1965). (In German).

The behavior of semiconductor surface barrier detectors was studied in the temperature range from 300 to 4.2°K. Measurements of the resolution for α and β particles are given. The mean energy E required for producing an electron-hole-pair in Si is found to be 3.54 ± 0.10 ev at 279°K, and 3.72 ± 0.11 ev at 78°K and 4.2°K respectively. Measured rise time of detector impulses is compared with theoretical values.

253 RECENT ADVANCES IN NUCLEAR RADIATION DETECTORS.

Ferguson A. T. G. (Atomic Energy Research Establishment Harwell, Eng.).

pp. 375-414 of Nuclear Structure and Electromagnetic Interactions. New York, Plenum Press, 1965.

Recent developments in gaseous ionization chambers, scintillation counters, and solid state devices relevant to low-energy nuclear physics are outlined. Applications of semiconductor counters to charged particle, gamma-ray, and neutron spectroscopy are discussed.

254 LARGE-VOLUME LITHIUM-DRIFTED GERMANIUM GAMMA-RAY DETECTORS.

Fiedler H. J., Hughes L. B., Kennett T. J., Prestwich W. V., Wall B. J. (McMaster Univ., Ontario, Ont.).

Nucl. Instrum. Methods, 40: 229-34 (Mar. 1966).

A new electroplating method was used for the fabrication of large-volume Ge(Li)-detectors in "wrap-around" configuration. The properties and performance of a 6 cm^3 and a 10 cm^3 detector were investigated. Some applications are described.

255 AN ALPHA SPECTROMETER WITH SEMICONDUCTOR SURFACE BARRIER DETECTOR.

Finsterwalder L. (Technische Hochschule, Munich).

Kerntechnik, 7: 515-17 (Nov. 1965). (In German).

A spectrometer using a semiconductor surface barrier detector was constructed. The spectrometer consists of two parts, the vacuum chamber with the semiconductor surface barrier detector and the charge-sensitive preamplifier. The wiring diagram of the preamplifier is given and the results of tests on its linearity using a series of alpha preparations are reported.

256 IMPROVEMENTS RELATING TO RADIATION DETECTORS.

Freck David Vernon (Associated Electrical Industries, Ltd.).

British Patent 1,018,402. Jan. 26, 1966. Filed May 9, 1961.

A radiation detector made up of several semi-conductor surface barriers or p-n junction devices stacked as slices, one over the other but electrically insulated from one another by insulating material or air spaces, is proposed for the detection of high energy radiation. A reverse potential bias can be applied to the surface barriers or junctions, and all the separate slices are connected to a common amplifier and detector.

257 SEMICONDUCTOR NUCLEAR PARTICLE DETECTORS. II.

Fujibayashi Keiji, Miyashita Kyoichi (Mitsubishi Electric Manufacturing Co., Ltd., Japan).

Mitsubishi Denki Giho, 39: 1221-7 (Oct. 1965). (In Japanese).

Semiconductor nuclear particle detectors have been developed. They are oxide passivated silicon p-n junction detectors and lithium-drifted silicon p-i-n detectors. Also, low noise charge sensitive amplifiers for use with semiconductor detectors have been developed. The oxide-passivated detectors are 7 mm^2 and 20 mm^2 in area respectively. The energy resolution is 27 kev for 5.3 Mev alpha particles. The oxide-passivation enables the detectors to be of very low leakage currents and very stable even in high humidity. Lithium-drifted detectors are 4×5 mm^2 in area, their intrinsic region ranges from 0.5 to 2 mm, and their energy resolution is 22 kev for 625 kev beta particles. The charge sensitive amplifiers are fully transistorized, and the resolution broadening due to amplifier noise is reduced to 10—12 kev (FWHM) by newly developed circuits.

258 (KFK-335) IMPULSFORMDISKRIMINIERUNG BEI HALBLEITERZAEHLERN ZUR UNTERSUCHUNG VON (γ,α)-REAKTIONEN.

(Pulse Shape Discrimination in Half-Life Determination for a Study of (γ,α) Reactions).

Gehm Helmut, Ullrich Horst (Kernforschungszentrum, Karlsruhe (West Germany). Institut für Experimentelle Kernphysik).

June 1965. 30 p. Dep. mn.

A method for pulse-form discrimination for semiconductor counters is developed and tested. The method makes possible the discrimination of α particles and protons, and thereby the measurement of photoalpha particles in the presence of an interfering proton and electron background. The efficiency of the method is discussed and illustrated on the reaction $^{27}Al(\gamma,\alpha)^{23}Na$. For this reaction the yield ratio $Y(\gamma,\alpha)/(\gamma,p)$ can be measured. The experimental α spectrum is compared with the α spectrum calculated by the statistical theory.

259 THE DOPING OF SEMICONDUCTORS BY ION BOMBARDMENT.

Gibbons J. F., Moll J. L., Meyer N. I.

Nuclear Instruments and Methods, Vol. 38 (1965), p. 165-168.

An investigation of the effects of bombarding various semiconductors (Si, GaAs, CdS and ZnS) with ions of the rare earth elements thulium and neodymium has been carried out. Preliminary measurements of the electrical and optical properties of the resulting bombarded layers will be described.

260 THE DESIGN AND APPLICATION OF LITHIUM-DRIFT SILICON DIODES AS NUCLEAR RADIATION DETECTORS.

Gibbons P. E., Blamires N. G. (Atomic Energy Research Establishment, Harwell, Eng.).

J. Sci. Instrum., 42: 862-4 (Dec. 1965). (AERE-R-4948).

A range of lithium-drifted silicon radiation detectors is described. Areas up to 8 cm^2 and thicknesses up to 0.6 cm were achieved. At—20°C, a resolution of 8 kev full width half maximum was obtained on 661 kev beta particles using a 1 cm^2 detector 0.1 cm thick. The performance of the detectors is discussed in relation to other device parameters.

261 (UCRL-16480) A METHOD OF MAKING THIN-WINDOW GERMANIUM DETECTORS.

Goulding Fred S., Jarrett Blair V. (Lawrence Radiation Lab., Univ. of California, Berkeley).

Contract W-7405-eng-48. 9 p. Dep. mn. CFSTI $1.00 cy. $0.50 mn.

A method is described for producing thin-window lithium-drifted germanium x- or γ-ray detectors. The success of the process is indicated by a high yield of good detectors. Measurements show that the window thickness is in the range of 1 micron or less and x-ray energy resolution figures of 1.4 kev (full width at half minimum) were obtained. Some initial tests using the detectors for long-range proton energy measurements show that the negligible window thicknesses combined with thick depletion layers (easily obtained with germanium) promise to extend the usefulness of semiconductor detectors in particle as well as x-ray experiments.

262 (AECL-2505) TIMING CHARACTERISTICS OF LARGE COAXIAL Ge(Li) DETECTORS FOR COINCIDENCE EXPERIMENTS.

Graham R. L., MacKenzie I. K., Ewan G. T. (Atomic Energy of Canada Ltd., Chalk River [Ontario]).

Oct. 1965. 23 p. (CRGP-1225; CONF-651001-17). Dep. AECL $1.00.

From IEEE Nuclear Science Symposium, San Francisco.

The results are presented of a study of the variation with position of the charge collection time and its influence on coincidence resolving time. With two Ge(Li) spectrometers both detecting 511-kev events the coincidence resolution curve has a full width at half-maximum of $\sim$15 nsec and approximately exponential tails with half slopes $\sim$5 nsec. An example of a gamma-gamma coincidence spectrum observed in the study of the ^{156}Gd level scheme is described.

263 ON THE QUANTITATIVE AND QUALITATIVE DETECTION OF NEUTRONS USING SEMICONDUCTOR BODIES AND METHOD FOR THEIR PREPARATION.

Guenther Paul, Koehl Guenter, Schneider Wilhelm (Licentia Patent-Verwaltungs-GmbH).

German Patent 1,202,909. Oct. 14, 1965. Filed Apr. 5, 1956.

The semiconductor of silicon or germanium consists of an n-type body, which is provided with a p-type surface layer by doping with Al. The p-type surface layer is preferentially doped additionally with boron.

264 PULSE HEIGHT DEFECT AND ENERGY DISPERSION IN SEMICONDUCTOR DETECTORS.

Haines Eldon L., Whitehead A. Bruce (California Inst. of Tech., Pasadena).

Rev. Sci. Instrum., 37: 190-4 (Feb. 1966).

The contributions of the atomic (screened Coulombic) scattering process to the pulse height defect and energy dispersion observed when heavy ions expend their energies in semiconductor detectors were calculated. Atomic scattering appears to account qualitatively for the pulse height defect observed for most heavy ions in both silicon and germanium detectors. Atomic scattering also contributes substantially to the energy dispersion.

265 DESIGNING SEMICONDUCTOR SYSTEM FOR OPTIMUM PERFORMANCE.

Heath R. L., Black W. W., Cline J. E.

Nucleonics, Vol. 24, No. 5, May 1966, p. 52-56.

As refinements in germanium crystals and preamplifiers continue to improve resolutions, the limitation in semiconductor-detector performance stems mainly from the electronics.

266 AN ALPHA PARTICLE HYGROMETER.

Hallowes K. H., Hodgson A. E. M. (Atomic Energy Research Establishment, Wantage, Eng.).

Vienna, International Atomic Energy Agency, 1965, Preprint No. SM-68/19, 10 p. (CONF-651023-8). ORINS.

From Symposium on Radioisotope Instruments in Industry and Geophysics, Warsaw.

A method of measuring the relative humidity of air by the transmission of alpha particles through a very thin film containing an equilibrium proportion of moisture is described. The scope of application is similar to that of electrical hygrometers in which the conductivity of a hygroscopic surface layer is measured. However, the employment of the alpha particle technique greatly reduces the dependence of the readings upon traces of sulphur di-oxide and the like, in the air. The method provides a rapid response and covers the full range of relative humidities at normal atmospheric temperatures. The radioactive source is americium-241 in a glass bead, providing effectively infinite thickness for alpha particle self-absorption, and with negligible contamination hazard. The use of an infinitely thick source provides a good sensitivity to changes of relative humidity over the whole working range. The detector is a small surface-barrier semiconductor, thus allowing the construction of a compact probe to facilitate measurements in confined places, e.g., in connection with warehouse ventilation problems. The hygroscopic film is specially made from sulphonated cross-linked polystyrene, and mounted on a vane rotated by a miniature electric motor. Rotation of the vane alternates the hygroscopic film with an otherwise similar non-hygroscopic one in the source-detector gap, thus providing a means of compensating for changes in temperature and pressure of the air in the gap, and for detector temperature. The rotation also ensures the necessary circulation of air in the immediate proximity of the hygroscopic film. The output provides for continuous direct or remote indication, servo control, or recording. Details of the performance of the hygrometer, the preparation of the hygroscopic film, and the associated circuit design are included.

267 A COMPARATIVE STUDY OF SEMICONDUCTOR GAMMA SPECTROMETERS FOR SCANNING OF IRRADIATED DRAGON FUEL ELEMENTS.

Hick H. (Reactor Center, Seibersdorf, Austria).

Nucl. Instrum. Methods, 40: 337-47 (Mar. 1966).

Three types of γ-spectrometers using a Ge-Li-detector (full energy peak spectrometer, anti-Compton spectrometer, Compton-spectrometer) are compared with respect to their usefulness in analysis of complex spectra between 100 kev and 3 Mev. Approximate response functions for various energies are given.

268 (UCRL-16307) THE IMPACT OF SEMICONDUCTOR DETECTORS ON GAMMA-RAY AND ELECTRON SPECTROSCOPY.

Hollander Jack M. (Lawrence Radiation Lab., Univ. of California, Berkeley).

Aug. 1, 1965. Contract W-7405-eng-48. 131 p. (CONF-650832-1). Dep. mn; CFSTI $4.00 cy, $1.00 mn.

From International Meeting on Nuclear Instrumentation, Herceg-Novi, Yugoslavia.

A review of the semiconductor impact on gamma spectroscopy is presented. In particular, the operating characteristics of Ge(Li) detectors are discussed along with its many uses. Examples of data taken with semiconductor detectors are presented for the following: decay scheme studies, measurement of pair production cross section near threshold, heavy-ion reactions, low temperature nuclear orientation, g-factors of nuclear-excited states, observation of the effect of chemical state on the lifetime of a low-energy isomer, neutron activation analysis, and electron-gamma spectroscopy.

269 CALCULATED EFFICIENCIES OF Ge(Li) DETECTORS.

Hotz H. P., Mathiesen J. M., Hurley J. P. (Naval Radiological Defense Lab., San Francisco).

Nucl. Instrum. Methods, 37: 93-7 (Nov. 1965).

Gamma-ray detection efficiencies for Ge(Li) detectors were calculated on an IBM 704 computer for crystals of 1.0×2.0 cm and 2.0×3.0 cm cross section. Depletion depths from 1.0 to 10.0 mm and source-to-crystal distances from 1.0 to 25.0 cm were selected.

270 IMPROVEMENTS RELATING TO RADIATION DETECTORS.

Hunt Stanley Ernest (Associated Electrical Industries Ltd.).

British Patent 1,014,682. Dec. 31, 1965. Filed June 4, 1961.

A radiation detector suitable for neutron detection includes a semi-conductor having formed in it a p-n junction with a thick depletion zone, means for applying a reverse voltage bias to the p-n junction, and an additional surface layer in the semi-conductor of a threshold detector material that does not respond to radiation below a predetermined energy level but reponds to radiation above this threshold level releasing secondary particles into the depletion zone to cause pulse discharge through the p-n junction. A number of these semi-conductor p-n junction devices, each coated with a different threshold detector material having a different energy threshold level, may be combined to selectively determine neutron radiation of different energy levels. Means are provided for detecting the pulse discharge pulses produced in each detector.

271 RECENT RESULTS OBTAINED WITH HIGH FIELD, INTERNALLY AMPLIFYING SEMICONDUCTOR RADIATION DETECTORS.

Huth G. C.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 1, February 1966, p. 36-42.

Characterization of the gallium diffused junctions found useful as amplifying radiation detectors indicate a rather surprising window-junction depth relationship. The window, at only the self bias of the junction, has been measured to be a micron or so although the junction depth is $\sim$50 microns. This is a result of the unusual diffusion process used-diffusion to 75 microns with subsequent removal of the heavily acceptor doped, first 25 micron region. Because of potential for low energy detection of these structures (which require thin windows) stress is placed upon window measurements. Measurements made of the response of these structures as photon detectors in the near infrared (0.7—1.1 micron) wavelength region are reported. Also initial results which indicate that the x-ray cutoff for these structures lies in the 44-60 Angstrom range.

272 A STUDY OF THE INFLUENCE OF FABRICATION TECHNIQUES ON THE BULK MINORITY CARRIER LIFETIME IN SILICON RADIATION DETECTORS [Thesis].

Jones Ernest Olin.

Raleigh N. C., North Carolina State of the Univ. of North Carolina, 1964. 64 p.

The minority carrier lifetime of several samples of silicon was measured at various stages in the preparation of lithium-drifted silicon radiation detectors fabricated by two different techniques. Each stage of the processes that appeared to result in lifetime changes was investigated. Processing, including lithium drift, resulted in a lifetime loss of 49% of the initial value by one method and 58% by another. Those techniques involving treatments at high temperatures (around 1050°C) were found to have more influence in reducing lifetime. The presence of both lithium and phosphorus was found to reduce the severity of lifetime loss. With these materials in the samples, reduction in lifetime was less if the samples were quenched after diffusion rather than cooled slowly. An oxigen atmosphere during heat treatments was noted to result in a smaller loss in lifetime than atmospheres of argon or a nitrogen-hydrogen mixture. In the examination of fabrication techniques the diffusion of phosphorus at 1050°C and of lithium at 400°C each resulted in substantial lifetime losses. The process of lithium drift in oil at 150°C appeared to have little effect on the sample lifetime. A preferred fabrication procedure could not be selected based on lifetime loss. Annealing in the temperature range of 300-500°C for six hours in various atmospheres was found to restore a portion of the lifetime lost in prior heat treatment. More recovery was noted in an oxigen atmosphere than in argon. A possible mechanism for the annealing results was proposed based on the Kaiser model of donor formation by oxygen dissolved in silicon.

273 A PORTABLE DOSE-RATE METER USING A SILICON p-n JUNCTION AS A DETECTOR.

Jones A. R. (Atomic Energy of Canada Ltd., Chalk River, Ont.).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 1, 652-7 (Feb. 1966).

A dose-rate meter that comprises a small-area p-n counter, charge and linear pulse amplifiers, a discriminator, and a three-decade logarithmic count-rate circuit is described. The meter is designed to measure tissue dose rates from beta particles in the range of 0.1 to 100 Rad/hr as well as dose rates from gamma rays in the same range.

274 SEMICONDUCTING DETECTORS AND THEIR APPLICATIONS.

Jungclaussen H. (Zentralinstitut für Kernforschung, Rossendorf, Ger. Institut für Kernforschung, Dubna, USSR).

Kernenergie, 8: 514-41 (Sept. 1965). (In German).

The functions and types of semiconductor detectors and their physical basis are discussed. Charge carrier collection, energy resolution, amplification, noise, time dependence, and radiation damage in the detector-amplifier system are considered. Applications of these detectors are discussed. (157 references).

275 CHARGE-SENSITIVE TRANSISTOR PREAMPLIFIER FOR USE WITH SEMICONDUCTOR NUCLEAR RADIATION DETECTORS.

Karwowski M., Wlodarski W., Pawlowski Z.

Nukleonika, 10: 189-93 (1965). (In Polish).

The performance characteristics and stability of the preamplifier are described in detail for a 6-transistor preamplifier utilizing OC-170 transistors. The limiting gain is 8×10^{-4} V/1000 ion pairs for a signal from a zero-capacity source, and this gain is held to within 3% of the limiting value for 0-400 pF of source capacitance. The linearity is 1% from 0—3v output, and the gain variation is less than 2% for a supply voltage change of 30%. Temperature characteristics curves are presented. A ^{210}Po alpha pulse-height spectrum is shown for the preamplifier connected to the output of a 20 mm^2 surface-barrier diode and to the input of a ZPT-0173 amplifier feeding a type AA-102 pulse height analyzer. A half-width of about 1% is obtained with this arrangement for the 5.298 Mev alpha line.

276 MODERN DETECTORS IN RADIATION PROTECTION.

Kiefeer H., Maushart R. (Kernforschungszentrum, Karlsruhe, Ger.).

Atomwirtschaft, 10: 529-33 (Oct. 1965). (In German).

Geiger counters and film packets do not always completely satisfy the present requirements of personnel dosimetry. An effective radiation protection is possible with numerous special measurement devices with special detectors. The basic considerations that lead to the development and introduction of modern detectors were explained using 3 examples. The large-surface proportional counter, glass dosimeters, and semiconductor detectors are considered.

277 EXPERIENCE IN FABRICATING SEMICONDUCTOR DEVICES USING ION IMPLANTATION TECHNIQUES.

King W. J., Burrill J. T., Harrison S., Martin F., Kellett C.

Nuclear Instruments and Methods, Vol. 38 (1965), p. 178-179.

The described process of ion "implantation" is defined as one in which the distribution of the arrested ions is determined by the target material and the species, energy, integrated flux and relative orientation of the incident ions. Energies utilized in this technique are sufficiently high (greater than 50 keV) to minimize sputtering and to produce useful junction depths without invoking the process of "channeling" along preferred crystal planes. The resulting process is highly controlled and can be used to fabricate semiconductor devices by implanting through a passivating surface oxide. Spectroscopically pure ^{11}B and ^{31}P ion beams α routinely accelerated to energies between 50 ke and 400 keV to produce p- and n-type layers in silicon, respectively. The following p-n junction devices have been successfully fabricated during the past 4 ½ year: a) *Solar cells:* consistent state-of-the-art cells with efficiencies greater than 13% under tungsten (2800°K) illumination and 10% under solar (air mass zero) illumination. b) *Radiation detectors:* passivated single counters (1.27 cm dia.) and spectrometer with depletion depths of 1 mm (break-down voltages >700 V), dead layers less than 0.2 μm and best room temperature resolutions of 60 keV. c) *Unipolar field effect transistors:* transconductance greater than 2000 μmho. d) *Bipolar transistors:* $\beta > 40$. Preliminary results on extension of the technique to wide band-gap materials are discussed.

278 RESPONSE OF SOLID-STATE DETECTORS TO FISSION FRAGMENTS.

Klema E. D. (Northestern Univ., Evanston, Ill.); Pleasonton Frances, Schmitt H. W., Unik J.

IEEE (Inst. Elec. Electron, Eng.), Trans. Nucl. Sci., NS-13: No. 1, 43-7 (Feb. 1966).

Pulse-amplitude spectra for fission fragments from the spontaneous fission of ^{252}Cf were studied for more than 50 silicon surface-barrier detectors. Silicon resistivities ranged from 100 to 2000 ohm-cm; spectra were obtained for several bias voltages for each detector. A search for correlations among shape parameters associated with ^{252}Cf fragment pulse-amplitude spectra was carried out. Such correlations were, in fact, observed and were shown to be related to the pulse-height response characteristics of surface-barrier detectors for fission fragments some guidelines by which the quality of a fission-fragment detector may be determined from the spectrum parameters are given.

279 (IBM-65-825-1487) NEUTRON AND GAMMA SENSITIVITIES OF DYNAMIC DETECTORS.

Kloepper R. M., Martin J. A., Shatzkes M. (International Business Machines Corp., Owego, N. Y. FSD Space Guidance Center).

July 1965. 13 p.

The neutron and gamma sensitivities of nine detectors were studied in experiments performed at the Sandia Pulsed Reactor (SPR). Of the detectors tested, six are predominantly gamma detectors and three produce a significant fraction of their total current as a result of the neutron flux during a normal SPR burst. None of the detectors studied were found to be predominantly sensitive to the neutron flux during a normal SPR burst. Tests performed at pure gamma sources on a PIN diode detector are also described. The neutron-induced current in the silicon detectors is treated theoretically.

280 THE SEMICONDUCTOR FAST-NEUTRON DOSIMETER. ITS CHARACTERISTICS AND APPLICATIONS.

Kramer G.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 1, February 1966, p. 104-110.

The characteristics and most recent results with a semiconductor fast-neutron dosimeter are described. This device is a wide-base silicon n^+-p-p^+ junction whose forward resistance is controlled by the density of injected charge carriers in the base region. The injected carrier density profile is a function of the carrier diffusion length. Upon neutron bombardmeent, the diffusion length is decreased, which results in a decrease in injected carrier density within the base region and thus an increase in the forward resistance of the device . A sensitivity range from 10^{10} nvt to $>10^{14}$ nvt is presently attainable. The accuracy of readout ranges from $\pm 50\%$at 10^{10} nvt to $\pm 50\%$ at 10^{11} nvt and continues to improve at higher integrated fluxes. The effect of base width, forward current level, material properties, and processing parameters on the sensitivity and uniformity of device characteristics are discussed. The current-voltage behavior of the device is shown to correspond to a model by Rose for diffusion-dominated double injection in semiconductors. The small size and ruggedness of the dosimeter and the simplicity of readout make it particularly suited for radiation-effects experimentation, accident dosimetry, and biological dosimetry.

281 (INR-621/XV/I) SILICONE LITHIUM DRIFTED DETECTORS.

Kuchcinski A. (Institute of Nuclear Research, Warsaw [Poland]). Apr. 1965. 28 p.

An investigation of lithium-drifted silicon detectors is summarized. The preparation of the detectors is described, and the performance of the detectors in detection of alpha particles and beta particles is discussed.

282 (UCRL-14405) RESPONSE FUNCTION AND SENSITIVITY OF DOUBLE-DIFFUSED SILICON DETECTORS IN HIGH γ-DOSE RATE FIELDS.

Kuckuck R. W., Bernescut R., Zatzick M. R., Jupiter C. (Lawrence Radiation Lab., Univ. of California, Livermore).

Oct. 12, 1965. Contract W-7405-eng-48. 29 p. (CONF-651001-12). Dep. mn; CFSTI $2.00 cy, $0.50 mn.

From IEEE Nuclear Science Symposium, San Francisco.

A number of double-diffused (PIN) silicon detectors were exposed to peak γ-dose rates of 10^{19} γ-Mev/cm^2-sec generated by a flash x-ray machine. Detailed examination of the rate-of-rise and linearity was accomplished by superposition of 200-Mc Rossi signal on the oscilloscope traces of the test detector, as well as that of the non-saturable monitor detector. At detector bias voltages of 3000 v, and load impedances of 25 ohms, peak linear currents of approximately 48 amp were observed with rise times less than 10 nanoseconds. Sensitivity measurements of the detectors were obtained at lower dose rates of about 10^{16} γ-Mev/cm^2-sec by exposure to a thick target bremsstrahlung source, using a 10-Mev linac beam. The current-time integral of a detector signal provided a measure of the charge per pulse and a thimble ionization chamber was used to measure the average dose per pulse.

283 ARRANGEMENT FOR POSITION AND ENERGY DETERMINATION WITH SEMICONDUCTOR DETECTORS.

Kuhlmann W. R., Lauterjung K. H., Schimmer B. (Univ., Cologne).

Nucl. Instrum. Methods, 40: 109-12 (Feb. 1966). (In German).

Charged particles produce in position-sensitive solid state detectors information proportional to the energy and energy-dependent information proportional to the position. The quotient of the two types of information delivers energy-independent position data. A detector bank of 40 mm length, made of 4 such detectors, was connected to a pulse division circuit, delivering energy information and energy-independent position information.

284 (NYO-3510-14) BIOLOGICAL AND CLINICAL DOSIMETRY.

Annual Progress Report, July 1, 1964 - June 30, 1965. Laughlin John S. (Sloan-Kettering Inst. for Cancer Research, New York).

July 6. 1965. Contract AT(30-1)-3510. 80 p. Dep. mn; CFSTI $3.00 cy, $0.75 mn.

During the period of this report local dose microcalorimeter previously described was employed to examine the depth-dose distribution produced in carbon by high energy electrons. Cavity ionization measurements were made in the same geometry and corrected to dose in rads with and without the polarization correction. It is significant that at large depths where the electron energy was low the absolute values of dose obtained by these two methods agree. At lesser depths the polarization correction was required to bring the two methods into approximate agreement. The significance of some remaining discrepancy at higher energies is being further investigated. An intercomparison of the dose produced by high energy electron beams as measured at different institutions was instituted. Both the lithium fluoride thermoluminescent dosimeter and the Fricke ferrous sulphate dosimeter have been under extensive development with respect to different methods of packaging for mailing, procedures for optimum reproducibility, etc. A significant difference between the dose in rads as measured by lithium fluoride luminescence and by the Fricke ferrous sulphate dosimeter between cobalt-60 gamma rays and high energy electrons was discovered. The significance of this unexpected dependence of lithium fluoride thermoluminescence on radiation quality is being investigated. Measurements of the dose produced by the electrons from a high intensity source (600 kev field emission generator) have been initiated. Doses of the order of megarads delivered in 30 nanoseconds have been measured with cellophane dye and thermoluminescent methods. A calorimeter is being designed to carry out these measurements on a

more absolute basis. The investigation of solid state detectors uncovered a temperature dependence. A further effect involving a change in current output from the detectors under prolonged irradiation was found to be associated with the effects of ionized air on the surface of the devices. Irradiation in vacuum eliminated this. (28 references.)

285 (UCRL-16613) BIOLOGY AND MEDICINE SEMIANNUAL REPORT, FALL 1965.

Lawrence John H (ed.) (California Univ., Berkeley, Donner Pavilion. Lawrence Radiation Lab., Univ. of California, Berkeley).

Contract W-7405-eng-48. 109 p. Dep. mn. CFSTI $4.00 cy, $0.75 mn.

Progress is reported in diverse radiobiological studies including: estimations of radiation doses astronauts will encounter on the Apollo mission to the moon: the response of Li-drifted silicon detectors to high-energy α and proton beams; a comparison of the biological effects of the π^- beam produced by the 184-in. cyclotron with the effects of the x radiation, γ radiation, and α particles on the production of chromosome aberrations in *Vicia faba* root meristems; the effect of the negative pion beams on the proliferative capacity of an ascites lymphoma irradiated in mice and assayed *in vivo;* the isolation of DNA from bacteriophages; the recovery of yeast (*Saccharomyces cerevisiae*) after exposure to x radiation or heavy ions (^{4}He, ^{12}C, or ^{20}Ne); genetic studies of x and uv induced yeast mutations; the relative magnitude of mutational and balanced components of genetic load in populations; electrophoretic studies of light-induced electrical charge in spinach chloroplasts; the content of erythropoietin in urine of patients with anemia secondary to hookworm; the phagocytic activity of the reticuloendothelial system of mice after suppression of immune responsiveness by neonatal thymectomy or by adult thymectomy plus wholebody γ irradiation; and studies on the ESR spectrum of OH free radicals produced in irradiated H_2O and ice samples in both polycrystalline and single crystal form. A list is included of 24 papers published during the period covered by this report.

286 CONTRIBUTION TO THE THEORY OF SEMICONDUCTOR COUNTERS FOR IONIZING PARTICLES.

Lenchenko V. M., Iminov I. (Inst. of Nuclear Physics, Academy of Sciences, USSR).

Izv. Akad. Nauk Uz. SSR, Ser. Fiz.-Mat. Nauk, No. 2, 54-9 (1965). (In Russian).

A surface-barrier n-p counter with a broad space-charge region which encloses the entire track of the ionizing particle is considered. To obtain information on the effect of the semiconductor properties (carrier lifetime, mobility, etc.) on its counting ability, the track length, and the ionizing ability of the particle, it is necessary to calculate the waveform of the current and voltage pulses produced by the ionizing particle in the counter. Calculations were made neglecting the deviation of the semiconductor space-charge field from homogeneity, neglecting the dependence of the carrier lifetime on their density, and assuming the width of the space-charge region to be much larger than the track length. Typical current and voltage pulses obtained for such a counter are shown and are in good agreement with experimental data. Calculation of the amplitude of the voltage pulse and its growth time as functions of the parameters and of the particle are also in satisfactory agreement with experiment.

287 MINIMUM CHARGE DETECTION USING SELECTED TUNNEL DIODES AND CHARGE MULTIPLYING SEMICONDUCTORS.

Locker Robert J. (General Electric Co., Philadelphia).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 1, 382-8 (Feb. 1966).

The use of a charge-multiplying semiconductor detector in a circuit containing a tunnel diode biased for charge detection is discussed, and an instrument that was developed to detect 5.6-kev x rays from ^{55}Fe is described. The characteristics of the instrument are summarized.

288 (D2-84071-1) THE RESPONSE OF P-I-N DETECTIONS TO VARIOUS NUCLEAR RADIATION ENVIRONMENTS.

Lowrey A. R., Friddell K. D. (Boeing Co., Seattle, Wash.).

(1964). Contract AF29(601)-6425. 50 p.

Si and Ge p-i-n detectors are exposed to various transient and steady-state radiation environments, and the theoretical and experimental variations in response are tabulated, compared, and analyzed. The radiations to which the detectors are exposed include gamma rays, x rays, and electrons.

289 (UCRL-16446) SOME USES AND CHARACTERISTICS OF MOS TRANSISTORS FOR HEALTH PHYSICS APPLICATIONS.

McCaslin Joseph B. (Lawrence Radiation Lab., Univ. of California, Berkeley).

July 1965. Contract W-7405-eng-48. 31 p. (CONF-651109-6). Dep. mn; CFSTI $2.00 cy, $0.50 mn.

From 1st Symposium on Accelerator Radiation Dosimetry and Experience, Upton, N. Y.

Some of the characteristics of metal-oxide-semiconductor field-effect transistors (MOS), which may be useful in problems of radiation detection, are studied. It was found that these transistors are particularly suitable for electrometer applications. Input leakage currents of $\approx 10^{-16}$ A and transconductances of 750 μmhos are typical. Semiguarded MOS's exhibit leakage currents near 10^{-18} A, but the transconductance is down to about 70 μmhos. The MOS, unlike its vacuum-tube counterpart, is a high-frequency device which is capable of operation in the nanosecond region. A fast BF_3 detector, pulse shaper, and line driver were constructed which produce pulses of 30 to 80 ns duration at half-maximum pulse height. This moderated BF_3 system was useful for fast-neutron monitor-

ing at the Bevatron during rapid beam extraction. The sensitivity is 2 counts/n-cm^2. A 4π anticoincidence G-M foil counter was constructed with MOS's in digital circuitry. The saturated zero-time sensitivity for 2-in.-dia. 2-g indium foils is 21 counts/min per n/cm^2-sec. Background with 2 in. of lead is 22 counts/min. Static radiation damage tests were made in order to determine the suitability of MOS's in areas of high-level radiation such as target areas. Tests were performed with 7.5-Mev electrons in the range of absorbed dose from 10^4 through 10^8 rads, 7.5-Mev bremsstrahlung gammas at 10^6 rads, and an integrated thermal neutron exposure of 4×10^{14} n/cm^2. Data are presented that show postirradiation shifts in gate threshold voltage V_{GST}, d-c transconductance g_m, drain-source leakage current I_{DSS}, and gate leakage current I_G. Effects of radiation on the drain-source and gate-source breakdown voltages are also given. The predominant effect of ionizing radiation on these devices is a gradual upward shifting of the gate threshold voltage such that at 10^8 rads the required bias is $\approx$—15 v instead of the preirradiated value of —4.5 to —5 v. Gate input leakage current is considerably increased to 10^7 rads and is unpredictable at 10^8 rads. These tests indicate that MOS transistors, although superior in most respects to conventional vacuum-tube electrometers, are more easily damaged by large doses of ionizing radiation. They must be shielded when used in areas of sustained high radiation intensity.

290 FLUCTUATIONS OF ENERGY LOSS BY HEAVY CHARGED PARTICLES IN SILICON DETECTORS: PRELIMINARY MEASUREMENTS.

Maccabee H. D., Raju M. R. (Univ. of California, Berkeley).

Nucl. Instrum. Methods, 37: 176-8 (Nov. 1965).

The probability distributions of energy losses of 730-Mev protons and 370-Mev pions in 0.48-g/cm^2 and 0.45-g/cm^2. Si detectors, respectively, are measured over the energy-loss range of 0.5 to 1.4 Mev. The results are compared with the Vavilov and Landau theories for the proton and pion energy losses, respectively. Explanations are proposed for the discrepancies noted.

291 RADIOACTIVE MEASUREMENTS IN RADIO-CHEMISTRY.

Maddock, A. G. (Cambridge Univ., Eng.).

pp. 359-62 of Primera Conferencia Interamericana de Radioquimica. Washington, D. C., Union Panamericana, 1965.

The advantages, disadvantages, and the precautions necessary in radioactive measurements are reviewed. Scintillation counters, proportional counters, and solid-state detectors are considered.

292 LARGE-VOLUME COAXIAL GERMANIUM GAMMA-RAY SPECTROMETERS.

Malm H. L., Fowler I. L. (Atomic Energy of Canada Ltd., Chalk River, Ont.).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 1, 62-71 (Feb. 1966).

Lithium-drifted germanium p-i-n diodes with sensitive volumes in the range of 16 to 54 cm^3 were fabricated using the coaxial method of drift. The performance of the diodes as gamma spectrometers was investigated. With a gamma energy of 122 kev, resolutions of 3.0 and 4.4 kev (full width at half maximum) were obtained using diodes with sensitive volumes of 23 and 54 cm^3, respectively. The coaxial diodes also had high efficiencies.

293 (CRGP-1224) LARGE-VOLUME COAXIAL GERMANIUM GAMMA-RAY SPECTROMETERS.

Malm H. L., Fowler I. L. (Atomic Energy of Canada Ltd., Chalk River [Ontario]).

Oct. 1965. 35 p. (AECL-2504). AECL $1.00.

Germanium lithium-drift p-i-n diodes for high resolution γ-ray spectroscopy were made with sensitive volumes in the range 16 to 54 cm^3 (1 to 3.3 in.^{3}) using the coaxial method of drift. Details of the construction, mounting, and preparation as spectrometers are given. The shape of the undrifted p-type core was determined by scanning with a collimated γ-ray beam and by copper plating the surface of a sectioned diode. The characteristics as spectrometers using γ rays of energies in the range 0.1 to 7.5 Mev, are shown. At 122 kev energy, resolutions of 3.0 and 4.4 kev (fwhm) were obtained with diodes of sensitive volumes 23 and 54 cm^3 respectively. A 16 cm^3 volume diode had a resolution of 4.8 kev at 1333 kev γ-ray energy, and a 45 cm^3 diode had resolutions of 6.5 and 19 kev at energies of 1.1 and 5.1 Mev respectively. The diodes were operated at bias voltages in the range 600 to 1500 v. Intrinsic full energy peak efficiencies are shown for different diode sizes over a range of γ-ray energies. For the 54 cm^3 volume diode, these efficiencies are 21 and 8% respectively for γ-ray energies of 0.5 and 1.0 Mev with a source to diode distance of 30 cm. The larger diodes show a greatly enhanced peak/total ratio, and the higher efficiencies make these spectrometers extremely useful in reaction γray, γ-γ coincidence, and n,γ studies.

294 DOPING OF SILICON BY ION IMPLANTATION.

Manchester K. E., Sibley C. B., Alton G.

Nuclear Instruments and Methods, Vol. 38 (1965), p. 169-174.

The feasibility of doping silicon by directly implanting impurity atoms has been demonstrated. Both phosphorus and boron ions have been successfully implanted in silicon to produce electrical junctions. Junctions as deep as 1.2 μm have been produced by phosphorus ions having energies the order of 80 keV. An electromagnetic separator has been used to controllably produce uniform, large area implantations for evaluation experimentation. Correlations between junction depths and ion energies have been obtained. Orientation effects have been observed and it has been found that the <110> direction is the easy direction for implanting. Monitoring of thermal treatments of implated substrates by sheet resistance measurement indicates a very mild thermal anneal and removes most of the damage done during the implantation. These indications are further substantiated by reverse current

measurements of junctions produced by implantation. Electrical characteristics of implanted junctions will be compared with those of diffused junctions.

295 JUNCTION COUNTERS PRODUCED BY IRRADIATION OF SILICON WITH DOPANT IONS.

Martin F. W., Harrison S., King W. J. (Ion Physics Corp., Burlington, Mass.).

IEEE (Inst. Elec. Electron. Eng.). Trans. Nucl. Sci., NS-13: No. 1, 22-9 (Feb. 1966).

The fabrication of Si junctions by implantation of B ions and P ions through a previously applied layer of sputtered quartz is described, and the characteristics of the counters are summarized. The production of ten counters on a single slice for use in the focal plane of a magnetic spectrograph is also discussed, and the parameters of the 10-element counter are given.

296 NEUTRON AND GAMMA SENSITIVITIES OF DYNAMIC DETECTORS.

Martin J. A., Shatzkes M., Kloepper R. M.

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-12: 101-11 (Oct. 1965).

The neutron and gamma sensitivities of nine detectors were studied in experiments performed at the Sandia Pulsed Reactor (SPR). Six of the detectors tested are predominantly gamma detectors at the SPR and three produce a significant fraction of their total current due to the neutron flux during a normal SPR burst. None of the detectors studied were found to be predominantly sensitive to the neutron flux during a normal SPR burst. Tests performed at pure gamma sources on a pin diode detector are also described. The neutron induced current in the silicon detectors is treated theoretically. The pin response characteristics, and the relative neutron and gamma sensitivity of the radiation detectors are considered.

297 (AD-627930) GERMANIUM (LITHIUM) DETECTOR FABRICATION.

Mathiesen J. M., Hurley J. P. (Naval Radiological Defense Lab., San Francisco, Calif.).

Dec. 9, 1965, 29 p. (USNRDL-TR-949). CFSTI $2.00 cy, $0.50 mn.

The techniques used in the fabrication of lithium-drifted germanium detectors at NRDL are described. Some examples of gamma pulse-height spectra were recorded with one of the detectors are included.

298 (IKF-14) ENTWICKLUNG EINES HALBLEITERZAEHLER-TELESKOPS UND SEINE ANWENDUNG ZUR UNTERSUCHUNG DER REAKTION ^{28}Si(n.p)^{28}Al.

(Development of a Solid-State Detector Telescope and its Application for Studying the Reaction $^{28}Si(n,p)^{28}Al$).

Mausberg W. (Institut für Kernphysik, Universität Frankfurt [West Germany]).

Dec. 1965. 88 p. Dep. mn.

A telescope was developed consisting of four solid state detectors, the first of them serving as target for the reaction $^{28}Si(n,p)^{28}Al$.
Angular distributions of the proton group $p_{0,1}$ emerging from the transition to the ground state doublet of ^{28}Al were measured at neutron energies of 9.1, 14.1, and 21 Mev, the neutrons having an energy spread of about 200 kev. Absolute values of the cross sections are given. The distribution at 9.1 Mev is symmetric to 90°, but cannot be described by a Hauser-Feshbach calculation. The distributions at 14.1 and 21 Mev are asymmetric; they are fitted well by DWBA calculations of Agodi and Schiffrer, if one assumes for 14.1 Mev an isotropic compound contribution of 60%.

299 METHOD OF MEASURING NUCLEAR RADIATION UTILIZING A SEMICONDUCTOR CRYSTAL HAVING A LITHIUM COMPENSATED INTRINSIC REGION.

Mayer James W. (Hughes Aircraft Co.).

U. S. Patent 3,225,198. Dec. 21, 1965. Filed May 16, 1961.

A device for measuring nuclear radiation consists of a silicon semiconductor crystal having a lithium compensated intrinsic region between the P and N type regions and means for measuring the electrical pulses generated between the P and N type regions. The crystal is maintained at a temperature below 100°C, and the bias voltage is maintained between 10 and 500 v. The bias and the width of the intrinsic region are sufficient to produce a depletion region in the crystal in excess of 1 mm thick.

300 IMPLANTATION AND CHANNELING EFFECTS OF ALKALI ION BEAMS IN SEMICONDUCTORS.

Medved D. B., Perel J., Daley H. L., Rolik G. P.

Nuclear Instruments and Methods, Vol. 38 (1965), p. 175-177.

Ion beams of K^+ and Cs^+ in an energy range from 1-20 keV have been employed in a study of penetration, channeling and type conversion in targets of oriented single crystal semiconductors, particularly silicon. The alkalis form n-type impurities in silicon. Targets of p-type silicon over a wide resistivity range have been used to study conversion and junction formation effects. Target resistivity, crystallographic orientation energy and target temperature are important parameters in determining the profile of the implanted species and the junction depth X_3. The effects of crystallographic orientation on junction depths (determined directly by angle/section and stain techniques) are strongly suggestive of a channeling process. The order of penetrability is $(110)>(111)\geqslant(100)$ and the sheet resistance of the implanted layers is consistently smaller for the transparent directions. The variation of junction depth with the energy of the ion is not as important as its dependence on the target temperature on crystallographic orientation (with the velocity of the ion rather than its energy being the determinant factor for measured values of X_3). The magnitude of the channeling effect is strongly temperature dependent. Concentrations of electrically active species

in targets implanted by potassium are an order of magnitude higher than those achieved with cesium implantation under similar conditions. The profile of the electrically active species appears to have two parts; there is a layer of high concentration and relatively steep gradient followed by a persistent straggling tail.

301 (NP-tr-1302) POSITION FINDING COUNTER FOR THE BUECHNER MAGNET.

Melzer W., Puehlhofer F. (Max-Planck-Institut für Kernphysik, Heidelberg [West Germany]).

Translated by L. J. Herbst (U.K.A.E.A. Atomic Energy Research Establishment, Harwell, Eng.), from report 1965/V/2. 21 p. Dep. mn; JCL $2.60 fs, $0.83 mf.

Silicon surface barrier detectors for determining simultaneously the energy of the incident particle and the position of impact are described. The counters are used for arranging the focal plane of the Buechner magnetic spectrograph. The principle of the counter and a calculation of position resolving power are given. Experiments are described which illustrate the testing and application of position finding counters. The arrangement of the Buechner spectrograph is discussed.

302 FABRICATION AND STUDY OF THICK BASE FREE SURFACE BARRIER DETECTORS.

Meyer O., Langmann H. J. (Kernforschungszentrum, Karlsruhe, Ger.).

Nucl. Instrum. Methods, 39: 119-24 (Jan. 1966). (In German).

Surface barrier detectors are fabricated with depletion layers up to 3 mm. Some special construction details, necessary to produce fully depleted counters, are given. Fully depleted counters used in a stack diminish the pulse rise time and stop high energy particles. A reproducible measurement of the resistivity of the bulk material is described. The best energy resolution obtained with a 2-mm-thick liquid-air-cooled counter for 1 Mev electrons was 2.1 kev. The Fano factor for electrons is found to have a value of 0.13 ± 0.02.

303 (KFK-328) HERSTELLUNG UND UNTERSUCHUNG VON DICKEN BASISFREIEN OBERFLÄCHENSPERRSCHICHT-ZÄHLERN.

(Preparation and Study of Thick Depleted Surface Barrier Detectors).

Meyer O., Langmann H.-J. (Kernforschungszentrum, Karlsruhe [West Germany]).

May 1965. 14 p. Dep. mn.

The preparation and performance of depleted surface-barrier detectors were studied. Detectors with depletion layers up to 3 mm thick were fabricated, and a method of measuring the resistivity of the bulk material was developed. The best energy resolution, obtained with a 2-mm-thick liquid-air-cooled counter for 1-Mev electrons, was 2.1 kev.

304 RADIATION MONITOR.

Moncaster Michael Edward, Northrop David Covell, Raines John Arthur (Services Electronics Research Lab.); Pretty William Edward (Admiralty Research and Development Services).

British Patent 1,008,945. Nov. 3, 1965. Filed May 2, 1962.

A solid state radiation detector comprises a slice of a single crystal high resistivity Si having one of its opposite faces converted into a P-N junction and the other face into an ohmic contact by the diffusion into them of appropriate impurities. The slice is mounted and sealed in a metal capsule by attachment of one of the faces to the metal of the capsule constituting an external connection to the detector. If the slice is to serve as a gamma ray detector, the capsule is hermetically sealed around the slice by enclosing it with its ohmic contact face attached to the capsule and an insulated spring contact to the junction face as the other external contact. If the detector is to be used for charged particles, the slice is sealed at its junction face across an aperture in the capsule with the insulating spring contact bearing on the ohmic contact face.

305 (CEA-R-2846) SUR QUELQUES UTILISATIONS DE L'ENREGISTREMENT DES FRAGMENTS DE FISSION DANS LES ISOLANTS.

(On Some Uses of the Recording of Fission Fragments Occurring in Insulators).

Mory Jean (Commissariat à l'Energie Atomique, Fontenay-aux-Roses (France). Centre d'Etudes Nucléaires).
Sept. 1965. 60 p. Dep. mn.

After briefly recalling the interaction processes between charged particles and matter, and giving a quantitative study of the relationships connecting the various parameters, some of the following applications are considered; thermal neutron dosimetry, fast neutron dosimetry, dosage of very low fissile impurity concentrations, and study of fissile elements occurring in atmospheric dusts. Results are then briefly given of an automated counting test for traces effected by measuring the electrical resistivity of the irradiated membrane. Finally, the advantages and disadvantages of these solid detectors are discussed, especially with respect to nuclear emulsions whose uses are approximately identical.

306 ROCKET MEASUREMENTS OF ENERGETIC PARTICLES. 1. DESCRIPTION OF THE EXPERIMENT.

Mozer F. S., Crifo J. J., Blamont J. E. (Service d'Aéronomie, Verrières-le-Buisson, France).

J. Geophys. Res., 80: 5699-5707 (Dec. 1, 1965).

Two rockets were fired along the magnetic field line $L = 5.6$ to altitudes above 400 km to measure the fluxes, energy spectrums, and angular distributions of protons and electrons with energies above 150 kev. The objectives of the experiment are stated and the payload operation is described.

307 ETCHING CELL FOR SEMICONDUCTOR COUNTERS.

Muggleton A. H. F. (Atomic Weapons Research Establishment, Aldermaston, Eng.).

Nucl. Instrum. Methods, 37: 345 (Nov. 1965).

A cell is designed in which semiconductors (and, in particular, lithium-drifted semiconductors) can be etched under controlled conditions with ease. The cell may be constructed of polythene or Teflon.

308 FABRICATION METHODS FOR LITHIUM-DRIFTED SURFACE-BARRIER SILICON DETECTORS.

Murray H. M., Harpster J. W., Casper K. J. (Western Reserve Univ., Cleveland).

Nucl. Instrum. Methods, 40: 330-6 (Mar. 1966).

Techniques for the fabrication of lithium surface barrier silicon detectors are presented. All important chemical procedures are described in detail. The detectors made by these techniques exhibit resolutions of 15-30 kev on internal conversion electrons when operated at room temperature.

309 CHARGE COLLECTION IN CERTAIN TYPES OF SEMICONDUCTOR RADIATION DETECTORS.

Papadakis A. C. (Post Office Research Station, London).

Nucl. Instrum. Methods, 40: 177-8 (Feb. 1966).

A discussion of charge collection in semiconductor detectors is given with restriction to the common case where ionization occurs very close to one electrode so that the contribution of one type of carrier is negligible over most of the collection time. Only transit of the remaining carriers needs then be considered, and it is further assumed that recombination and trapping during their transit time is negligible since field perturbations are then most significant. Two stages of charge collection are considered: from a time after ionization until the time when the first of the excess mobile carriers reach the opposite electrode, and from this time until the time when collection of the excess carriers is complete.

310 DETECTION OF 30 AND 40 Mev PROTONS BY A THIN-WINDOW LITHIUM-DRIFTED GERMANIUM COUNTER.

Pehl R. H., Landis D. A., Goulding F. S., Jarrett B. V. (Univ. of California, Berkeley).

Phys. Lett., 19: 495-6 (Dec. 1, 1965).

The response of thin-window lithium-drifted germanium counters is investigated. Corrections were made for the spread of the beam energy, the thin window, and electronic noise. The remaining spread was found to be 21 kev for 30-Mev protons, and 30 kev for 40-Mev protons. Also the theoretical limitation of the energy resolution is given as a function of the energy deposited in a germanium crystal for different non-detector contributions.

311 NUCLEAR RADIATION DETECTORS WITH SEMICONDUCTOR DEVICES. PART I.

Poenaru Dorin, Vilcov N. (Inst. of Atomic Physics, Bucharest).

Acad. Repub. Pop. Rom. Stud. Cercet. Fiz., 17: 203-42 (1965). (In Rumanian).

Although it has been known for some time that solids present advantages for counting x or γ radiation, such as low ionization energy and higher stopping power, they were employed only in the form of photographic emulsions or scintillators. Since 1949 attempts were made to employ high-purity Ge as a detector of charged particles; following these studies, many semiconductor detectors were developed, in particular for recording heavy charged particles, such as protons, deuterons, α particles, fission fragments, etc. These instruments have excellent resolving power, they withstand fluxes up to 10^{14} protons/cm^2 and 10^{11} α particles/cm^2 and may be used in the presence of a relatively high γ background. With special circuitry, high energy electrons and γ rays may also be recorded. A 4-Mev α particle is able to transfer about 2 kev maximum energy. This collision process also allows a shift of electrons from the valency band to the conductance band, forming electron vacancy pairs. The path of the low-energy electrons formed by collision is only about 0.1 μ; therefore, the trajectory of heavy primary particles is marked by a thin cylindrical plasma of vacancies and electrons. The time of stoppage is estimated at 2.8×10^{-12} sec for electrons and 2.6×10^{-11} sec for α particles. Equations were derived for following the movement of charge carriers, and their collection in actual devices, taking into account the problem presented by the noise. (Review article, 27 references).

312 RADIATION DETECTORS WITH SEMICONDUCTOR DEVICES. PART II. CHARACTERISTICS OF SEMICONDUCTOR DETECTORS.

Poenaru D., Vilcov N.

Acad. Repub. Pop. Rom. Stud. Cercet. Fiz., 17: 695-723 (1965). (In Rumanian).

Operation of semiconductor detectors depends on electric parameters, such as the volt-ampere characteristics, the capacity of the barrier layer and the thickness of the space charge region. Knowledge of these parameters makes it possible to determine the width of the profile of the detector, establishing the maximum energy, at which linearity of the spectrometric measurements can still be maintained. A nomogram was developed for facilitating calculation of the space charge region for a given resistivity of the semiconducting material and a given voltage. The detection characteristics include the maximum energy that can be linearly detected as a function of the applied voltage, the efficiency, energy resolution, and time-related properties. The energy resolution can be conveniently measured by means of a ^{241}Am source which possesses three suitable lines at 5.477, 5.435, and 5.375 Mev. A fast time response is especially important for time-of-flight measurements, multiple coincidences, detection of charged particles in the presence of a strong γ background, and rapid collection of data from a pulsed accelerator.

The effect of temperature, of magnetic field, and of light on the sensitivity of the detector was also examined, together with the effect of γ and neutron radiations. (Review article).

313 (BNL-9980) A PARAMETRIC RADIATION DETECTOR PREAMPLIFIER.

Radeka V., Chase R.L. (Brookhaven National Lab., Upton, N. Y.).
[nd].

Contract AT-30-2-GEN-16, 21 p. (CONF-660304-2). Dep. mn. CFSTI $1.00 cy, $0.50 mn.

From Institute of Electrical and Electronics Engineers, Scintillation and Semiconductor Counter Symposium, Washington, D. C.

A charge-sensitive preamplifier is described, in which a pair of varactor diodes is used in a parametric configuration as the first amplifying element.

314 PION STUDIES WITH SILION DETECTORS.

Raju M. R., Aceto H., Richman C. (Univ. of California, Berkeley).

Nucl. Instrum. Methods, 37: 152-8 (Nov. 1965). (UCRL-16071).

Measurements are made of the probable energy loss in silicon for pions of energies extending from 365 to 50 Mev. The results agree within 2% with the theoretical values. The behavior of the pion beam with its inherent muon and electron contaminants, as it passes through various thicknesses of absorbing material, is displayed. The energy distribution of negative pion stars in silicon is measured and found to be a constantly decreasing function of energy, with the high-energy tail extending beyond 60 Mev.

315 LOW-ENERGY MOSAIC ELECTRON SENSOR.

Reinitz Karl (Westinghouse Defense and Space Center, Baltimore).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 1, 762-4 (Feb. 1966).

A composite surface-barrier diode for the detection of low-energy electrons is described. The device is fabricated on a Si wafer with a diameter of approximately 1 in. and has a sensitive window (0.5 in. $\times$ 0.5 in.) on the active side of the unit. The back side of the unit has two perpendicular sets of parallel evaporated conductors that are used for readout. The location of an incident particle is determined by the particular channels through which the readout is accomplished.

316 AN ELECTRON-PROTON SPECTROMETER FOR ROCKETS USING SOLID STATE DETECTORS.

Riedler W. (Kiruna Geophysical Observatory, Sweden).

pp. 137-45 of Proceedings of a Symposium on High Latitude Particles and the Ionosphere, Alpbach, 1964. Maehlum B. (ed). New York, Academic Press, 1965.

An instrument is described which was designed to measure integral energy spectra of auroral electrons and protons in the range from 40 to 104 kev. Silicon junction particle detectors were used for this purpose. Preliminary results from a successful launch on 12 March 1964 from Andøya, Norway, are given.

317 GAMMA-RAY ENERGIES DETERMINED WITH A LITHIUM-DRIFTED GERMANIUM DETECTOR.

Robinson R. L., Stelson P. H., McGowan F. K., Ford J. L. C. Jr., Milner W. T. (Oak Ridge National Lab., Tenn.).

Nucl. Phys., 74: 281-8 (1965). (ORNL-P-1518).

The energies of gamma rays from about sixty nuclides have been determined to within a few tenths of a kev by means of a lithium-drifted germanium detector. They include values for the transitions resulting from the decay of ^{51}Cr, ^{7}Be, ^{207}Bi, ^{54}Mn, ^{88}Y, ^{65}Zn, and ^{22}Na which are frequently used as calibration standards. The majority of energies are for transitions following Coulomb excitation. Previously unresolved gamma-ray doublets have been observed in the decay of the radioactive nuclei ^{102} Rh and ^{106}Rh and in Coulomb-excited ^{75}As, ^{77}Se, ^{117}Sn, and ^{119}Sn. From the relative intensities of the members of the ^{77}Se doublet, new estimates have been made for the $B(E2)_{ex,s}$ of the 239,3 and 250.1 kev states. They are, respectively, 1770 $\pm$ 160 and 94 $\pm$ 26 e^2 fm^4.

318 A SIMPLE METHOD FOR THE MEASUREMENTS OF TOTAL NEUTRON CROSS SECTIONS.

Roessle E., Tauber M. (Johann-Wolfgang-Goethe-Univ., Frankfurt am Main).

Nucl. Instrum. Methods, 39: 261-4 (Jan. 11, 1966).

The ground state transition of the reaction $^{28}Si(n,\alpha)^{25}Mg$ in solid state detectors is used for recording the neutron intensities in the transmission experiments for the evaluation of neutron total cross sections. The absorber is placed between two solid state detectors and the transmission determined in a single measurement. The method is particularly suitable in the energy range of $6 < E_n < 9$ Mev.

319 GOLD-SILICON SURFACE-BARRIER BETASPECTROMETER WITH MULTI-GUARD-RING.

Roman Jerzy (Central Lab. for Radiological Protection, Warsaw). Chwaszczewska Janina, Dabrowski Andrzej.

Nukleonika, 10: 255-7 (1965).

Gold-silicon surface-barrier detectors with very low leakage-current, good energy resolution at high reverse bias, and high stability in long-term operation and containing multiple-guard-rings were constructed. The detectors were tested up to 1,500 v reverse bias at room temperature without any sign of breakdown. A long-term test proved that the detectors operate for several weeks in air and in vacuum without any visible changes in their characteristics and any measurable increase of noise level. The detectors were used as high resolution beta spectrometers.

320 THE MEASUREMENT OF THE RANGE-ENERGY RELATION AND STRAGGLING OF α PARTICLES IN AIR USING A SOLID-STATE DETECTOR.

Rotondi E., Geiger K. W. (National Research Council, Ottawa, Can.).

Nucl. Instrum. Methods, 40: 192-6 (Mar. 1966).

The energy loss of α particles was studied with a surface barrier detector making use of its much higher resolution than that of ion chambers used in the older work. The range-energy relation was redetermined with ^{210}Po α particles. The mean range was found to be 3.835 ± 0.010 cm, which is in agreement with previous work. The semiconductor detector made it possible to measure energy straggling over the whole energy range. The range straggling parameter was derived and good agreement was found with the quantum mechanical theory of straggling which takes into account the effect of electron binding.

321 IMPROVEMENTS RELATING TO SOLID STATE RADIATION DETECTORS.

Rouse Robert Lindsay (Associated Electrical Industries Ltd.).

British Patent 1,006,233. Sept. 29, 1965. Filed May 8, 1962.

A method of manufacturing p-i-n junction semiconductor radiation detectors includes the steps of treating a semiconductor alloy of Si and Ge (at least 10% Ge) by a lithium ion drift process at a high temperature to form a p-n junction, applying a reverse electrical bias to the junction at a lower temperature to increase the thickness of the depletion zone and form a p-i-n junction, and connecting electrical leads to the device for connection to external circuitry. Appropriate circuitry may include a biasing source connected to apply a reverse bias to the p-i-n detector and a pulse height analyzer for measuring the output. The device may be cooled below ambient temperature.

322 PARTICLE COUNTING BY CASCADE PRODUCTION IN SOLIDS ESPECIALLY IN Si p-n LAYERS [Thesis].

Ruge I. (Munich, Tech. Univ.).

1964. 138 p. $2.00 Gmelin, AED-DISS. 64-581.

The application of charge multiplication in plasma channels in solids for particle counting is studied. Methods for production of microchannels in Si p-n layers are discussed. The effective volume of the counter is estimated. A probe operating by charge transport in plasma channels can also be used as an infrared detector.

323 (EUR 2487.e) EFFICIENCY OF A SEMICONDUCTOR SANDWICH DETECTOR IN A FLUX OF FISSION NEUTRONS FROM A DISK SOURCE.

Rydin R. A. (European Atomic Energy Community, Ispra (Italy). Joint Nuclear Research Center).

1965. 20 p. Dep. mn.

The detection efficiency of a semiconductor sandwich spectrometer is calculated as a function of energy and distance from a disk type fission neutron source. The efficiency is found to vary with the angular distribution of incident neutrons as well as with the incident neutron energy. The difference between the actual differential cross sections for the ^6Li reaction and the isotropic cross sections is not large.

324 (EUR 2712.e) DESIGN CONSIDERATIONS AND CALCULATIONS FOR A ^6Li SEMICONDUCTOR SANDWICH FAST NEUTRON SPECTROMETER EXPERIMENT.

Rydin R. A. (European Atomic Energy Community, Ispra (Italy). Joint Nuclear Research Center).

1966. 24 p. Dep. mn.

A semiconductor sandwich fast neutron spectrometer, using ^6Li as the sensitive material, is considered for use in a fission neutron type spectrum having a thermal neutron component. Calculations were made of the true coincidence background spectrum produced by reactions in the silicon of the diodes for various conditions of depletion depth and low level discriminator settings. Calculations were also made of the detection efficiency of the spectrometer for a low level discriminator bias set to discriminate against all thermal neutron caused events.

325 RADIATION POSITION DETECTOR.

Sandborg Alan O. (to Nuclear Diodes, Inc.).

U. S. Patent 3,207,902. Sept. 21, 1965. Filed June 20, 1963.

An improved surface barrier p-n junction particle detector is described that can be made to identify the position in which a particle strikes the detection surface and to identify the energy imparted by the impinging particle. A first electrode is positioned on one surface of the semiconductor material and a pair of second electrodes are spaced at opposite edges of the opposite surface. Biasing means are provided between the first and second electrodes. When a radiation particle penetrates the p-n junction, the charge collected at the first electrode corresponds to the sum of the charge collected at the second electrodes; and the proportion of the charge collected at one pair of electrodes to the sum of the charge collected at both of the second electrodes is directly related to the position of impingement of the particles between the second electrodes.

326 (NP-15172) CONTRIBUTION A L'ETUDE DU BRUIT DE GENERATION-RECOMBINATION DANS UN DETECTEUR DE RAYONNEMENTS NUCLEAIRES A BARRIERE DE SURFACE (Thèse).

(Contribution to the Study of Generation-Recombination Noise in a Surface-Barrier Nuclear Radiation Detector [thesis]).

Sau Jacques (Lyon Univ. (France). Faculté des Sciences). May 1965. 60 p. Dep. mn.

The noise of Si surface-barrier detectors (the distribution according to the frequency of the mean power and the Fourier transformation of this distribution called the autocorrelation function) was measured. A theoretical model was constructed to interpret the results obtained. The formation of a potential barrier at the surface of a semiconductor is first described. Various characteristics of time-dependent functions are reviewed. The results are given and interpreted using a model based on the generation and disappearance of charge carriers intervening in the electric conduction.

327 INSTRUMENT FOR RECORDING PROTONS WITH E =3 TO 14 Mev, α PARTICLES, AND NUCLEI OF Z > 2.

Savenko I. A., Savun O. I., Yurovskii A. V. (Moscow State Univ.).

Geomagn. Aeronomy (USSR) (Engl. Transl., 5: 423-5 (1965).

Translated from Geomagn. Aeronomiya, 3: 550-3 (1965).

An instrument is described in which surface-barrier type silicon detectors are used to record protons, α particles, and nuclei with $Z > 2$. Protons are recorded in three ranges: 0.3 — 8, 7 — 11, and 11 — 14 Mev. The advantages and possibilities of this method of recording particles without using amplitude analysis and pulse selecting logic circuits are described.

328 EVALUATION OF SEMICONDUCTOR DETECTORS FOR FISSION-FRAGMENT ENERGY MEASUREMENTS.

Schmitt H. W., Pleasonton Frances (Oak Ridge National Lab., Tenn.).

Nucl. Instrum. Methods, 40: 204-8 (Mar. 1966). (ORNL-P-1625).

A practical guide for the evaluation of silicon semiconductor detectors for fission fragment energy measurements is given. The evaluation is based on shape parameters associated with the pulse amplitude spectrum for ^{252}Cf spontaneous fission fragments. Reasonable limits for these parameters are suggested and the significance of each is discussed. Measurements of similar parameters for the ^{235}U thermal-neutron fission fragment pulse amplitude spectrum are reported. A method for computer determination of the spectrum parameters is outlined.

329 LITHIUM DRIFTED GERMANIUM DETECTORS: APPLICATIONS TO NEUTRON-ACTIVATION ANALYSIS.

Schroeder Gerald L., Kraner Hobart W., Robley D. (Massachusetts Inst. of Tech., Cambridge).

Science, 151: 815-17 (Feb. 18, 1966).

Lithium-drifted germanium detectors for high-resolution gamma-ray spectroscopy reduce the need for wet chemistry in neutron-activation analysis. Problems in fields as diverse as geochemistry and the history of 15th-century printing are shown to be susceptible to this analytic technique.

330 THE APPLICATION OF LITHIUM-DRIFTED GERMANIUM DETECTORS TO NEUTRON ACTIVATION ANALYSIS-STUDIES IN GEOCHEMISTRY AND OF 15th CENTURY PRINTING.

Schroeder Gerald L., Kraner Hobart W., Evans Robley D. (Massachusetts Inst. of Tech., Cambridge).

Trans. Amer. Nucl. Soc., 8: 327 (Nov. 1965).

331 STUDY FOR GENERALIZED MODEL SEMICONDUCTOR RADIATION RESPONSE PREDICTION.

James P. Raymond et al. (Ventura Div. Northrop Corp. Van Nuys, Calif.).

NVR 3840. Ecom-004231. DA 28 043 AMC 00423 E. 146 p. Jun. 1965.

332 LOW ENERGY α-p PULSE-SHAPE DISCRIMINATION WITH SILICON SURFACE BARRIER DETECTORS.

Siffert P., Coche A. (Centre de Recherches Nucléaires, Strasbourg).

22 p. (CONF-651001-27). ORAU. Gmelin, AED-CONF-65-293-27.

From IEEE Nuclear Science Symposium, San Francisco.

A system that permits the discrimination between alpha particles and protons with energies greater than 3 Mev is described.

333 SEMICONDUCTOR DETECTORS STUDIES OF RECOILS FROM 15-Mev DEUTERONS ON ^{12}C [Thesis].

Sodd, Vincent Joseph.

Pittsburgh, Univ. of Pittsburgh, 1964. 145 p.

A method is described by which recoiling residual nuclei from nuclear reactions are counted and analyzed with good resolution as they escape from thin targets during

accelerator bombardments. The properties of the silicon surface barrier detectors used are described. Spectra of 1- to 8-Mev ^{10}B, ^{12}C, ^{13}C, and ^{13}N recoils from 15-Mev deuteron-induced reactions of carbon were obtained as a function of detector bias, target thickness, and thickness of interposed absorber. Applications of the method to studies of the range, energy loss, and charge-state distributions of low-energy heavy ions are described. The equilibrium charge-state distributions of ^{12}C ions with velocities between 8.77 and 9.77×10^8 cm/sec and of ^{13}C ions with velocities between 7.08 and 8.46×10^8 cm/sec were determined. The ions were produced as recoils from ^{12}C (d,d′) and ^{12}C(d,p) reactions induced by 15-Mev deuterons, equilibrated during the process of escaping from the carbon targets, subjected to magnetic analysis, and detected with a low-resistivity Si surface-barrier detector. The data join smoothly to previous results, which are predominately at higher velocities.

334 DISCRIMINATING RADIATION DETECTOR FOR DETERMINING A GIVEN RADIATION IN THE PRESENCE OF OTHER RADIATIONS.

Sun Kuan H. (Westinghouse Electric Corp.).

U. S. Patent 3,201,590. Aug. 17, 1965. Filed Dec. 4, 1958.

A radiation detector is patented that includes means sensitive to a given type of radiation and also an arrangement for cancelling out the effects of other radiations in order to render the detector insensitive to any other than the given radiation, e.g., a neutron flux meter that is completely insensitive to gamma and fast neutron radiation. The detector includes opposed semiconductor devices, each having p- and n-type regions with a junction between them. The outputs of the semiconductor devices are connected in opposition. A quantity of neutron-reactive material is supported by one of the devices in proximity to its output region, and a neutron insensitive material is supported by the other device in proximity to its output region with means provided for measuring the differential output of the devices.

335 (TID-22335) A FEASIBILITY STUDY OF A HIGH SENSITIVE FAST NEUTRON DOSIMETER.

Summary Report.

Swartz J. M., Chase B. H., Thurston M. O. (Continental Electronics Corp., Columbus, Ohio).

Dec. 31, 1963. Contract AT(11-1)-1226. 54 p. Dep. mn; CFSTI $2.00 cy, $0.50 mn.

The development of a fast neutron dosimeter based on the radioinduced degradation of the excess electron and excess hole lifetimes is described. The dosimeter is envisioned for use as a personnel radiation monitor.

336 SEMICONDUCTOR P-N JUNCTION DETECTOR FOR NUCLEAR RADIATION AS ELECTRIC SIGNAL SOURCE.

Szawlowski Marek (Univ. Warsaw).

Nukleonika, 10: 613-18 (1965). (In Polish).

An equation describing the voltage pulse, arising at the preamplifier input, for a p-n junction detector from an equivalent circuit was derived. The analysis may be used for detector preamplifier system optimization, when high resolution of energy is involved.

337 STABILIZATION OF LITHIUM-DRIFTED SILICON SURFACE-BARRIER DETECTORS.

Tuzzolino A. J., Perkins M. A., Kristoff J. (Univ. of Chicago).

Nucl. Instrum. Methods, 37: 204-16 (Nov. 1965).

A simple fabrication technique is found that yields lithium-drifted silicon surface-barrier detectors that have a low leakage current, and that exhibit stable electrical and α-particle characteristics under conditions of prolonged aging and repeated exposure to thermal-vacuum environments. The detectors operate at a temperature of 65°C and high vacuum for several days with no evidence of noise instability. The operating characteristics of such detectors are studied over a period of several months. These studies include measurements of the electrical and α-particle characteristics taken before, during, and after thermal-vacuum testing at 65°C and additional testing at 50°C. Degradation in electrical and α-particle characteristics resulting from such testing and aging is found to be negligible over a period of approximately four months. The measurements at 50 and 65°C indicate that the fractional change in the mean energy per ion pair is approximately -1.3×10^{-4}/°C over the temperature range from room temperature to 65°C. The results of those studies are reported.

338 (ORNL-P-1657) CONVERSION COEFFICIENT MEASUREMENTS EMPLOYING MAGNETIC AND SOLID-STATE SPECTROMETERS.

van Nooijen B., Ramayya A. V., Hamilton J. H. (Vanderbilt Univ., Nashville, Tenn.); Pinajian J. J., Johnson N. R. (Oak Ridge National Lab., Tenn.).

[nd]. Contract W-7405-eng-26. 5 p. (CONF-650563-3). Dep. mn; CFSTI $1.00 cy, $0.50 mn.

From International Conference on the Internal Conversion Process, Nashville.

A brief discussion of using β-ray spectrometers in conjunction with lithium-drifted germanium detectors for conversion coefficient measurements is presented. This method was used to calculate K-conversion coefficients for yttrium-86. The results are presented.

339 SEMICONDUCTOR PARTICLE DETECTORS.

Varga Dezsoe.

At. Kozlemen., 7: 155-75 (June 1965). (In Hungarian).

Recent increase in the use of semiconductor particle detectors is due to the newly developed simplified fabrication processes, greater variety in the parameters of the commercially available types and the large reduction in their price. It is possible to prepare reliably operating, thick sensitive layers, extending the use of semiconductor

detectors into the field of β and γ spectrometry, in addition to the spectrometry of heavy particles. The action of the detectors is based on the interaction of the high-energy charged particles with the electrons of the solid. As a result of the collisions, the electrons of the semiconductor are lifted from the valency or deeper-lying zones to the conductance zone. This results in the creation of electron-hole pairs, originally located at various levels, but collected within 10^{-32} sec at both sides of the forbidden zone. The energy liberated during this process creates additional pairs. In the case of Si, an energy of $\epsilon_0 = 3.6$ ev is needed for creating a pair. It can be experimentally demonstrated that the number N of carrier couples generated in a crystal is directly proportional with the energy E of the particle, $N = E/\epsilon_0$. The electrons and holes recombine ultimately in the semiconductor. For good detection, the recombination losses must be minimized. Requirements concerning homogeneous crystal detectors, such as halides, diamond, CdS, Si, diffus? p-n detectors, surface barrier detector and Li-ion compensation detectors are reviewed and the limits of energy resolution under various conditions are given. (30 references).

340 (AD-622629) NUCLEAR TIME BASE-FEASIBILITY STUDY.

Voeller Duane E. (Harry Diamond Labs., Washington, D. C.).

Aug. 12, 1965. 50 p. CFSTI $2.00 cy, $0.50 mn.

An investigation was made to determine the feasibility of using random disintegration events of a radioactive isotope in conjunction with a nuclear particle detector as a low-frequency, high-accuracy time base for an electronic timer. The objectives were directed toward a time base suited for various ordnance applications. The various types of detection devices and radioisotopes that were considered are reviewed. Test data are included from the time base that was subsequently developed. The time base evolving from this study consists of an alpha particle source, a semiconductor nuclear particle detector, and a preamplifier with voltage discriminator. A timing error of <0.1 percent was obtained with this system within a —55 to +75C range. Using integrated electronics, the system could be packaged within 1 cu in. and consume <25 mw. Based on this investigation, the use of random disintegration events of a radioisotope in conjunction with a nuclear particle detector was determined feasible but impractical at present, because of the long calibration time and relatively expensive associated electronics.

341 A dE/dx-E CHARGED-PARTICLE SPECTROMETER FOR STUDYING NEUTRON-INDUCED REACTIONS.

Wang, Wei-Noon (Tsing Hua Univ., Hsinchu, Taiwan).

Chin. J. Phys. (Taiwan), 3: 75-89 (Oct. 1965).

A dE/dx-E counter telescope with a silicon surface-barrier detector was constructed for measuring energies and angular distributions of the charged particles produced in reaction with 14-Mev neutrons. The detecting efficiency, particle discrimination, angular definition, counting rate and background were considered and discussed. Actually performance of the counter is presented.

342 INTEGRATED-CIRCUIT CHARGE-SENSITIVE PREAMPLIFIER.

Warble Keith V., Gri Norman J. (AVCO Corp., Tulsa, Okla.).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 1, 346-50 (Feb. 1966).

An integrated-circuit charge-sensitive preamplifier that was developed for use with gas-filled proportional counters and/or silicon detectors is described.

343 PROBLEMS WITH SEMICONDUCTOR DETECTORS DUE TO ANOMALOUS ENERGY LOSS.

Wegner H. E. (Brookhaven National Lab., Upton, N. Y.).

Nucleonics, 23: No. 12, 52-6 (Dec. 1965).

A series of measurements were made of energy distributions of monoenergetic protons and ^{4}He ions after penetrating silicon crystals in order to study the channeling effects on data obtained with semiconductor detectors. The energy-loss and multiple-scattering effects are discussed.

344 (AD-629511) DESIGN CRITERIA FOR WIDE-RANGE GAMMA RADIACS USING SEMICONDUCTOR DIODE DETECTORS.

Wesley E. J., Joseph W. F. (Naval Radiological Defense Lab., San Francisco, Calif.).

Feb. 8, 1966. 39 p. (USNRDL-TR-975).

The application of silicon semiconductor detectors to a wide-range, gamma-ray doserate meter using the detectors in a pulse counting mode is discussed. Pertinent circuit and detector characteristics that establish the doserate ranges that can be covered, the energy dependence to be covered, the energy dependence to be expected from both large lithium-drifted detectors and very small silicon junction diodes, and the stability requirements imposed on the electronics by the pulse mode of operation are reviewed. Methods of tailoring the photon energy response of semiconductor detectors are reviewed. Particular attention is given to the effect on design of amplifier and detector noise and variations in the noise level. One example of a combination of detectors to cover the doserate range from 0.2 mR/h to 2000 R/h is shown.

345 YIELD AND ENERGY SPECTRUM OF SECONDARY ELECTRONS GENERATED BY FISSION FRAGMENTS.

Whitehead A. Bruce (California Inst. of Tech., Pasadena).

9 p. (CONF-651001-24). ORAU. Gmelin. AED-CONF-65-293-59.

From IEEE Nuclear Science Symposium, San Francisco.

A technique for measuring the yield and energy spectrum of secondary electrons generated by the passage of a fission fragment through a metal foil is described. The electrons are accelerated through an electrostatic potential

V and focussed on a solid-state detector using a lens. A number N of low-energy secondaries are thus detected as a pulse corresponding to energy NV in coincidence with the fragment. An integral energy spectrum is obtained by using a suppression grid. The technique also yields information about the response of solid-state detectors to electrons in the energy region below 30 kev.

346 THE CHARACTERISTICS OF VERY SHALLOW SILICON JUNCTIONS.

Wolfgang L. G. (ITT Industrial Labs., Fort Wayne, Ind.); Abraham J. M., Inskeep C. N.

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 1, 30-5 (Feb. 1966).

The results of a series of investigations that was undertaken to optimize the properties of detector junctions are summarized-junctions ranging in depth from 0.75 micron to several angstroms were studied, particularly the diffusion of B and P into Si. The details of junction structure were determined by electron-beam scanning.

347 (NASA-SP-71, pp 245-50) AN APPLICATION OF THE GENERALIZED CONCEPT OF DOSIMETRY TO SPACE RADIATIONS.

Wright H. A., Hurst G. S., Wagner E. B. (Oak Ridge National Lab., Tenn.).

(ORNL-P-706).

The application of the generalized concept of dosimetry to the dosimetry of high-energy protons is illustrated. Calculations are made of the distribution of energy losses in an array of silicon detectors exposed to an isotropic flux of monoenergetic protons. The array consists of a main crystal of dimensions $1 \times 1 \times 1$ cm bounded on each of its six faces by a crystal of dimensions $0.1 \times 1 \times 1$ cm. A computer code is used to plot the distribution of energy losses for several selected energies up to 400 Mev. An energy loss operator is defined that transforms an energy loss distribution function into a dose function. This operator can be used to calculate the rem dose accurately at selected energies, and within a given tolerance at intermediate energies. An electronic circuit is described that selects energy-loss signals from the detector and routes them to the appropriate section of a data processor, thus permitting the calculation of the dose received from radiation by high-energy protons of arbitrary energy spectrum.

348 A TRANSISTORIZED LOW-NOISE PREAMPLIFIER FOR SOLID-STATE RADIATION DETECTOR.

Yoshimura Atsushi, Sonoda Masateru (Kyushu Univ., Japan).

Kyushu Daigaku Kogaku Shuho, 38: 38-44 (Mar. 1965). (In Japanese).

Since the capacity of a solid state detector (SSD) changes with the applied bias voltage, the preamplifier must be charge-sensitive and must have a low-noise to prevent the pulses from becoming broad due to the noise fluctuation of the preamplifier. Several low-noise charge-sensitive preamplifiers were prepared in trial for the fission fragment measurement. The operating principles of the semiconductor detector and the design considerations for the charge-sensitive amplifier are discussed. If the total voltage gain is sufficiently large, the output voltage V_0 of the charge-sensitive amplifier can be given approximately by $V_0 = Q/C_f$, where Q is the total charge deposited on the SSD and C_f is the feedback capacitor. Consequently, the output voltage is approximately proportional to the inverse of C_f. In the transistorized model, 4 silicon transistors, 2SC32, with a good S/N ratio were used. The value of C_f should be determined according to the energy of radiation to be measured. With $C_f = 5$pF, the amplifier exhibited good linearity up to 60-Mev equivalent pulses; and with $C_f = 10$pF, it could be used up to 90 Mev with the output voltage reduced somewhat. The overall energy resolution of this low-noise charge-sensitive preamplifier is about 4.1% for 6.05 and 8.78 Mev alpha particles emitted from Th C. C′ source. The use of a field effect transistor may reduce the noise considerably.

349 (JINR-P-2489) O VYYAVLENII DEFEKTOV V KREMNIEVYKH p-i-n-DETEKTORAKH YADERNYKH IZLUCHENII.

(On Revealing of Defects in Silicon p-i-n Detectors).

Yuskeselieva L. G. (Joint Inst. for Nuclear Research, Dubna (USSR). Lab. of Nuclear Problems).

1965, 14 p. Dep. mn.

Defects in p-n junction of silicon p-i-n detectors are investigated by means of electrophotography and electrochemical depositing of copper. The study of the defects is associated with electric characteristics of detectors.

350 (AD-623722) NEUTRON DETECTION AND SPECTROSCOPY WITH SEMICONDUCTOR DETECTORS.

Zatzick M. R., Zimmerman E. L. (Solid State Radiations, Inc., Los Angeles, Calif.).

Revised Apr. 1965.

Contract DA18-108-405-Cml-1012. 114 p. (NDL-TR-54). CFSTI $4.00 cy, $0.75 mn.

Results are presented of a study of methods for utilizing diffused-junction semiconductor detectors in neutron detection and spectroscopy. Various neutron-sensitive coated detectors, and the ^{6}Li epithermal-neutron spectrometer system, which consists of a ^{6}Li-sandwich detector and a complete, integrated electronic system, are described.

351 (ANL-7110, pp 231-310) EXPERIMENTAL TECHNIQUES AND FACILITIES.

(Argonne National Lab., Ill.).

Counting errors and the dead time of counting systems were studied; and instrumentation was developed for the TREAT sodium loops, along with equipment and techniques for exposure in TREAT. Neutron-detection techniques were studied, and a fast-neutron hodoscope was

deevloped. Methods for measuring capture-to-fission ratios, decay constants, uranium fission rates, and the neutron capture rate of ^{238}U were also studied. A system for the control of a Van de Graaff accelerator by an on-line computer was developed.

352 (BNL-949) PROCESS RADIATION DEVELOPMENT PROGRAM SUMMARIES.

Fifth Annual Contractors Meeting, October 7-8, 1965. (Brookhaven National Lab., Upton, N. Y.).

Contract AT-30-2-GEN-16. 95 p. (CONF-651064). Dep. mn. CFSTI $3.00 cy, $0.75 mn.

Twenty-eight articles are included on radiation processed wood-plastic materials; radiation chemistry and radiation synthesis of fluorocarbons, polymers, organo-metallic compounds, and organic compounds; artificial kidney membranes; radiation engineering; semiconductor device fabrication by neutron transmutation techniques; radiation chemical reactors; HIRDL operations; devices for recording activity of ^{60}Co gamma sources; theory and design of gamma monochromator; radiation effects on optical maser materials; and industrial application of radiation to colloid systems.

353 (BNL-929, pp 58-66) INSTRUMENTATION.

(Brookhaven National Lab., Upton, N. Y.).

Activities associated with development and procurement of instruments and systems for research projects are summarized. Major projects during the year include development and production of digitized discharge planes for hodoscope experiments and design of computer systems to operate HFBR spectrometers.

354 (BNL-929, pp 3-43) PHYSICS.

(Brookhaven National Lab., Upton, N. Y.).

Research efforts devoted to particle physics, atomic and molecular physics, neutron physics, nuclear structure, and solid state physics are summarized.

355 LES DETECTEURS DE RAYONNEMENTS NUCLEAIRES A SEMI-CONDUCTEURS.

Coche A.

Industries Atomiques, 9e année, No. 11, 1965, p. 61-69.

Semi-conductor counters have undergone a significant development in the past few years and have, in a certain number of fields, taken the place of other devices for detecting nuclear radiations. This critical study examines the principal characteristics of diodes with a N-P linkage and with surface barriers, and the essential uses to which they are put. Next it sets forth the principle of the method for compensating a material of the P type by the migration of lithium, and lastly it studies the properties of N-I-P diodes of silicium and of germanium, as well as their applications, with special attention to gamma spectrometry.

356 (IA-920) RESEARCH LABORATORIES SEMI-ANNUAL REPORT FOR THE PERIOD JULY-DECEMBER 1963.

(Israel Atomic Energy Commission, Yavne. Soreq Research Establishment).

196 p. Dep. mn.

Progress and trends in the research program are reported, and operational services are described. Information is included on operation of the IRR-1 Reactor and isotope production. Research progress is reported on elementary particle theory, reactor physics, nuclear physics, solid state physics, inorganic chemistry, radiation chemistry, nuclear chemistry, analytical chemistry, and applications technology. Biological and medical research are summarized. Results of research on nuclear hazards are presented along with research progress on nuclear and mechanical instrumentation. A bibliography of reports and papers associated with the project is included.

357 LITHIUM DRIFTED GERMANIUM DETECTORS (Engineering Materials).

(Lawrence Radiation Lab., Univ. of California, Livermore).

(CAPE-1317). 18 drawings.

The Li-drifted Ge detectors are used in high resolution β and γ spectroscopy, in nuclear decay scheme determinations, and in identifying the isotopic content of samples containing many isotopes. One of the detectors, with an active volume in excess of 6 cm^3, is primarily intended for high energy (>1.0 Mev) γ spectroscopy. The second type is a large-area, low-capacity, windowless detector intended for very high resolution β and low-energy γ spectroscopy. Both operate in a vacuum at liquid nitrogen temperature (77°K). (For details, see TID-4100).

358 (MIT-952-2) RADIUM AND MESOTHORIUM POISONING AND DOSIMETRY AND INSTRUMENTATION TECHNIQUES IN APPLIED RADIOACTIVITY.

Annual Progress Report. (Massachusetts Inst. of Tech., Cambridge. Dept. of Physics).

May 1965. Contract AT (30-1)-952. 213 p. Dep. mn; CFSTI $6.00 cy, $1.25 mn.

Results of studies concerning Ra and mesothorium toxicity in humans are reported. Investigations concerning differential uptake of injected Ra and Th in humans are described. Research results on radiobiology, nuclear physics, instrumentation techniques, and radiochemistry are summarized.

359 (NYO-72-28) PEGRAM NUCLEAR PHYSICS LABORATORIES.

Progress Report, January 1964 - January 1965. (Columbia Univ., New York, Dept. of Physics).

Feb. 1966. Contract AT(30-1)-Gen-72. 164 p. Dep. mn. CFSTI $5.00 cy, $1.00 mn.

Various experimental and theoretical studies were made in the areas of neutron physics, nuclear reactions with charged particles, beta and gamma spectroscopy and application to nuclear structure, neutron interactions with condensed matter, macroscopic neutron physics, and instrument development.

360 (NYO-3246-5) STUDY OF SURFACE CONTOURING AS APPLIED TO SEMICONDUCTOR RADIATION DETECTORS.

Semiannual Report, January 1965 - June 1965. (General Electric Co., Philadelphia, Pa. Missile and Space Div.).

July 1965. Contract AT(30-1)-3246, 36 p. Dep. mn. CFSTI $3.00 cy, $0.50 mn.

The application of geometrical surface field control (termed "surface contouring") to semiconductor p-n junctions of use in radiation detection and spectroscopy was investigated. Efforts during this perioid have dwelled on the junctions themselves with particular emphasis on study of the window or energy defect at the particle entrance face. This would seem to be of importance in realizing the potential for very low energy particle detection. Other experimentation was in the areas of attempts to arrive at the inherent speed or pulse risetime of the structures and measurements of uniformity of amplification laterally across the junction. Additional effort went into the development of a stable, low resistance base (n-type) junction contact. In this regard, a gold-antimony alloy contact applied by the thermal compression method was found to work well.

361 (ORNL-3029) AIRCRAFT NUCLEAR PROPULSION PROJECT SEMIANNUAL PROGRESS REPORT FOR PERIOD ENDING OCTOBER 31, 1960.

(Oak Ridge National Lab., Tenn.).

Dec. 22, 1960. Contract W-7405-eng-26 125 p. Dep. mn; CFSTI $4.00 cy, $0.75 mn.

The gamma response of CsI and NaI crystals was investigated, as well as line widths in NaI(Tl) spectrometers. The BSF gamma spectrometer was completed, and methods for unscrambling spectra and obtaining response functions for spectrometers were studied. The use of silicon surface-barrier detectors in fast-neutron detection and spectroscopy was investigated; the energy distribution of alpha-triton pairs from the $^{6}Li(n,\alpha)T$ reaction in ^{6}LiF was calculated. The preliminary design of a neutron-chopper spectrometer for Bulk Shielding Facility was completed, and corrections to thermal-neutron flux measurements in water by gold activation were studied further. The investigation of the spectrum of prompt gamma rays from thermal-neutron fission of ^{235}U continued; the response function of the gamma pair spectrometer was determined. Computer programs for shielding calculations were developed, and the angular distributions of neutrons emerging from hydrogenous slabs and lead slabs were measured. Shielding calculations for space vehicles were also considered. Additionally, the gamma and neutron dose rates in the crew compartment of a nuclear aircraft were analyzed; and gamma and neutron attenuation in lithium hydride-uranium shielding was studied experimentally, together with secondary gamma production in the shielding. The shield configuration proposed for the ML-1 reactor was evaluated in a series of experiments at the Lid Tank Shielding Facility. Optimization calculations were made for the design of a reactor shadow shield.

362 PHYSICS OF SEMICONDUCTORS.

Proceedings of the 7th International Conference, Paris. July, 19-24, 1964.

Paris, Dunod, 1964. 1368 p. (CONF-679).

Papers (186) are included on band structure, optical properties, magento-optical effects, transport properties, impurities, free excitons, photoconductivity, phonon-photon interactions, and semiconducting materials.

363 (TID-22407) NEW METHOD FOR OXIDE PASSIVATION OF SEMICONDUCTOR DETECTORS.

Final Report. (Solid State Radiations, Inc., Los Angeles, Calif.).

July 30, 1965. Contract AT(04-3)-574. 17 p. Dep. mn; CFSTI $1.00 cy, $0.50 mn.

The production of silica surface layers on Si semiconductor detectors by immersion in oxigen plasma is reported. The properties of the protective surface layers thus formed under controlled conditions are studied. The results obtained using this method are compared with those obtained using film-deposition and thermal-oxidation processes.

364 (UCRL-14739(Pt.2)) PROGRAM BOOK FOR THE ADVISORY COMMITTEE FOR BIOLOGY AND MEDICINE OF THE UNITED STATES ATOMIC ENERGY COMMISSION. PART II.

(Lawrence Radiation Lab., Univ. of California, Livermore).

Mar. 10, 1966. Contract W-7405-eng-48. 177 p. Dep. mn. CFSTI $5.00 cy, $1.00 mn.

Studies are reported on: radionuclide metabolism in man and other organisms; biochemical and metabolic reactions; the effects of ionizing radiation on biosynthesis and genetics; radionuclide burdens in man and the terrestrial environment; biological ultrastructure; particulate behavior and fallout deposition; and radiation detectors and monitoring systems.

365 (AECL-2569) PRELIMINARY TESTS ON ENCAPSULATED LITHIUM-DRIFT GERMANIUM GAMMA RAY SPECTROTMETERS MADE BY RCA VICTOR RESEARCH LABORATORIES, MONTREAL.

Fowler I. L., Toone R. J. (Atomic Energy of Canada Ltd., Chalk River [Ontario]).

July 1964. 14 p. (GPI-59). Dep. mn. AECL $0.50.

Tests were carried out on three encapsulated germanium lithium-drift γ-ray spectrometers. The detectors are approximately 2 cm^2 in area and 2 mm depletion (sensitive)

depth and are encapsulated in modified standard steel transistor cans. After a straight-forward electrical clean-up procedure the detectors were cooled to liquid nitrogen temperature (77°K) and gamma spectra taken. All three detectors gave resolutions of 2.6 to 2.7 kev (fwhm) for 122-kev γ rays, and 6.3 kev for 1173-kev γ rays. The detectors were found to operate satisfactorily after storage for several days in a freezer at —22°C without further clean-up. One detector was operated, cooled to near 77°K with liquid nitrogen, in an insulated mount with no vacuum system. Such an arrangement is only possible with encapsulated detectors of this type and should prove convenient for many users for short-term experiments. Details of this non-vacuum mount are given.

The observation of the time relation between the protons and gamma rays detected in a plastic scintillator was used to demonstrate the performance for p-γ delayed coincidence measurements. For the $^{16}O(d,p)^{17}O$ reaction to the first excited state, the timing resolution obtained was approximately 1.3 nanoseconds. This indicates that lifetimes greater than $\sim$0.5 nanoseconds can be measured directly from the slope of the delayed edge of the resolution curve.

366 NUCLEAR REACTION STUDIES OF ^{12}B AND ^{17}O.

Alexander Thomas Kennedy,

Edmonton, Alta., Univ. of Alberta, 1964. 140 p.

Thesis.

The first two excited states of ^{12}B were studied using the $^{11}B(d,p)^{12}B$ reaction and particle-gamma coincidence techniques. The gamma branching ration of the 1.67-Mev state to the 0.95-Mev state was found to be $6 \pm 3\%$ of the ground-state transition. An upper limit on the lifetime of the 0.95-Mev state was obtained by direct timing ($\tau < 3 \times 10^{-10}$ sec.). The angular correlation of the 0.95-Mev gamma ray measured in time coincidence with protons observed at 90° is isotropic at a bombarding energy of 1.5 Mev. The combined data are not sufficient to determine the spin of the 0.95-Mev state. The proton-gamma angular correlation of the 1.67-Mev state is isotropic for the same experimental conditions. The 3.06- and 3.85-Mev level of ^{17}O were investigated using the $^{14}C(\alpha,n)^{17}O$ reaction and neutron-gamma coincidence techniques. Doppler-shift measurements of the 3.85- and 2.19-Mev gamma rays yielded $\tau \leqslant 0.25 \times 10^{-13}$ sec and $\tau = 1.2 \times 10^{-13}$ sec for the lifetimes of the 3.85- and 3.06-Mev states, respectively. The measurements of the neutron-gamma angular correlations, combined with the lifetime estimates, give the spin assignment $5/2^-$ for the 3.85-Mev state and confirm the $1/2^-$ spin assignment for the 3.06-Mev state. A fast timing system was developed for use with solid-state particle detectors.

367 EFFECTS OF NEUTRON IRRADIATION ON SOLID-STATE DETECTORS.

Cantarell I., Facetti J. F., Trabal E., Vega R. (Centro Nuclear de Puerto Rico, Mayaguez).

pp. 45-6 of I Conferencia de Espectroscopia Nuclear y Fisica del Estado Solido. Lima, Organizacion de Universidades Catolicas de America Latina, 1964. (In Spanish).

Solid-state detectors exposed to reactor neutrons showed a progressive decrease of the resolution in the first two days of irradiation, and false tracks appeared in the lower zone of the spectrum. The detector showed other pronounced variations after a month of irradiation and did not recover during a month of rest. There was an almost complete loss of resolution and a large number of false tracks which deform the spectrum. γ spectra made of the detector and its components showed the presence of Cu and Co isotopes in the accessory components of the detector. The initial variation of resolution seems to be caused by the activation of the detector.

368 ELECTRIC CONDUCTIVITY OF ORGANIC SEMICONDUCTORS.

Cobas Amador (Centro Nuclear de Puerto Rico, Rio Piedras).

pp. 99-110 of I Conferencia de Espectroscopia Nuclear y Fisica del Estado Solido. Lima, Organizacion de Universidades Catolicas de America Latina, 1964. (In Spanish).

A bibliographic review is made of the properties of organic semiconductors, with emphasis on the electric conductivity. The measurement technique used in the study of organic semiconductors is outlined. The technical uses of these semiconductors are summarized.

369 (PAEC(A)IN-658) SEMICONDUCTOR DETECTORS.

A Literature Search. (Philippine Atomic Energy Commission, Manila). Aug. 1965. 54 p. Dep. mn.

A bibliography is presented on semiconductor detectors. The entries are listed under the subject headings of biology and medicine, engineering, health and safety, instrumentation, reactor technology, and physics.

370 DETECTION OF RADIOACTIVITY.

Gibbons D. (United Kingdom Atomic Energy Authority, Wantage, Eng.), Wainerdi R. E.

pp. 19-25 of Activation Analysis, Principles and Applications. Lenihan J. M. A., Thomson S. J. (eds.). New York, Academic Press, 1965.

Detection of β particles and positrons at 0.5 to 3 Mev, x rays at 1 kev, γ rays at 0.1 to 3 Mev, α particles (limited number of applications), and neutrons with energies up to around 14 Mev is discussed. Advantages and disadvantages of gas ionization methods, scintillation counters, solid-state detectors, surface-barrier detectors, and neutron spectrometers are given.

371 SEMICONDUCTOR PARTICLE SPECTROMETERS.

Gibson W. M., Miller G. L., Donovan P. F.

pp. 345-78 of Alpha-, Beta- and Gamma-Ray Spectroscopy. Vol. I. Siegbahn Kai (ed.). Amsterdam, North-Holland Publishing Co., 1965.

The important properties and applications of semiconductor particle detectors are discussed. Consideration is given to detector noise, radiation damage, electronics, and detector types. A brief account is given of the chief advantages and limitations of these detectors as applied to nuclear physics experiments. (130 references.)

372 (ORNL-3924) PHYSICS DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING DECEMBER 31, 1965.

(Oak Ridge National Lab., Tenn.).

May 1966. Contract W-7405-eng-26. 179 p. Dep. mn. CFSTI $5.00 cy, $1.00 mn.

A report is presented on research in progress by the physics division of ORNL. Preliminary results are presented on research in high energy physics, instrumentation, nuclear reactions, neutron scattering, fission, solid state physics, superconductivity, mathematics, and biomedicine. A brief description of the 3.0-Mv, 5.5-Mv, and Tandem Van de Graaff facilities, including a cross reference to reports and papers resulting from research done on each is included. Abstracts of papers which have been published since the last annual report are also presented.

373 (NYO-3246-6) STUDY OF SURFACE CONTOURING AS APPLIED TO SEMICONDUCTOR RADIATION DETECTORS.

Semiannual Report, July 1965 - December 1965.

Huth Gerald C. (General Electric Co., Philadelphia, Pa. Missile and Space Div.).

Jan. 1966, Contract AT(30-1)-3246. 77 p. Dep. mn. CFSTI $3.00 cy, $0.75 mn.

A report is presented on a study of carrier multiplication phenomena in a particular silicon diffused junction radiation detector and the applications of the detector. A systemized characterization of the contoured structure is discussed. Detection and potentially interesting spectroscopy of soft x rays is also reported.

374 USING OF SEMICONDUCTORS ALL COUNTERS OF TYPE p-i-n FOR STUDY OF NUCLEAR REACTIONS.

Vavilov V. S., Golovina N. V., Iferov G. A., Tulinov A. F., Chukichev M. V.

Vestn. Moskov. Univ., Ser. III, Fiz. Astron., No. 1, 81-4 (Jan.-Feb. 1966). (In Russian).

Semiconductor charged-particle detectors with p-i-n junctions were prepared on the basis of lithium ion drift in silicon. The counters were used in the investigation of nuclear reactions of α-particles accelerated in a 26-Mev cyclotron. Diagrams of differential cross sections and angular distributions from elastic and inelastic scattering of α particles in $^{12}C(\alpha,\alpha)^{12}C$ are given.

375 DETERMINATION OF DEPTH OF BARRIER WINDOW IN N-I-P STRUCTURE.

Mikhaleva T. N., Mednikov A. K., Stroikin N. I., Chuprunov D. L.

Vestn. Moskov. Univ., Ser. III, Fiz. Astron., No. 1, 120-1 (Jan.-Feb. 1966). (In Russian).

A method is suggested for measuring the barrier (the lithium saturated layer) without any technological change in the n-i-p Si detector. An amplitude analyzer was used for measuring the shift of conversion lines with the change in the direction of detector irradiation and the track-range curve in the silicon. Measurements of protons and α particles accelerated in a 120 cm cyclotron were tabulated. Measurements of α particles scattered on a thin Au target at 60° and recorded with n-i-p Si detector, with 1000 ohm cm specific resistance and $\sim$1 cm^2 working area and $\sim$1.3 mm depth sensitivity were in good agreement with the data on the depth of barrier during α particle and proton measurement.

376 SOME DOSIMETRIC SPECIFICATIONS OF THE GAMMA THERAPY UNIT " LUCH-1 ".

Ostretsov L. A., Galina L. S., Vasil'eva E. D., Partolin O. F.

Med. Radiol., 11: No. 3, 77-81 (Mar. 1966). (In Russian).

Isodose curves for a new ^{60}Co gamma therapy unit, Luch-1, were plotted for skin-source distances of 50 and 75 cm. The dosage rate is shown to depend upon the extent of the field. The dosage rate is noted to go up parallel with the increase in the extent of the field and, for this reason, the qualitative characteristics of the unit can be established only when the dosage rate is measrured for a definite size of the field. An estimation of the backscattering contribution from the phantom was made. The maximum of ionization for E-1.25 Mev in a tissue equivalent medium was determined. Evidence was obtained proving that for relative measurements it is possible to use semiconductor CdS detectors, with a corresponding provision for energy dependence compensation. The essential advantage of the method are simplicity of the measuring circuit and small dimensions of the detector.

377 (AECL-2565) USE OF Ge(Li) DETECTORS IN γ-γ COINCIDENCE EXPERIMENTS.

Ewan G. T., Graham R. L., Mackenzie I. K. (Atomic Energy of Canada Ltd., Chalk River (Ontario). Chalk River Nuclear Labs.).

Mar. 1966. 11 p. (CRGP-1237). Dep. mn. AECL $0.50.

Large volume Ge(Li) detectors were used in a γ-γ coincidence arrangement employing two Ge(Li) detectors. The results of studies of the timing properties of planar and coaxial diodes and the time resolution curves that can be obtained are reported. For two cylindrical coaxial diodes the full-width at half-maximum of the time resolution curve was 14 nsec for 511-kev γ rays. The application of the detectors in γ-γ coincidence experiments is described. The coincidence counting rates are limited by

the total singles counting rates that can be tolerated without excessive loss of energy resolution. Results are shown illustrating the application of a Ge(Li)—Ge(Li) coincidence arrangement to a complex γ-ray spectrum and the ability of this technique to reveal new information on γ-γ cascades.

378 SHORT REVIEW ON THE DEVELOPMENT AND USE OF SEMICONDUCTOR DETECTORS.

Kuhn L.

Mitteilungsbl. Strahlungsmessgeräte, 7: No. 15, 13-15 (Apr. 1966). (In German).

The development and use of semiconductor detectors are briefly reviewed. The results obtainable with semiconductor detector are compared with results obtainable by other detection devices. Data on the special electronics for the operation of semiconductor detectors are tabulated.

379 FAST NEUTRON SPECTROMETER USING Si SURFACE-BARRIER DETECTORS AND Li^6F.

Degtyarev Yu. G., Kazarinova M. I., Protopopov V. N.

Prib. Tekh. Eksp., No. 2, 37-40 (Mar.-Apr. 1966). (In Russian).

A semiconductor neutron spectrometer was developed whose sensing element is a thin film of ^6LiF sandwiched between two layers of n-Si. Neutron bombardment of the film yields the splitting reaction $^6Li + n \rightarrow T + \alpha + Q$, in which the combined energies of the triton T and the α-particle equal the neutron kinetic energy plus the reaction energy Q. A section of the sensor is shown. Allowing for the loss caused by the gold foil, a figure of $Q = 4.6$ Mev is used for thermal neutrons and 4.7 Mev for those above 3 Mev energies. The preamplified pulses from each counter are summed, giving an output of about $E_n + Q$, and this output is connected via an expander to the spectrum analyzer with the expander, any desired portion of the energy spectrum can be observed. Amplitude spectra of tritons, α-particles, and neutrons were obtained for bombarding energies up to 3.2 Mev. Detected pulse amplitudes vs neutron energies over the test range showed a linear relationship. The spectrometer design is recommended as being reliable and stable.

380 (UCRL-16718) HIGH-VOLTAGE LITHIUM-DRIFTED SILICON DETECTORS.

Lothrop Robert P., Goulding F. S. (Lawrence Radiation Lab., Univ. of California, Berkeley).

April. 1966. Contract W-7105-eng-18. 13 p. Dep. mn. CFSTI $1.00 cy, $ 0.50 mn.

A double-drifted geometry, which may take several forms, is described. The geometry makes possible the very-high-voltage operation of lithium-drifted silicon radiation detectors.

381 (AERE-R-5206) THE DEVELOPMENT AND APPLICATION OF Li-DRIFT GERMANIUM DIODES AT A.E.R.E.

Gibbons P. E. (Atomic Energy Research Establishment, Harwell [England]).

May 1966, 24 p. Dep. BIS $0.80. HMSO 4s.

A state-of-the-art account of detector fabrication and developments in cryostat design and low noise head amplifiers, using field effect transistors is presented. Present applications and future requirements are summarized.

382 (UCRL-16819) SOLID-STATE COUNTERS FOR IMMEDIATE ANALYSIS DURING COLUMN CHEMISTRY.

Haley James T., Walker Robert J., Corbin Tommy R. (Lawrence Radiation Lab., Univ. of California, Berkeley).

May 12, 1966. Contract W-7405-eng-48. 11 p. Dep. mn. CFSTI $1.00 cy, $0.50 mn.

A reliable method, using solid-state detectors, is described for the immediate determination of actinide and lanthanide elution peak positions during separation of transplutonium elements and rare earths.

383 PRESENT STATUS AND PROSPECTS FOR SEMICONDUCTOR RADIATION DETECTORS.

Fertin J.

Bull. Inform. Sci. Tech. (Paris), No. 104. Suppl., 17-25 (May 1966). (In French).

A brief review is given of the effect of electromagnetic radiation with emphasis on the semiconductor crystals. The general characteristics of junction detectors are defined. The different types of semiconductor detectors discussed are diffuse-junction detectors, neutron detectors, surface-barrier detectors, lithium-compensated silicon detectors, and lithium-compensated germanium. New areas in which semiconductors detectors can be used are tabulated.

384 (UCRL-16814) COMPUTER-CONTROLLED 4096-CHANNEL SEMICONDUCTOR DETECTOR SYSTEM WITH STABILIZATION.

Swierkowski Stefan P., Lafore Robert W. (Lawrence Radiation Lab., Univ. of California, Berkeley).

May 18, 1966. Contract W-7405-eng-48 18 p. (CONF-661007-1). Dep. mn. CFSTI $1.00 cy, $0.50 mn.

From Institute of Electrical and Electronics Engineers, 22nd National Electronics Conference and Exhibits, Chicago, Ill.

The construction and operation of the hardware and software that constitutes a 4,906 channel bistabilized pulse-height analyzer, data processing, and control system are described. The system was designed for studying γ-ray spectra at the 184 in. cyclotron.

385 (AD-634718) DEVELOPMENT, TESTING, AND EVALUATION OF GERMANIUM NUCLEAR PARTICLE DETECTORS.

Katzenstein H. S., Ziemba F. P. (Solid State Radiations, Inc., Los Angeles, Calif.).

June 1966. Contract DA-18-108-AMC-142(A). 116 p. (NDL-TR-76). CFSTI $3.00 cy, $0.75 mn.

Results are presented of a study of some of the properties of thin-window germanium nuclear-particle detectors that were fabricated by use of the surface barrier lithium-ion-drift techniques. Emphasis was placed on the development of germanium-particle detectors that were suitable for application in the neutron spectrometer which employs the Li^6 sandwich technique. The study resulted in a fabrication procedure for the production of these devices, a preamplifier for germanium detectors, a cooling system for the germanium detectors, an improved electronic system, utilizing nanosecond electronics, for the Li^6 spectrometer, some general comparisons between silicon and germanium detectors, qualitative information on the fast-neutron-induced reaction in silicon and germanium and preliminary data on the response of a neutron spectrometer using thin-window silicon and germanium nuclear-particle detectors. The thin-window germanium detectors were fabricated by use of techniques similar to those employed in the corresponding silicon lithium-ion-drift detector. Although silicon detectors may be operated at room temperature, germanium detectors must be operated at reduced temperatures because of the large thermal-carrier generation rate in germanium at room temperature. Operation in contact with liquid nitrogen is the most suitable because of its general availability and ease of handling in the laboratory. The response of thin-window germanium detectors to charged particles is similar to that obtained with silicon devices, with the exception that the energy to form an electron-hold pair is about 1.26 times greater in silicon than in germanium. The gamma-ray response of germanium detectors is higher than that of silicon detectors since the efficiencies of the gamma-ray absorption processes increase with atomic number. This property, as well as excellent energy resolution, has led to the use of germanium detectors in high-resolution photoelectric gamma-ray spectrometers. In contrast, the higher atomic number produces a larger Coulomb barrier against charged-particle emission, which is reflected in lower (n,p) and (n,α) cross sections. Thus, the background from neutron-induced reactions in germanium detectors is lower than that in silicon detectors.

386 (COO-1420-124) RESEARCH IN NUCLEAR PHYSICS.

Progress Report No. 16. (Purdue Research Foundation, Lafayette, Ind.).

June 15, 1966. Contract AT(11-1)-1420. 56 p. Dep. mn. CFSTI $3.00 cy, $0.50 mn.

Brief summaries of research on various nuclear reactions are presented. Results of an investigation on isobaric spin conservation in the reaction $^{40}Ca(d,\alpha)^{38}K$ are presented. The fabrication and use of Ge(Li) detectors for gamma-gamma angular correlation measurements are described.

387 (KFK-429) ON THE APPLICATION OF LITHIUM-DRIFTED GERMANIUM DIODES IN NEUTRON CAPTURE GAMMA RAY SPECTROSCOPY.

Michaelis W., Schmidt H. (Kernforschungszentrum, Karlsruhe (West Germany). Institut für Angewandte Kernphysik).

June 1966. 15 p. (CONF-660625-2). Dep. mn.

From IAEA Panel Meeting, Vienna.

A status report is presented on the application of lithium-drifted germanium diodes in neutron capture gamma ray spectroscopy. The report includes a summary of the research being done at Karlsruhe on neutron capture. A review of the capabilities and limitations in the application of germanium diodes, and indications of trends in future applications.

388 METHOD FOR THE PRODUCTION OF SURFACE-BARRIER DETECTORS FOR NUCLEAR RADIATION.

Kaufmann Klaus (Deutsche Akademie der Wissenschaften).

German Patent 1,218,073. June 2, 1966, Filed Nov. 18, 1963.

The method comprises the steps of treating p-type silicon discs with an amine containing substance, e.g. epoxies with amine containing hardeners, of storing the discs on air, and of depositing gold by evaporation.

389 PARTICLE DETECTOR OF THE SEMICONDUCTOR TYPE.

Walsh Charles J., Sandborg Alan O. (Nuclear Diodes, Inc.).

U. S. Patent 3,255,351. June 7, 1966. Filed Apr. 19, 1963.

In a system for particle identification an energy detecting device is provided in which the mass-charge-energy detector and the energy detector are both interchangeable and can be substituted conveniently without endangering the semiconductor barriers. The first detector includes a first apertured conductive housing in which is supported an insulator plate that is apertured concentrically with the housing. A first semi-conductor barrier is mounted to the insulator plate at its aperture and is of a thickness so as to dissipate in the barrier without totally absorbing the energy of any one of the intercepted radiation particles. A conductive coating is provided between the one surface of the first semiconductor barrier and the conductive housing, and a first electrode extends from the other surface of the semiconductor barrier. A second apertured conductive housing of the second detector is coaxially aligned with the aperture of the first housing and is detachably engaged to the first housing. The second detector is formed essentially like the first except the second conductive barrier is of a thickness so as to absorb substantially all the remaining energy of one intercepted particle. A conductive base connector is formed to

detachably engage the second conductive housing for applying a reference voltage to the first and second housings and to the surfaces of the first and second barriers electrically connected to the housings. At the first electrode a potential can be established across the first barrier, and changes in the potential responsive to dissipation in the barrier of the energy of one radiation particle can be detected; while at the second electrode a potential can be established across the second barrier, and changes in potential responsive to absorption in the barrier of energy of the radiation particles can be detected.

390 (ANL-7226) CHARGE COLLECTION AND CHARGE-COLLECTION TIME IN SEMICONDUCTOR PARTICLE DETECTORS.

Hansen Niels J. (Argonne National Lab., Ill.).

June 1966. Contract W-31-109-eng-38. 27 p. Dep. mn. CFSTI $2.00 cy, $0.50 mn.

Charge collection in semiconductor junction and lithium-drifted, charged-particle detectors was investigated. Analytical solutions were obtained for the charge collected as a function of time and for the charge-collection times in terms of a parameter $\beta_0 = x_0/D$, the reduced range of the incident ionizing particle. It is assumed that the stopping power, dE/dx, of the detector is constant, that there is no loss of carriers by trapping or recombination, and that the mobilities of the carriers are constant, independent of the field strength. The implications of these simplifying assumptions are discussed. Figures are presented to illustrate the dependence of the pulse shape on the parameter β_0, and optimum operating conditions for the detectors are established. The effect on the collection time of the high fields in the ionization column is estimated.

391 (NYO-3246-7) STUDY OF SURFACE CONTOURING AS APPLIED TO SEMICONDUCTOR RADIATION DETECTORS.

Three Year Summary Report, 1963-1966. (General Electric Co., Philadelphia, Pa. Missile and Space Div.).

June 1966. Contract AT(30-1)-3246. 28 p. Dep. mn. CFSTI $2.00 cy, $0.50 mn.

A summary is presented on work accomplished on determining the usefulness of surface contouring as applied to semiconductor radiation detectors. Topics discussed are contouring and junction perfection, contoured internally amplifying detectors, and specific measurements which utilize the contoured detector.

392 SILICON CARBIDE HIGH-TEMPERATURE NEUTRON DETECTORS FOR REACTOR INSTRUMENTATION.

Ferber R. R., Hamilton G. N. (Westinghouse Electric Corp., Pittsburgh).

Nucl. Appl., 2: 246-51 (June 1966).

Miniature neutron detectors were constructed by positioning a ^{235}U layer above the sensitive surface of a shallow-junction silicon carbide diode to act as a neutron conversion coating. A series of tests were performed to verify the neutron detecting characteristics of ^{235}U-coated SiC detectors operating in a reactor environment. The reactor neutron flux was varied between 10^7 and 10^{11} n/(cm^2 sec) to determine the linearity of response of the detector the changes in reactor power. The potential of the SiC neutron detector as a flux-mapping device was demonstrated by making axial traverses of the reactor core while holding the peak flux level constant at 10^9 n/(cm^2 sec). The α-particle counting capabilities of these SiC diodes have been demonstrated to temperatures above 700°C (≈1300°F) and with integrated neutron fluxes greater than 6×10^{15} n/cm^2.

393 PHOTOGRAPHIC, GLASS, OR THERMOLUMINESCENCE DOSIMETRY.

Becker K. (Jülich Nuclear Research Establishment, Ger.).

Health Phys., 12: 955-64 (July 1966).

An attempt is made to compare advantages and disadvantages of classical photographic and modern solid-state detectors. Both advanced thermoluminescent detectors (TLD), in particular LiF and similar materials, and more recent radiophotoluminescent glasses are superior to photographic systems with regard to reliability and accuracy of the dose indication, sensitivity, dose range, energy and directional dependence of sensitivity, fading and fogging stability, reusability, fast and cheap evaluation etc. LiF seems to be superior for certain radiobiological and medical purposes because of its flat response. For routine and accident (military or civil defense) personnel dosimetry, however, a properly designed glass badge gives more information and is a remeasurable document of the exposure similar to the photographic film because the radiation effect is integrated in spite of an unlimited number of interval measurements. As an example of a possible next generation personnel dosimeter, proposals for amultiglass badge are brieflp described. It is capable to give instant information about the gamma and beta dose, the average gamma energy and the presence of neutrons. Fast neutrons can be measured by automatic counting of the number of fission fragment tracks in glass or other nonphotographic nuclear track detectors. Some practical aspects of this system are discussed.

394 FABRICATION OF LITHIUM-DRIFTED GERMANIUM PIN DETECTORS FOR HIGH-RESOLUTION GAMMA SPECTROSCOPY.

Ruge I., Eichinger P., Koepp F. (Technische Hochschule, Munich).

Kerntechnik, 8. 297-300 (July 1966). (In German).

The principle of the lithium-drift is given and the germanium-lithium system is described. The drift procedures are outlined with emphasis on the difficulties of preparation. A method for the preparation of germanium p-i-n detectors for γ spectroscopy is given.

395 INSTRUMENTATION FOR FISSION STUDIES.

Britt Harold C., Stein William E. (Los Alamos Scientific Lab., N. Mex.).

Phys. Today, 19: No. 7, 79-84 (July 1966). (LA-DC-7854).

Multiparameter experiments for similtaneously measuring the velocities of fission fragments and particles emitted by the de-exciting fragments are described. The development of semiconductor detectors for high-resolution measurements are discussed.

396 INSTRUMENTATION FOR GAMMA-RAY SPECTROSCOPY.

Kennett Terence J. (McMaster Univ., Hamilton, Ont.).

Phys. Today, 19: No. 7, 86-9 (July 1966).

The development of semiconductor detector and computer technology along with analog-to-digital converters for collection storage, and analysis of gamma spectra are reviewed. The demands placed on existing data acquisition systems for spectrometers using Ge(Li) detectors are pointed out. A brief discussion of experimental results on neutron-capture gamma studies is given for illustration. The new acquisition system designed and constructed for McMaster University is described.

397 (NYO-3510-2) BIOLOGICAL AND CLINICAL DOSIMETRY.

Annual Progress Report, July 1, 1965 - June 30, 1966. Laughlin John S. (Sloan-Kettering Inst. for Cancer Research, New York).

July 7, 1966. Contract AT(30-1)-3510. 32 p. Dep. mn. CFSTI $2.00 cy, $0.50 mn.

The microcalorimeter was employed to verify and define the extent of the energy dependence of lithium fluoride dosimeters for high energy radiation. Further comparison of calorimetric and ionometric determinations of absorbed dose were undertaken using an extrapolation chamber, and some inherent problems in this comparison were investigated. Extensive measurements of the radiation field around various isotope sources used in implant therapy were performed, and the differences between theoretical and actual dose distributions in an implant were investigated by use of a computer. This work conducted in conjunction with the Medical Physics Department of Memorial Hospital was reported at the annual meeting of the RSNA and is being prepared for publication. A total intensity calorimeter providing absolute dose measurements for the field emission electron generator was constructed and preliminary data obtained. In the area of research intended to clarify problems of standarization of dose measurement for high energy radiation, an intercomparison of the Sloan-Kettering Institute and Argonne National Laboratory calorimeters has been initiated. Measurements in the short circuit mode of p-i-n junctions indicate that only diodes with shallow lithium drifts or undrifted p-n junctions are suitable for calibrations as x-ray dosimeters due to the appearance of a large negative temperature coefficient ($\sim$1%/°C) in units drifted beyond $\sim$3 mm. RMS noise measurements and spectral (FWHM) measurements using Bi-207 and Cs-137 were made on diodes fabricated at Sloan-Kettering yielding noise levels of 40 to 90 kev. A device based upon the combination of a plastic scintillator and a pair of silicon diodes is being developed, which is expected to measure absorbed dose from high energy electrons with a sensitivity two orders of magnitude greater than an ionization chamber of equal volume.

398 (NYO-3246-8) STUDY OF SURFACE CONTOURING AS APPLIED TO SEMI-CONDUCTOR RADIATION DETECTORS.

Semiannual Report, January-June 1966.

Huth Gerald C. (General Electric Co., Philadelphia, Pa. Missile and Space Div.).

July 1966. Contract AT(30-1)-3246. 51 p. Dep. mn. CFSTI $3.00 cy, $0.50 mn.

A study of semiconductor physics and application of avalanching or internal amplification in silicon junction detectors is presented with emphasis on surface contoured detectors. The characteristics and detection capabilities of the contoured detector-tunnel diode circuit are investigated.

399 COLLECTION TIME OF SEMICONDUCTOR DETECTORS.

Tanguy J. (CEN, Saclay, France).

Onde Elec., 46: 785-94 (July-Aug. 1966). (In French).

Charge collection times were calculated for PN and PIN junctions. The rise times obtained for surface barrier detectors were quite different from the theoretical values, especially for heavy particles entering the back side of the detector. This effect will be used for pulse shape discrimination between particles of different mass.

400 DIRECT RECORDING OF PULSES FROM JUNCTION DETECTORS.

Vacher J. (CEN, Grenoble, France).

Onde Elec. 46: 795-800 (July-Aug. 1966). (In French).

A device which permits the observation of the current pulses produced in semiconductor detectors by α particles is described. Due to the rapidity of these pulses a sampling oscilloscope must be used. The amplitude of the pulses to be observed is, however, smaller than the noise level of available scopes. To eliminate this noise, a series of circuits is used to restore the mean value of the samples in digital form. These samples are then fed to a multichannel analyzer, used as a mlutiscaler which reconstructs the shape of the pulse, point by point.

401 ON THE USE OF Ge(Li) DETECTORS IN SHORT TIME MEASUREMENTS.

Miehe J. A., Ostertag E., Coche A. (Centre de Recherches Nucléaires, Strasbourg).

Onde Elec., 46: 801-3 (July-Aug. 1966). (In French).

Preliminary results of resolving time measurements performed with an experimental arrangement using one Ge(Li) detector in coincidence with one scintillation counter are given. The prompt resolution curve shows a full width at half maximum of 3 ns.

402 FAST AMPLIFIER FOR SEMICONDUCTOR DETECTORS WITH VERY HIGH COUNTING RATE CAPABILITY.

Bosshard R. (Faculté des Sciences, Orsay, France).

Onde Elec., 46: 804-18 (July-Aug. 1966). (In French).

An amplifier is described which is capable of handling very high counting rates without pile up. The amplifier has a 6 ns risetime; pulses can be clipped down to 10 ns. Gain is 300 and noise levels in the range of 30 kev (F.W.H.M. for silicon) are achieved. α particle pulses of 10^8 counts per second due to protons from an electrostatic accelerator have been correctly measured. Operation with pulsed accelerators yields satisfactory background reduction. The structure of the amplifier is given. Pile up problems are discussed both in pulsed and continuous operation. The noise characteristics were studied, taking into account the effect of amplifier and detector risetimes and clipping time.

403 RESOLVING TIME OF SEMICONDUCTOR DETECTORS.

Balland J. C., Goyot M., Pigneret J., Camueli J. J. (Institut de Physique Nucléaire, Lyon).

Onde Elec., 46: 844-52 (July-Aug. 1966) (In French).

The output of a surface barrier detector is theoretically studied taking into account the fast amplifier input impedance. The resolution time is found to be limited only by the electronic system noise. The time response of a Ge(Li) p-i-n detector is computed in the case of gamma ray detection. The pulse rise time and a triggering time (fixed threshold) variations are plotted in particular cases. The theoretical models were checked with the experimental results. The design of sophisticated electronic circuitry permits the achievement of delayed coincidence experiments with a 2 mm width p-i-n junction. A fast, low noise, high input impedance amplifier, and a fast discriminator are described. With such circuits the prompt time spectrum obtained was 1.1 ns (fwhm) with a ^{60}Co source and 2.8 ns (fwhm) with a ^{22}Na source.

404 ON A FEW PROBLEMS OF FAST ELECTRONICS CONCERNING TIME OF FLIGHT METHOD.

Szabo I. (CEN, Cadarache, France).

Onde Elec., 46: 860-3 (July-Aug. 1966). (In French).

The most specific point encountered in the fast neutron time of flight work, with the 5 Mev Van de Graaff is the definition of the measurement starting time. When using the pulsed beam of the accelerator, this time is obtained from ion bursts, by means of a pick up loop, the main characterisctic of which is the independence of the magnitude and duration fluctuations of the ion bursts. The associated particle method is also of interest, particularly when using the T(p,n)^{3}He reaction which gives a very large neutron energy range. In this case the difficulty is mainly due to the high background of the fast amplifiers associated with the solid state detector. Minor questions concerning the use and performances of time to pulse height converters, amplifiers, and fast discriminators are briefly related.

405 PROMPT RESOLUTION CURVE OBTAINED WITH A SURFACE-BARRIER SEMICONDUCTOR DETECTOR IN A COINCIDENCE EXPERIMENT.

Gorodetzky S., Merdinger J. C., Armbruster R. (CRN, Strasbourg).

Onde Elec., 46: 864-6 (July-Aug. 1966). (In French).

The measurement of the prompt resolution curve obtained with a surface-barrier semiconductor detector in an alpha-gamma coincidence experiment using a ^{211}Bi source is reported.

406 SEMICONDUCTOR DETECTORS FOR NUCLEAR SPECTROMETRY.

I. Gouding F. S. (Univ. of California, Berkeley).

Nucl. Instrum. Methods, 43: 1-54 (Aug. 1, 1966).

Background information is presented on the development of detectors. Topics discussed are semi-conductor materials and the theory of junctions necessary for an understanding of detectors, the methods of making detectors by diffusion and also by lithium drifting are detailed and the relative merits of different types of detectors are discussed, the problems associated with obtaining good energy resolution in detector systems dealing primarily with electrical noise and statistical fluctuations of the charge produced in the detector, semitheoretical treatment of the detector pulse shape considerations, and the subject of radiation damage.

407 SEMICONDUCTOR DETECTORS FOR NUCLEAR SPECTROMETRY.

II. Mayer J. W. (Hughes Research Lab., Malibu, Calif.).

Nucl. Instrum. Methods, 43: 55-64 (Aug. 1, 1966).

A general description is presented of the "position" detector and the avalanche detector including their uses and limitations. Several diverse factors concerned with detector performances are discussed, such as charge collection, energy resolution and Fano factor, energy required to form a hole-electron pair, fission fragment pulse height defect, etc. The considerations leading to the choice of materials for use in gamma-ray spectroscopy are discussed. Experimental results with CdTe are presented. A compendium of fabrication techniques is discussed with primary emphasis on diagnostic techniques, suitable to determine failure modes.

408 IMPACT OF SEMICONDUCTOR DETECTORS ON GAMMA-RAY AND ELECTRON SPECTROSCOPY.

Hollander J. M. (Univ. of California, Berkeley).

Nucl. Instrum. Methods, 43: 65-109 (Aug. 1, 1966).

A discussion is given of the basic operating characteristics and some applications of lithium-drifted silicon and germanium detectors for conversion-electron and gamma-ray spectroscopy. The following properties of Ge(Li) detector systems are reviewed: photopeak resolution; energy linearity and calibration; photopeak detection efficiency; and Compton scattering and pair production. In discussion of the relevance of these properties to the practical use of Ge(Li) and Si(Li) detector systems an attempt is made to place their advantages and disadvantages in perspective with respect to the properties of other important gamma-ray and electron spectrometer systems. Some measurements with Ge(Li) systems are discussed briefly, in the areas: decay scheme studies with radioactive isotopes; in-beam spectroscopy; low-temperature nuclear orientation; and applied gamma-ray spectroscopy (activation analysis). The advantages of simultaneous use of Si(Li) and Ge(Li) detectors for electron-gamma spectroscopy is stressed and applications for measurements of internal conversion coefficients and electron-gamma angular are reviewed.

409 COMPUTER TECHNIQUES FOR THE ANALYSIS OF GAMMA-RAY SPECTRA OBTAINED WITH NaI AND LITHIUM-ION DRIFTED GERMANIUM DETECTORS.

Heath R. L. (National Reactor Testing Station, Idaho Falls, Idaho).

Nucl. Instrum. Methods, 43: 209-29 (Aug. 1, 1966).

Methods for the analysis of complex gamma-ray spectra obained with NaI and lithium-ion drifted germanium detectors are examined in some detail. Computer programs are described that have been developed for the calculation of pulse-height distributions representing the response of detectors to monoenergetic photons. This method is based upon an interpolation between experimental spectra. Problems incidental to the analysis of gamma-ray spectra are discussed. Computer programs developed for the analysis of complex spectra are described — including linear and non-linear least squares programs for peak fitting and spectrum analysis, gain normalization and the calculation of sum spectra.

410 IMPROVEMENTS RELATING TO SOLID-STATE RADIATION DETECTORS.

Freck David Vernon, Wakefield James (Associated Electrical Industries Ltd.).

British Patent 1,038,041. Aug. 3, 1966. Filed Oct. 4, 1961.

A method is described for manufacturing a solid state p-i-n junction radiation detection apparatus consists in heating a member formed of a p-type semiconductor element having an atomic number of at least 30, preferably Ge, in a stream of Li in an inert gas formed by passing the gas over a Li-source heated to about 700°C while the Ge is heated to about 200°C to diffuse the Li into the semiconductor to form a p-n junction. A reverse electrical bias is then applied across the junction while the semiconductor is heated to about 70°C to increase the thickness of the depletion zone and form a p-i-n junction device. The device is then connected in circuit with a voltage pulse height analyzer.

411 THE ACCURATE MEASUREMENT OF THE RELATIVE EFFICIENCY OF Ge(Li) GAMMA-RAY DETECTORS IN THE ENERGY RANGE 500 to 1500 kev.

Freeman J. M., Jenkin J. G. (Atomic Energy Research Establishment, Harwell, Eng.).

Nucl. Instrum. Methods, 43: 269-77 (Aug. 1966). (AERE-R-5142).

A method is discussed for obtaining empirically the relative total-energy-peak efficiency, ϵ, over the gamma-ray energy range 500 to 1500 kev, for any given Ge(Li) detector in a specific geometry. Use is made of sources for which the relative emission rates of pairs of gamma rays are precisely known. An accuracy of about 1% in the relative efficiency curve is obtainable by use of the semi-empirical formula $\epsilon \propto \tau + \sigma A \exp(-BE)$, where τ and σ are photoelectric and Compton absorption coefficients respectively, E is the gamma-ray energy and A and B are constants determined from the gamma-ray measurements.

412 SEMICONDUCTOR AMPLIFYING RADIATION DETECTOR.

Bergstrom James W., Bockemuehl Robert R. (General Motors Corp.).

U. S. Patent 3,265,899. Aug. 9, 1966. Filed July 25, 1962.

A radiation detector means which is capable of controlling sizable currents and has a short time of response even at high frequencies is described. The design of this semiconductor amplifying radiation detector is shown and discussed.

413 (ORNL-TM-1295) TEMPERATURE DEPENDENCE OF THE RESPONSE OF LITHIUM-DRIFTED GERMANIUM DETECTORS TO GAMMA RAYS.

El-Shishini M. M., Zobel W. (Oak Ridge National Lab., Tenn.).

Sept. 1966. Contract W-7405-eng-26. 78 p. Dep. mn. CFSTI $3.00 cy, $0.75 mn.

Thesis. Submitted by M. M. El-Shishini to Univ. of Tennessee, Knoxville.

While it has generally been stated that lithium-drifted germanium detectors must be operated at liquid-nitrogen temperature for optimum performance, no systematic investigation to prove or disprove the statement has been reported. The closest experiment is that of Tavendale who, however, only investigated the resolution as a function of temperature for one low-energy gamma ray. The resolution and efficiency of two lithium-drifted germanium detectors, approximately 20-mm diameter and 3-mm thickness, were studied in the temperature range from 85 to 160°K, using gamma-ray sources whose energies varied from 279 to 1332 kev. It was found that, contrary to the results of Tavendale, the resolution of the detectors had a pronounced peak at about 105°K. The origin of this peak is not known, but is not due to changes in diode capacitance or leakage current. The efficiency of the diodes is approximately constant for each energy over the temperature range.

414 REVERSE CURRENT OF HIGH-RESISTIVITY SILICON SURFACE-BARRIER COUNTERS.

Langmann H. J., Meyer O. (Karlsruhe Nuclear Research Center, Ger.).

Nucl. Instrum. Methods, 44: 55-60 (Sept. 1966).

The reverse current of surface barrier counters made of high-resistivity n-silicon was analyzed. It was compared with theoretical calculations using measured values for the specific resistivity and the effective lifetime. It is shown that the reverse current of carefully fabricated metal-semiconductor diodes at voltages above about 5 v has mainly two components: the diffusion and the generation current. The condition of the surface is of extreme importance even in the case when surface currents are negligible. The influence of the surface current is discussed. The diffusion current is dependent on the thickness of the undepleted material of the base of the diode and to some extent on the condition of the back contact.

415 LITHIUM COMPENSATED SILICON FOCAL PLANE DETECTORS FOR ELECTRON SCATTERING SPECTROMETERS.

Dodge W. R., Coleman J. A., Domen S. R., Whitakker J. K. (National Bureau of Standards, Washington, D. C.).

Rev. Sci. Instrum., 37: 1151-9 (Sept. 1966).

In order to utilize the inherent resolving power of a double focusing, 169.8°, 76.2 cm radius of curvature magnetic spectrometer being constructed at the National Bureau of Standards for elastic and inelastic electron nuclear scattering studies, focal plane counters were needed whose dimension along the direction of momentum dispersion was 1 mm. The fabrication techniques and performance of lithium compensated silicon 1 × 1 × 60 mm radiation detectors which seem well suited for use as focal plane detectors for the above spectrometer are described. Differential and integral pulse height distributions for 10—40 Mev electrons incident on the counters are presented as a function of the temperature and bias voltage. Effects due to the finite width of the counters are discussed. A tunnel diode discriminator which provides the desired binary information to the NBS data processing system is described.

416 CALCULATED GAMMA RAY RESPONSE CHARACTERISTICS OF SEMICONDUCTOR DETECTORS.

Wainio, K. M., Knoll G. F. (Univ. of Michigan, Ann. Arbor).

Nucl. Instrum. Methods, 44: 213-23 (Otc. 1966).

A Monte Carlo computer program was used to calculate characteristics of the response of fully depleted silicon and germanium radiation detectors to monoenergetic gamma rays. Data for total absorption probability, instrinsic efficiency, escape peak efficiency and pulse height spectra are presented as functions of detector thickness and photon energy. Other parameters of interest in analyzing detector response are also given. The results of a second Monte Carlo calculation of electron migration in silicon and germanium are employed to account for the leakage of secondary electrons from the detector volume. Bremsstrahlung energy loss by electrons is also simulated. The calculations are expected to be applicable in those cases in which secondary electron energies do not exceed 2 Mev. Comparison with experiment shows good agreement within this limitation.

417 CHARGE COLLECTION TIME OF LITHIUM-COMPENSATED SILICON RADIATION DETECTORS.

Kuchly J. M., Siffert P., Coche A. (Centre de Recherches Nucléaires, Strasbourg).

Nucl. Instrum. Methods, 44: 239-44 (Oct. 1966). (In French).

The charge collection time in silicon n-i-p detectors, with depletion layers between 100 μm and 11 mm, was investigated using protons and α-particles with energies up to 6 Mev. The results are compared with calculated values and the agreement is found to be good if the detector thickness is less than 3 mm. With thicker diodes and low electric fields, the difference between observed and calculated values is attributed to trapping effects. The influence of several parameters (polarization, ratio of the depletion layer width to the range of the impinging particles, temperature variation between 300 and 80°K) is analyzed. For field strengths between 12 and 38 kv/cm, the transient time and consequently, the drift velocity are constant; the mobility is therefore inversely proportional to the field strength.

418 INEFFICIENT CHARGE COLLECTION IN SILICON SURFACE BARRIER DETECTORS.

Eisler P. (Chemical Research Lab., Port Melbourne, Australia).

Nucl. Instrum. Methods, 44: 253-60 (Oct. 1966).

A theory is developed to predict the charge collection efficiency of silicon surface barrier detectors on the assumption that trapping occurs during the transit of the charge carriers to the collecting electrodes. This mode also takes into account the effect of thermal regeneration of the charges from traps and of the amplifier time constant settings, on the charge collection efficiency. The model is experimentally tested and found wanting. The evidence, however, suggests that the trapping occurs during the plasma state of the ionization column.

419 SEMICONDUCTOR REVOLUTION IN NUCLEAR RADIATION COUNTING.

Hollander J. M., Perlman I. (Univ. of California, Berkeley).

Science, 154: 84-93 (Oct. 7, 1966).

Some applications of gamma-ray spectroscopy using semiconductor materials are discussed. Accomplishments in the areas of semiconductor spectrometers, auxiliary aspects of nuclear spectroscopy, radiochemical tracing and analysis, and particle spectroscopy are reviewed.

420 (AWRE-NR-3/66) LARGE VOLUME LITHIUM DRIFTED GERMANIUM DIODES FOR GAMMA RAY SPECTROSCOPY.

Muggleton A. H. F. (Atomic Weapons Research Establishment, Aldermaston [England]).

Oct. 1966, 20 p. Dep. mn. BIS $0.60. HMSO 3s.

Coaxial, lithium drifted germanium diodes with sensitive volumes greater than 17 cc were manufactured and tested as γ ray spectrometers. Detailed fabrication techniques are described together with details of detector performance.

421 (PG-Report-711) THE APPLICATION OF CONDENSED-STATE TECHNIQUES TO NEUTRON DOSIMETRY.

Watt D. E. (Production Group, United Kingdom Atomic Energy Authority, Annon [Scotland]).

[1966]. 22 p. (CONF-660219-1). Dep. BIS $0.80. HMSO 4s.0d.

From Society for Radiological Protection, Symposium on Dose Measurement Techniques under Development, London.

There are three general approaches to dose measurement in a neutron radiation field. A review of the various types of solid and liquid neutron dosimeters under development is presented. The application and range of sensitivity within the three general categories are considered and summarized in a table. A full list of references to relevant work is provided.

422 USE OF SEMICONDUCTOR TELESCOPES IN CHARGE AND ENERGY SPECTROMETRY OF COSMIC PARTICLES.

Engelmann J., Koch L., Meyer J. P. (Centre d'Etudes Nucléaires, Saclay, Gif-sur-Yvette, France).

pp. 419-22 of Proceedings of the Ninth International Conference on Cosmic Rays. Vol. I. Stickland A. C.(ed.). London, The Institute of Physics and The Physical Society, 1966.

Results of a theoretical and experimental study on the capabilities of silicon as a cosmic particle detector are given. The Symon theory on the fluctuations in energy loss, which is valid for a unit charge incident particle is extended to the case of a particle of any charge Z. The most probable energy losses in silicon of protons, electrons and heavy ions were computed and the results compared with values obtained at the Saclay and Orsay accelerators. Landau-Symon fluctuations on these energy losses and corresponding limitations on the Z discrimination were computed for any thickness of silicon. For example, for relativistic particles in the range of the charge of iron, these fluctuations allow a Z discrimination to three units. Data collected on 7th October 1964 by a balloon-borne telescope comprising 2-mm thick silicon detectors at 6.4 g cm^{-2} air residual thickness are given. After correction for secondaries, splash and re-entrant albedo protons, the integral intensities of primary protons and alpha particles at 46°N GM are obtained. The results 680-$\pm$ 80 protons/m^2 sterad sec 60 $\pm$ 25 alpha particles/m^2 sterad sec are in reasonable agreement with accepted values.

423 RECOMBINATION LOSSES AND THEIR INFLUENCE ON THE ENERGY RESOLVING POWER OF p-i-n DETECTORS. SOME METHODS OF MEASURING τ, μ, AND HOMOGENEITY.

Kuhn A. (Inst. of Crystal Research, Turnov. Czech.).

Czech. J. Phys., 16: 697-722 (1966). (In German).

The general solution for the recombination losses was derived and some simpler equations for the different cases of irradiation were found. The theoretical spectrum of pulses for irradiation perpendicular to the field as a result of the general solution was proved experimentally. Some new methods of measuring the lifetime and mobility in p-i-n-type counters by means of the voltage dependence of the recombination losses and the transit time and new methods of measuring the detector homogeneity were developed. Different influences on the fluctuations of recombination losses and energy resolution, surface recombination, and the voltage and temperature dependence of the pulse spectra are treated in turn.

424 SEMICONDUCTOR COUNTERS FOR NUCLEAR RADIATIONS.

Second Edition.

Dearnaley G., Northrop D. C.

New York, John Wiley and Sons, Inc., 1966, 477 p. $12.75.

The discussion of semiconductor counters for nuclear radiations includes the properties of nuclear radiations and their absorption in solids. The principles of operation of other types of detectors are summarized, and comparisons are drawn. The behavior and requirements of semiconductors such as low noise, large volume, and good absorption are considered, and semiconductor diodes, preparation and testing of detectors, and their applications are discussed. Also considered are the effects of radiation damage.

425 (ORNL-P-2467) THE PRESENT STATUS OF NEUTRON MONITORING FOR PERSONNEL PROTECTION.

Auxier J. A. (Oak Ridge National Lab., Tenn.).

[1966]. Contract W-7405-eng-26. 27 p. (SM-76-67; CONF-660807-4). Dep. mn. CFSTI $2.00 cy, $0.50 mn.

From Symposium on Neutron Monitoring for Radiological Protection, Vienna, Austria.

Developments in neutron dosimetry during the past twenty years are reviewed including: scintillation systems; cylindrical or spherical moderators with thermal neutron detectors located on the axes or at the centers; proportional counters; solid-state detectors; thermoluminescent and photoluminescent systems; liquid ionization chambers; and the use of heavy ion tracks in insulating solids. It is speculated that the most significant change in the field of radiological monitoring will be the substitution of solid-state devices for the film and nuclear emulsions in personal dosimeters, and it is foreseen that solid-state detectors and operational analyzers will be used for measurements of absorbed dose, LET, and other parameters.

426 SEMICONDUCTOR SYSTEM FOR CHARGED PARTICLES IDENTIFICATION.

Chwaszewska Janina (Inst. of Nuclear Research, Swierk, Poland), Freindl Ludwik, Karcz Waldemar, Przyborski Wincenty, Slapa Mieczyslaw.

Nukleonika, 11: 359-67 (1966).

A system consisting of two semiconductor counters of types dE/dx and E was built to separate particles from nuclear reactions. The properties of this system were checked by detection of products of reactions induced by 24.8 Mev alpha particles and 12.4 Mev deuterons on Au, C, and Ca nuclei.

427 BETA SPECTRUM SHAPE MEASUREMENTS WITH A π SEMICONDUCTOR SPECTROMETER.

Spejewski E. H. (Indiana Univ., Bloomington).

37 p. (CONF-651015-14). ORAU. Gmelin, AED-CONF-65-312-36.

From American Physical Society Meeting, Chicago.

A 4π semiconductor spectrometer employing diffused window lithium-drifted silicon detectors was constructed. It was tested by varying the parameters of the system, so as to eliminate possible sources of distortion. It was further tested by measuring the shapes of two simple β spectra (^{143}Pr and ^{139}W), and two inner-group β spectra (^{198}Au and ^{86}Rb) in coincidence with the subsequently emitted γ-rays. The γ-ray pulse, detected by a NaI well counter that envelops the beta spectrometer, supplied the gate to the 400-channel pulse-height analyzer. In all cases, the results of these measurements are in good agreement with those previously reported. The beta spectrum of the ^{170}Tm decay to the first excited level in ^{170}Yb was measured in coincidence with the 84-kev gamma-ray. The experiment was performed under the same measurement conditions used for the ^{198}Au and ^{86}Rb experiments. The spectrum exhibits a definite nonstatistical energy dependence, falling below any straight line Fermi-Kurie plot fit at low energies. The shape factor was fitted by a polynomial of the form $1+aW+b/W+cW^2$. A good fit was obtained for $a = 1.11$, $b = -0.85$, $c = -0.24$. The endpoint of this transition was determined to be 879 ± 7 kev.

428 MEASUREMENT OF HIGH-ENERGY γ-RAYS WITH Ge(Li) DETECTORS.

Berg R. E., Kashy E. (Michigan State Univ., East Lansing).

14 p. (CONF-651015-11). ORAU. Gmelin, AED-CONF-65-312.28.

From American Physical Society Meeting, Chicago.

A method of measuring the energy of high-energy gamma rays is described. It utilizes parallel capacitors as an effective energy multiplier of a pulser signal to compare unknown high-energy gamma rays to well-known low-energy standards. This method has also provided an effective tool for measuring the linearity of the energy response of Ge(Li) detectors. This response was found to be linear to better than $\pm$ 0.03% in the range 662 to 2614 kev, and better than $\pm$ 0.1% up to 6 Mev. As an example of this capacitor multiplying method the energy of the gamma ray from the 3^- excited level of ^{16}O was measured to be 6127.8 ± 1.2 kev.

429 GAMMA-RAY ANGULAR CORRELATIONS FOLLOWING NUCLEAR REACTIONS.

Broude C. (Chalk River Nuclear Labs., Ont.).

15 p. (CONF-651118-6). ORAU. Gmelin, AED-CONF-65-329-2.

From American Physical Society Meeting, Gatlinburg, Tenn.

New developments in the techniques of measuring gamma angular correlations following capture reactions are considered. The methods discussed for preparing discrete gamma-emitting states in an axially symmetric way for analysis of measured gamma correlations are via an intermediate unobserved radiation, e.g., discrete states in which the proton is not observed are axially symmetric, and via an emitted particle which is detected in an axially symmetric way with respect to the incident beam direction. The use of a gamma detector array and a Ge(Li) detector for these measurements is described.

430 MONTE-CARLO CALCULATION OF INTRINSIC DOUBLE-ESCAPE PEAK EFFICIENCY OF CYLINDRICAL LITHIUM-DRIFT GERMANIUM GAMMA RAY DETECTORS.

de Castro Faria N. V., Levesque R. J. A. (Univ, Montreal).

9 p. (CONF-660304-8). ORAU. Gmelin, AED-CONF-66-020-2.

From Tenth Scintillation and Semiconductor Counter Symposium, Washington, D. C.

Calculations were made of the intrinsic double-escape peak efficiency of cylindrical Li-Ge detectors for parallel beam of gamma rays ranging in energy from 1.5 to 10 Mev, using a computer code based on the Monte Carlo method. The detectors considered are 18 mm. in diameter with 2, 3.5, 4, 5, 8 and 10 mm. depletion depth. Comparison is made with the experimental results of Ewan and Tavendale for a 18 × 3.5 mm. detector.

431 (ORNL-3989, pp 78-88) ATOMIC AND MOLECULAR CROSS SECTIONS.

Barnett C. F., Krause M. O., Langley R. A., Ray J. A. (Oak Ridge National Lab., Tenn.).

Progress is reported on the following projects; measurements of kinetic energy of H^+ and H following dissociation of H_2 by electrons; high-energy charge-exchange cross sections; charge states of atoms following inner-shell ionization; absolute vacuum measurements; and the Atomic and Molecular Processes Information Center.

432 (ORNL-3875. pp 44-52) DETECTORS OF IONIZING PARTICLES AND RADIATION.

(Oak Ridge National Lab., Tenn.).

A report is presented on detectors of ionizing particles and radiation. Topics discussed are production and encapsulation of lithium-drifted germanium detectors, basic instrumentation in radioisotope applications, alpha scintillation detector response in gamma ray and neutron backgrounds, ion-chamber current fluctuations produced by neutron and gamma sources, PCP III ionization chamber, spherical RF_3 proportional counters, and radiation damage in cadmium sulfide and cadmium telluride.

433 VACUUM ENCAPSULATED LITHIUM-DRIFT DETECTOR TELESCOPE.

Hayashi I., Kern H. E., Rodgers J. W., Wheatley G. H. (Bell Telephone Labs., Inc., Murray Hill, N. J.).

26 p. (CONF-660304-22). ORAU. Gmelin, AED-CONF-66-020-44.

From Institute of Electrical and Electronics Engineers, Scintillation and Semiconductor Counter Symposium, Washington, D. C.

Fabrication techniques for producing lithium-drifted telescopes for space experiments were developed. High resistance grooves were obtained in lithium-drifted silicon detectors which can separate the detector into independent regions having small cross-talk as well as sharp spatial definition. This indicates the possibility of making integrated arrays of lithium-drifted detectors in a single substrate. The origin of leakage current and noise is not yet clear. The surface condition of the n-i junctions can be a contributing factor. In addition, there are indications that the surface barrier plays a prominent role in this problem. Results of environmental life tests show that the methods of detector fabrication and vacuum encapsulation are capable of providing detectors with the stability required for space experiments.

434 DIRECT READING INTRACAVITARY DOSIMETER FOR USE IN RADIUM THERAPY.

Baily Norman A., Norman Amos, Hilbert Jerald W. (Univ. of California, Los Angeles).

16 p. (CONF-660433-1). ORAU. Gmelin, AED-CONF-66-064-2.

From American Radium Society, 48th Annual Meeting, Phoenix, Ariz.

Direct dosimeter systems used in treating cancer of the vagina, cervix, or body of the uterus with intracavitary radium or external radiation are discussed. Instrumentation parameters and clinical experience are presented for silicon particle detectors operated in a mode where the carrier generation due to gamma rays interacting with the bulk silicon is measured by means of the open circuit voltage induced by these carriers. The dosimeter described is characterized by high sensitivity, rapid response, simple readout, and flexibility.

435 SILICON DIODES USED IN NEUTRON DIFFRACTION.

Gilly L., Robert A., Roult G. (CEN, Grenoble, France).

Rev. Phys. Appl., 1: 149-52 (June 1966). (In French).

Surface barrier detectors have been used in neutron diffraction: for optimum setting of the monochromator crystal and for drawing a monochromatic beam map, and as a counting monitor. A microdiode, which was located in several points of the channel used at the Siloe reactor, and a bigger diameter diode, which was mounted in a special container in the monochromatic beam, are discussed.

436 (ORNL-3973 (Vol. 2), pp 96-103) RADIATION DETECTOR STUDIES. [PART] II.

(Oak Ridge National Lab., Tenn.).

Experiments were performed to determine satisfactory amplifier and signal circuit configurations for simultaneous connection of fast and slow amplifier systems to semiconductor detectors. Time-of-flight techniques were used to measure the differential cross sections for production of neutrons resulting from the interactions of 160-Mev protons with target nuclei. As part of the analysis of these data, a study was made to determine the time response function for monoenergetic neutrons in the experimental geometry.

437 (AD-643685) NEW MATERIALS IN ENGINEERING.

Trostyanskaya E. B., Kolachev B. A., Silvestrovich S. I.,

Translation of Novye Materialy v Tekhnike, Moscow, 1962. 944 p. (FTD-HT-66-269). CFSTI $3.00 cy, $0.65 mn.

This book covers the new materials which are gaining acceptance in various engineering fields: synthetic polymers, silicate materials (glass, ceramics), metallic powders and cermets, metals and alloys (Ti and Zr alloys, Be, high-melting alloys), semiconductors and pure metals, and protective coatings. Specifications, properties, and methods and areas of their application are presented for each of the materials.

438 A SILICON PROBE DETECTOR FOR β. COUNTING AND γ-DOSIMETRY.

Parker R. P. (Royal Cancer Hospital, Belmont, Eng.).

pp. 448-57 of Med. Electron., Proc. 5th Intern. Conf. Liège. 1963. Liège, Ed. Desoer.

Advantages and disadvantages of solid-state radiation transducers for the detection and spectrometry of β-particles are considered, with special reference to the problems encountered in medical physics. A description is given of a cylindrical surface-barrier detector constructed from silicon. The detector is 10 mm long, 2.8 mm in dia, and encapsulated in stainless steel; its performance with regard to the assay of a solution of ^{32}P was examined. It was shown that a sensitivity of 0.6-0.7 cps/mμC-ml ^{32}P is possible, although in practice this performance is not attained due to the noise level, especially at body temperature. The performance of the silicon detector is shown to be competitive with that of existing G-M counters of comparable dimensions. Ways by which the performance might be improved are considered and mention is made of the application of the device to γ-dosimetric problems.

439 (AD-643601) NUCLEAR DETECTORS AND THEIR USES.

Wang Chu-hsian. Translation of Ho Wu Li T'an Ts'e Ch'i I Chi Ch'i Ying Yung, 1964.

774 p. (FTD-TT-65-552). CFSTI $3.00 cy, $0.65 mn.

An introduction to detection techniques in nuclear physics is presented. It is devided into four parts: the fundamentals of nucleonic experiments, various types of detectors, synchronous application of detectors, and reduction of experimental data.

440 (N-66-26148) AMPLIFIER FOR USE WITH SOLID STATE RADIATION DETECTORS IN SPACECRAFT APPLICATIONS.

Marshall J. H. (Jet Propulsion Lab., Pasadena, Calif.).

Oct. 30, 1964. Contract NAS7-100. 23 p. (NASA-CR-74885; JPL-TM-33-190). CFSTI $3.00 cy, $0.65 mn.

A charge-sensitive amplifier for use with solid state radiation detectors is described. Particular emphasis is placed on an analytic design approach so that optimal gain stability and resolution can be obtained for a minimum of weight and power. Measured results for an amplifier constructed for laboratory use are presented for comparison with the theoretical analysis. Presently this amplifier is being used in the second-generation alpha scattering experiment on Surveyor.

441 (AD-644024) SEMICONDUCTOR NUCLEAR PARTICLE COUNTERS.

Ryvkin S. M., Matveev O. A., Strokan N. B.

Translated from pp. 1-40 of Poluprovodnikovye Schetchiki Yadernykh Chastits, Vypusk 10, Leningradskii Dom Nauchno-Tekhnicheskoi Propagandy, 1964. 55 p. (FTD-MT-65-138). CFSTI $3.00 cy, $.65 mn.

Descriptions of n-p type counters, their basic characteristics, the energy spectra of various types of radiation, the special features of electronic equipment, and the radiation stability of detectors are presented. The possibilities of using homogeneous semiconductors as nuclear counters are considered.

442 POLARIZATION OF DIAMOND COUNTERS.

Afanaseva E. A., Agababyan E. V. (Lebedev Inst. of Physics, Moscow).

Izv. Akad. Nauk Arm. SSR, Ser. Fiz. Mat. Nauk, 18: No. 6, 80-90 (1965). (In Russian).

The polarization of a semiconductor particle is defined as the drop in the amplitude of pulses from particles, with increasing irradiation dose. Since this adversely affects the performance of the semiconductor counter, measurements were made to determine whether the field in the counter was uniform prior to the start of the irradiation and to determine the dependence of the polarization of the counter on the applied d-c voltage. Diamond was chosen because of the availability of a larger amount of published data. Five plane-parallel diamond plates were exposed in vacuum $\sim 10^{-4}$ mm Hg to alpha particles of $^{238+242}Pu$, at an intensity of approximately 10^3 particles/sec. The bombarding particles were incident on the diamond through an electrode ($^{-}$500 Å of gold). The maximum pulse, the integrating counting rate, and the pulse-height distribution were measured. The results show that the customary explanation, wherein polarization is attributed to distortion of the initially uniform field in the crystal (as a result of trapping of the electrons), is incorrect, since the field cannot be uniform in the counter before the passage of the pulse and the usual photoconductivity theory is not applicable. It is concluded that effects of dark photoconductivity and intrinsic polarization of the crystal, which are neglected in the ordinary theory, must be taken into account for a correct explanation of the phenomenon. Differences between the results of bombardment through the anode through the cathode are due to differences in the capture cross sections of the electrons and the holes. A model based on several experimental facts is proposed to explain the polarization.

443 LITHIUM DRIFT RATES AND OXYGEN CONTAMINATION IN GERMANIUM.

Fox R. J.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 367-369.

The unpredictable variations in lithium drift rates of various commercially available germanium crystals have made the production of germanium gamma-ray detectors rather difficult. Some as received germanium ingots have shown diffusion constants D reduced by nearly three decades. Because drift time varies inversely with D, the time required to drift such germanium to make large-volume detectors can become too long to be practical. The drift rates and lithium precipitation kinetics of such germanium were investigated to determine if they were

correlated. We have examined the lithium precipitation kinetics in 24 samples cut from 13 different germanium crystals covering a wide range of drift rates. These samples were cut from both zone- leveled and pulled crystals from three vendors.

444 (AD-628691) A SUMMARY OF SURFACE EFFECTS OF RADIATION ON SEMICONDUCTOR DEVICES.

Mitchell J. P., Wilson D. K. (Bell Telephone Labs., Inc., New York).

Dec. 1, 1965. Contract AF19(628)-4157. 79 p. (AFCRL-65-898). CFSTI $3o00 cy, $0.75 mn.

A review of surface physics is given as background for a discussion on the role of surfaces in the behavior of semiconductor devices. The effects of channels and surface generation-recombination on p-n junctions and transistor characteristics are discussed. The observed effects of ionizing radiation on nonpassivated, gas-filled transistors are interpreted in terms of a model in which ions formed in the gas ambient deposit charge on the device surface. The resultant surface charge buildup creates channels on the device surface which cause a decrease in h_{FE} and increase in I_{CBO}. Saturation, recovery, and the effects of dose rate and bias are also discussed. Degradation of planar passivated transistors and other devices employing SiO_2 layers due to radiation is similar to that observed for nonpassivated devices. Surface charge buildup affects the device surface and leads to degradation. The bulk of experimental evidence points to accumulation of positive charge at the SiO_2 — Si interface as the cause of degradation Several possible means of charge buildup at the interface are discussed. However, the process responsible has not, as yet, been identified. The direction of future experiments is discussed, particularly of those experiments which may yield information about the part played by radiation in positive charge accumulation at the SiO_2—Si interface.

445 (AECL-2612) PHYSICS DIVISION PROGRESS REPORT, OCTOBER 1, 1965 - DECEMBER 31, 1965.

(Atomic Energy of Canada Ltd., Chalk River [Ontario]).

58 p. (PR-P-68). Dep. mn. AECL $1.50.

The direct γ spectrum from the reaction $^{25}Mg(\alpha,n\gamma)^{28}Si$ was measured as a function of the α-particle energy and the angle of the emitted γ rays using a 25-cm^3 Li-drifted Ge γ detector. From the observed γ-ray Doppler broadenings and shifts, the lifetimes of all known levels up to 7.41 MeV in ^{28}Si are being determined. It is found that the electric quadrupole (E2) transitions from the 4+, 4.62-MeV and O+, 4.97-MeV levels to the 2+, 1.78-MeV level are enhanced by about a factor of six compared with the radiation from a single proton free to move throughout the nucleus, but the E2 transition from the 3+, 6.27-MeV level to the 1.78-MeV level is inhibited by a factor of about $^1/_{300}$. The 3-, 6.88 MeV level decays mainly by an enhanced electric octupole (E3) transition to the ground state. The evidence on the positive-parity levels of ^{28}Si tends to support a classification (SU_3) of the levels based on the amount of spatial symmetry in each level. Using the above technique with the reaction $^{26}Mg(\alpha,n\gamma)^{29}Si$, the γ decay scheme from the 3.62-MeV level in ^{29}Si was also studied. No Doppler shifts in the γ rays from this level were observed, and it is estimated that the lifetime of the 3.62-MeV level is $>3\times10^{-12}$ sec. This implies that the electric dipole transitions (E1) from the 3.62-MeV level to the 3.07- and 2.43-MeV levels are inhibited over single-particle estimates by factors of $<2\times10^{-4}$ and $<8\times10^{-5}$, respectively. These data are consistent with a collective model of ^{29}Si. Using the reaction $^{27}Al(\alpha,p)^{30}Si$, Doppler shift measurements were made, giving lifetime estimates for the lowest four excited states in ^{30}Si. A preliminary study of the electric quadrupole transition enhancements over single-particle values suggests that collective motions in this nucleus are relatively weak. The reaction $^{12}C(^{16}O,\alpha_1)^{24}Mg\bigstar(\alpha_2)^{20}Ne$ was used to study levels in ^{24}Mg. The α_1 particles were detected at 0 to the ^{16}O beam using a magnetic spectrometer with three surface-barrier detectors mounted in the focal plane. The angular distribution of the α_2 particles was measured with an array of eigth Li-drifted Si counters which could be rotated to cover a total angular range from 25 to 165°. In some measurements, one of the array counters was replaced by a 5 in. × 6 in. NaI(Tl) crystal in order to obtain coincidence γ spectra. The results established a 6+ level at 14.08 MeV, a 5- level at 14.14 MeV, and a probable 8+ level at a slightly higher energy in ^{24}Mg. Using the same technique with the reaction $^{12}C(^{12}C,\alpha_1)^{20}Ne\bigstar(\alpha_2)^{16}O$, further work was carried out on ^{20}Ne. A level at 11.99 MeV was identified as 8+ and is believed to be the fifth and last member of the ground-state band in ^{20}Ne. An experiment was carried out to measure the absolute yield of neutrons from thick targets of Be, Sn, Pb, and ^{238}U bombarded by high-energy protons. A further experiment was carried out using a 900-MeV proton beam to measure the neutron energies and angular distribution. The target was an 8 in. × 12 in. long cylinder of lead, and neutrons emerging from the target at various angles were analyzed in a time-of-flight spectrometer: a low-energy component (below 20 MeV) which was isotropic and a high-energy component (measured up to 200 MeV) mainly in a broad cone about the initial direction of the protons. The high-energy component is the expected cascade component arising from knock on nucleon-nucleon collisions, and the isotropic component is interpreted as due to neutron evaporation from the nuclei which are left highly excited by the high energy collisions. Uranium di-oxide is antiferromagnetic below 28°K; the magnetic excitations of the ordered spin structure were studied at 9°K using inelastic neutron scattering techniques. The measurements were made using the triple-axis crystal spectrometer at the C5 facility of NRU, and excitations propagating in several crystal symmetry directions were studied. The experiments show that there is a strong interaction between the magnetic excitations and certain transverse acoustic phonons. Theoretical work is in progress in an attempt to deduce the magnon-phonon coupling constant in uranium dioxide. The frequency of the normal modes of vibration in the (110) plane of potassium iodide at 92°K were determined by inelastic neutron scattering techniques. Two instruments were employed in these experiments: the phased-rotor time-of-flight machine at facility E2 of NRU and the triple-axis crystal spectrometer at C5 of NRU. With the phased-rotor instrument about 140 hf phonons propagating in

non-symmetry directions were measured. With the triple-axis spectrometer a detailed study of the phonons propagating along three high-symmetry directions was made. Interatomic force models similar to those used earlier for KBr and NaI were successfully fitted to the high-symmetry data, together with the refractive index and elastic constants of KI. The best-fitted model was then used to compute the frequencies of other normal modes. Good agreement between the calculated and observed values was obtained even for the non-symmetry direction modes. Analogous data for NaF were recorded at Harwell, and calculations carried out here have now successfully fitted these data with a similar interatomic force model.

446 SEMICONDUCTOR RADIATION DETECTOR.

Svelto V. (Laboratori CISE, Milan).

Nuovo Cimento (1), 3: Suppl., 598-612 (1965). (In Italian).

The development of semiconductor detectors in the past 5 years is briefly reviewed. Junction detectors, equivalent circuits of junction detectors, measurement of the time and resolution time, errors in the energy measurement, channel effect, energy to generate an electron-hole pair, and detectors with Li ions and their energy resolution are considered.

447 (N-66-19650) [THEORETICAL AND EXPERIMENTAL INVESTIGATION OF PARTICLE DETECTION AND PARTICLE DETECTORS TO IMPROVE EFFECTIVENESS, ACCURACY, AND DISCRIMINATION].

Status Report No. 5, Period Ending November 30, 1965. Ziock K., Ritter R. C. (Virginia Univ., Charlottesville, Dept. of Physics).

[1965]. 19 p. (NASA-CR-70719). CFSTI $3.00 cy. $0.65 mn.

New techniques, testing, and fabrication are reported in the development of Li drifted Ge particle detectors. Relative research is detailed, results of tests are given, and problem areas are cited. Advantages over planar and five sided coaxial detectors are summarized.

448 (NP-16489) UTILISATION DE DIODES DU TYPE SEMI-CONDUCTEUR COMME DETECTEURS DE NEUTRONS.

(Use of Semiconductor Diodes as Neutron Detectors).

Fabre R. (Commissariat à l'Energie Atomique, Grenoble (France). Centre d'Etudes Nucléaires).

Jan. 1965. 16 p. (In French). Dep. mn.

The advantages and disadvantages of the use of semiconductor diodes as neutron detectors were studied. The basic characteristics of diode detectors are outlined. The results show that the diodes have the following advantages. They are light and compact and can be made robust. The associated circuits occupy a small space. There is a significant counting rate with a low polarization voltage. Energy discrimination can be made and the diodes do not undergo significant damage at high counting rates. They have the disadvantage of having a low delivered amplitude so that amplification is necessary and a small sensitive zone.

449 (INR-682/I-A/PL) ELECTRONIC DEVICES FOR SEMICONDUCTOR RADIATION DETECTORS.

Dakowski Miroslaw, Konador Gerard (Institute of Nuclear Research, Warsaw [Poland]).

Dec. 1965. 24 p. Dep.

The necessity of construction of the family of charge sensitive low noise preamplifiers is described. This family allows utilization of the different properties of semiconductor detectors. Four schemes of such preamplifiers and the principle of their design are presented. The diagram of universal supply unit for detectors and preamplifiers is added.

450 CALCULATED GAMMA RAY RESPONSE CHARACTERISTICS OF SEMICONDUCTOR DETECTORS.

Wainio Kendle Murray.

Ann Arbor, Mich., Univ of Michigan, 1965. 267 p.

Thesis.

A Monte Carlo program was written to calculate gamma ray response parameters of germanium and silicon semiconductor detectors. The response parameters considered are: the total absorption probability, the intrinsic efficiency, the double escape peak efficiency, the pulse height distribution, and numerous parameters of analytic interest such as the probability for secondary electron leakage. Results were obtained for germanium and silicon detectors for several thicknesses ranging from 1 mm to 12 mm. Where direct comparisons can be made, the predictions of the program are in good agreement with experimental data. Calculations are limited to photon energies less than 2.5 MeV for the total absorption probability and less than 6 MeV for the double escape peak. These limits are set by the approximate method used to account for secondary electron leakage. Secondary electron leakage is calculated by using escape probability data generated with an electron penetration program also based on the Monte Carlo method. Predictions of this program are shown to be in good agreement with experimental data for the probability of electron transmission through slabs and for energy deposition in infinite media. Previously unavailable data for energy deposition in slabs and for the probability of electron escape from semi infinite media of germanium and silicon are reported. It is shown that the data for the average energy of transmitted electrons can be well represented by a single universal curve which holds for all energies less than 2 MeV, in analogy with the procedure commonly used to correlate transmission probabilities.

451 (UCRL-16507) MINIATURE SILICON DIODE AS A RADIATION DOSEMETER.

Raju M. R. (California Univ., Berkeley. Lawrence Radiation Lab.).

Nov. 9, 1965. Contract W-7405-eng-48. 15 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

The use of commercially available miniature silicon diodes as dosemeters, with particular reference to their application to bio-medical facilities at cyclotrons, is discussed. They are simple and convenient, and their small size makes them ideal to use as beam profile detectors or to measure depth-dose distribution of small collimated beams.

452 (JINR-P-2851) KORREKTSIYA AMPLITUDNYKH SPEKTROV S POMOSHCH'YU TSVM.

(Correction of Pulse Height Spectra With the Help of Digital Computers).

Zabiyakin G. I., Prikhod'ko V. I., Tishin V. G., Chelnokov L. P. (Joint Inst. for Nuclear Research, Dubna, USSR).

1966. 10 p. Dep. mn.

A method of correction of pulse height spectra with the help of digital computers is described.

453 (UCRL-16931) FLUCTUATIONS OF ENERGY LOSS BY HEAVY CHARGED PARTICLES IN MATTER.

Maccabee Howard David (Lawrence Radiation Lab., Univ. of California, Berkeley).

July 20, 1966. Contract W-7405-eng-48. 120 p. Dep. mn. CFSTI $4.00 cy, $0.75 mn.

Thesis.

Significant fluctuations of energy loss are expected in certain cases of the passage of fast heavy charged particles through thin absorbers. When the number of particle-electron collisions in the upper collision-loss interval is small, the energy-loss distribution is asymmetric and is characterized by a broad peak around the most probable energy loss (which is significantly less than the mean energy loss) and by a high-energy-loss tail. Several theories predict the energy-loss distribution function, but previous experimental work is incomplete with respect to verification of theory over the whole significant range of the paramaters involved. Beams of 730- and 45-MeV protons, 910-MeV helium ions, and 370-MeV π-mesons were passed through silicon semiconductor detectors of varying thicknesses, and measured the resulting energy-loss distributions. Within the limits of experimental error, there is very good agreement between the measured energy-loss distributions and those predicted by the theory of Vavilov, and good agreement on the value of the most probable energy loss. The results are tabulated and their physical and biological implications discussed.

454 USE OF SURFACE BARRIER DETECTORS FOR NEUTRON DETECTION.

Rao E. V. R. (Atomic Energy Establishment, Trombay, India).

Indian J. Pure Appl. Phys., 4: 340-3 (Sept. 1966).

Details of the procedure for fabricating surface barrier semiconductors using n-type silicon crystals are given and their characteristics analyzed. The suitability of these detectors for detecting neutrons was tested by studying the resolving power of the detectors in the casc of fission products, α particles, etc., using $U_{92}^{235}+n_0^1 \rightarrow U_{92}^{236}$ and $Li_3^6+n_0^1 \rightarrow He_2^4+H_1^3$ +4.78 Mev reactions. The potentialities of the surface barrier detectors in α-ray spectrometry and for detecting neutrons as well as heavy ions are indicated.

455 PREPARATION AND USE OF Ge (Li) GAMMA DETECTORS.

Nurmia Matti (Univ. of Helsinki), Stubb Tor.

Ann. Acad. Sci. Fenn., Ser. A VI, No. 213, 1-10 (1966).

Techniques used in the preparation of lithium-drifted germanium detectors are described. The lithium drifting process is controlled with a thermoelectric heating and cooling module. The method has yielded detectors with a thickness of up to 2.5 mm and a resolution limited by the preamplifier noise (under 5 kev FWHM). For γ spectroscopy the detectors are mounted in special liquid-air cryostats which require a refill every five days only.

456 OPTICAL CHARACTERISTICS OF SEMICONDUCTOR DETECTORS FOR NUCLEAR PARTICLES AND THEIR SURFACE PHENOMENA.

Akimov Yu K., Wang Chien-wa, Sidorov A. I., Epshtein M. I. (Joint Inst. for Nuclear Research., Dulna, USSR).

Prib. Tekh. Eksp., No. 2, 60-3 (Mar.-Apr. 1966). (In Russian).

The effective quantum η of thick silicon nuclear particle detectors illuminated from the end window was studied. A reduced η related to the surface recombinations was observed in the short-wave region. In some cases at the $\lambda = 800$ to 1000 nm range the quantum yield is close to unity. The instrument can be sued as a low inertia counter for incident quanta at a wide range of light signal amplitudes.

457 HIGH-IMPEDANCE SILICON SEMICONDUCTOR COUNTERS FOR CHARGED PARTICLES.

Maksimov Yu. S., Rodionov Yu. F., Yavlinskii Yu. N. (Inst. of Nuclear Energy, Moscow).

Prib. Tekh. Eksp., No. 2, 55-9 (Mar.-Apr. 1966). (In Russian).

A simple method is given for preparing high-impedance n-type silicon barrier counter for charged particles. Brief description is given of the recording mechanism and characteristics of a semiconductor α spectrometer for measuring the isotopic content of various α radioactive materials.

An alpha spectrometer consisting of a semiconductor detector with ~20 mm² working area and instrumentation of $\Delta E_\alpha/E_\alpha = 0.3\%$ resolving power for α particles with $E_\alpha = 6.1$ MeV is described. The device drift did not exceed 2 KeV/hr.

458 DISTRIBUTION OF IMPURITIES AND THE VARIATION OF ELECTRIC FIELD IN THE DRIFT REGION OF SILICON p-i-n DETECTORS.

Antonov A. S. (Joint Inst. for Nuclear Research, Moscow).

Soviet Phys.-Solid State (Engl. Transl.), 8: 1061-3 (Nov. 1966).

Translated from Fiz. Tverd. Tela, 8: 1325-8 (May 1966).

The concentration of impurities in the drift region of silicon p-i-n detectors was determined by measuring their capacitance as a function of reverse bias. The electric field distribution in this region was found. An analysis of the experimental results yielded a general expression for the electric field magnitude.

459 SIMPLE CRYOSTAT FOR COOLING SEMICONDUCTOR NUCLEAR RADIATION DETECTORS.

Przyborski Wincenty (Inst. of Nuclear Research, Swierk, Poland).

Nukleonika, 11: 137-8 (1966).

A cryostat was designed and constructed for cooling and heating semiconductor radiation detectors at much faster rates than previously described. The novelty of this cryostat consists of the utilization of special, very convenient in this case, thermal, mechanical, and electric properties of teflon. These properties, elasticity in particular, are preserved down to the temperature of about 200°K.

460 (AE-241) BURN-UP DETERMINATION BY HIGH RESOLUTION GAMMA SPECTROMETRY: SPECTRA FROM SLIGHTLY-IRRADIATED URANIUM AND PLUTONIUM BETWEEN 400-830 kev.

Forsyth R. S., Ronqvist N. (Aktiebolaget Atomenergi, Stockholm [Sweden]).

Aug. 1966. 23 p. Dep. mn.

Previously published studies of the short-cooled fission product spectra of irradiated uranium have been severely restricted by the poor energy resolution of the sodium iodide detectors used. In this report are presented fission product spectra of irradiated uranium and plutonium obtained by means of a lithium-drifted germanium detector. The resolved gamma peaks have been assigned to various fission products by correlation of measured energy and half-life values with published data. By simultaneous study of the spectra of two irradiated mixtures of plutonium and uranium, the possibility of using the activities of ^{103}Ru and ^{106}Ru as a measure of the relative fission rate in ^{235}U and ^{239}Pu has been briefly examined.

461 CALIBRATION OF URANIUM METAL FOILS AS STANDARDS BY AN ALPHA-GAMMA COINCIDENCE METHOD.

Nelson L. C. Jr., Zyskowski C. (Atomic Energy Commission, New Brunswick, N. J.).

Vienna, International Atomic Energy Agency, 1966, Preprint No. SM-79/23, 16 p. (CONF-661012-20). DTIE.

From IAEA Symposium on the Standardization of Radionuclides, Vienna.

Methods for the nondestructive determination of the total uranium-235 or the uranium-235 enrichment level in fabricated fuel elements, or fuel element assemblies, by gamma-ray spectrometry depend upon a comparison of the unknown unit with an almost identical, known unit or upon the destructive analysis of at least one of several units being analyzed. An alternative to this is to make corrections for the self absorption of the gamma rays in each unit analyzed. The most common method uses transmission-type absorption data to calculate the mass absorption coefficient. It has been shown that when these corrections are appreciable, errors are introduced giving results that are not consistent. In addition, when different cladding or alloying metals are used, unknown absorption factors are sometimes introduced making a correct analysis difficult. If, however, the disintegration rates and decay of the several isotopes of uranium were well known, and if the efficiency of the various detectors were known accurately, then the absorption coefficients for almost any configuration could be calculated. Studies of the decay schemes were made using electrodeposited films of National Bureau of Standards isotopic uranium standards and both a surface barrier-type semiconductor alpha detector and a lithium-drifted germanium gamma-ray detector. Estimates of the energies and relative yields of both the alpha particles and the gamma rays were made. These results were then used to set up the surface barrier detector and a sodium iodide gamma-ray detector to study and measure the alpha-gamma coincidences so that quantitative measures of the decay rates from each of the electro-deposited films could be made. The weight of uranium in each film was calculated from the decay rate, the known isotopic distributions, and the decay schemes. The self absorption of the films was assumed to be negligible. Inherently, then, the detector efficiencies were obtained from the coincidence data. The uranium metal foils of finite thickness and mockups with various cladding materials were assembled and measured to determine gamma-ray attenuation, scatter, and geometrical efficiencies of various systems. Data and figures are presented showing the alpha particle and gamma-ray spectra, their energies, and yields wherever new or improved data were determined.

462 (AE-249) OPTIMAL LINEAR FILTERS. II. PULSE TIME MEASUREMENTS IN THE PRESENCE OF NOISE.

Nygaard K. (Aktiebolaget Atomenergi, Stockholm [Sweden]).

Sept. 1966. 10 p. Dep. mn.

The problem of calculating the maximum available timing information contained in nuclear pulses in the presence of noise is solved theoretically. Practical experiments

show that the theoretical values can be obtained by very simple, but untraditional, means. An output pulse from a practical filter connected to a charge sensitive amplifier with a Ge(Li) detector showed a rise time of 30 ns and a noise level of less than 5 keV. The time jitter measured was inversely proportional to the pulse height and less than 30 ns for 10 keV pulses. With the timing filter shown solid state detectors can be classified somewhere between NaI scintillators and organic scintillators with respect to time resolution.

463 (AECL-2607) RECENT WORK WITH Ge (Li) γ-RAY SPECTROMETERS AT CHALK RIVER.

Ewan G. T., Malm H. L., Fowler I. L. (Atomic Energy of Canada Ltd., Chalk River [Ontario]).

July 1966. 58 p. (CONF-660625-3). Dep. mn. AECL $1.50.

From IAEA Panel Meeting, Vienna.

A review is given of some recent work with Ge(Li) detectors at Chalk River. The development and properties of large volume coaxial detectors are discussed briefly and typical results of measurements of the resolution, efficiency, and peak-to-total ratios for these detectors are presented. Results of performance tests on encapsulated detectors are summarized. Some of the factors affecting the pulse shape from Ge(Li). detectors are considered and time distribution measurements from coaxial detectors are shown. These detectors are being used in a Ge(Li)—Ge(Li) γ—γ coincidence arrangement and typical results are given. The use of the detectors in the experimental program at Chalk River is discussed briefly, with results from a few experiments chosen to illustrate their different applications. These include their use in experiments on nuclear decay schemes, γ rays from nuclear reactions, neutron capture γ rays, resonance γ-ray scattering, muonic x rays, and experiments associated with nuclear reactor development.

464 (BNL-10683) PRODUCTION OF LITHIUM DRIFTED GERMANIUM DETECTORS BY AC DRIFT.

Jamini M. A. (Brookhaven National Lab., Upton, N. Y.).

[1966]. Contract AT-30-2-GEN-16. 17 p. (CONF-661020-2). Dep. mn. CFSTI $1.00 cy, $0.50 mn.

From 13th Annual Nuclear Science Symposium, Boston, Mass.

Thick planar detectors were produced by ac drifting. Lithium is diffused on two opposite surfaces of a p-germanium block, thus producing an n^+pn^+ structure with two diodes back to back. Drift then proceeds from the two surfaces on alternate half cycles of the ac field. When the two compensated regions meet, one n-contact is removed and replaced by a p-contact. Any remaining uncompensated regions are then compensated by a dc drift. The p-contact is produced by diffusing gallium-indium eutectic at 400°C. By this technique it is possible to drift as deep at 2 cm and thus to produce a large volume detector with low capacitance.

465 USE OF SEMICONDUCTOR DETECTORS FOR MEASUREMENT OF NEUTRON YIELD.

Kim Ki-Hyon, Bartl Walter (Atomic Energy Research Inst., Seoul).

Acta Phys. Austr., 23; 51-4 (1066). (In German).

The neutron yield of a neutron generator at various acceleration voltages was measured using a semiconductor. The α radiation simultaneously emitted in the reaction $^3H(d,n)^4He$ was also measured with a semiconductor. The results were compared with those obtained with a conventional Long counter. The results showed an increase in the counting rate in the Long counter with respect to the α measurement. The origin of these discrepancies is discussed.

466 SURFACE BARRIER DETECTORS OF GALLIUM ARSENIDE.

Schuster P., Getoff N. (Institut für Radiumforschung und Kernphysik, Vienna).

Acta Phys. Austr., 23: 387-92 (1966). (In German).

The preparation of surface-barrier detectors of gallium arsenide is described. Measurements made with the detector show that good surface-barrier detectors can be prepared from gallium arsenide as long as a material with mean specific resistance and high charge carrier lifetime is available.

467 PRODUCTION OF COUNTER DIODES ACCORDING TO THE LITHIUM-DRIFT METHOD.

Braun H. (Institut für Radiumforschung und Kernphysik, Vienna).

Acta Phys. Austr., 23: 393-6 (1966). (In German).

A method for the preparation of β counters from Si using the Li drift method is described. Because of the low cost the apparatus is especially suitable for laboratory applications. The principle of the Li drift method is given.

468 RECORDING OF X RADIATION USING SEMICONDUCTOR LAYERS WITH HIGH-VOLTAGE PHOTOELECTROMOTIVE FORCE.

Tsukerman V. G., Vainshtein E. E., Lyubin V. M. (Inst. of Inorganic Chemistry, Novosibirsk, USSR).

Prib. Tekh. Eksp., No. 3, 205-7 (May-June 1966). (In Russian).

The effect of ionizing radiation (particularly x radiation) on the size of the hf photoelectromotive force of a series of semiconductor layers was investigated. The effect of the nature of the surrounding gas and of the intensity of the x ray and visual light on the sensitivity of the layer to radiation was established. The time for the attainment of stationary values of the photoelectromotive force does not exceed a tenth of a second.

469 KERNPHYSIKALISCHE MESSVERFAHREN ZUM NACHWEIS FUER TEILCHEN UND QUANTEN.

(Nuclear Physics Measuring Methods for the Detection of Particles and Quanta).

Neuert Hugo.

Karlsruhe, Ger., Verlag G. Braun, 1966. 542 p.

A detailed description is given of the different types of detectors used in the study of radioactivity, cosmic radiation, physics of sub-atomic particles, and x rays. Their technical construction and uses are discussed. The radiation detection instruments considered are ionization chambers, proportional counters, emitting counters, spark counters and chambers, Cherenkov counters, scintillation counters, semiconductor counters, detectors for special purposes, and neutron counters. Counting statistics and counter circuits are also discussed. An extensive bibliography follows each subject.

470 SEMICONDUCTOR AVALANCHE DETECTOR FOR HIGH GAMMA INTENSITIES.

Bernt H., Keil G., Ruge I. (Technische Hochschule, Munich).

Vienna, International Atomic Energy Agency, 1966, Preprint No. SM-78/42, 18 p. (CONF-661005-7). DTIE.

From Symposium on Solid-State and Chemical Radiation Dosimetry, Vienna.

A silicon radiation detector is described that uses avalanche multiplication of carriers similar to a G.M. counter. The detector is a p-n diode operated in the reverse direction beyond its breakdown.

471 SILICON PN JUNCTION SURFACE BARRIER DETECTORS AND THEIR APPLICATION TO THE DOSIMETRY OF X- AND γ-RAY BEAMS.

Parker R. P., Morley B. J. (Inst. of Cancer Research, Sutton, Eng.).

Vienna, International Atomic Energy Agency, 1966, Preprint No. SM-78/40. 20 p. (CONF- 661005-16). DTIE.

From Symposium on Solid-State and Chemical Radiation Dosimetry, Vienna.

The recent availability of very pure semiconductors such as silicon permits the construction of solid-state ionization chambers. The basic mechanism of such a device will be briefly described, particularly in relation to its gas-filled counterpart. On exposure to ionizing radiation the sizes of the charged pulses formed in the device are proportional to the energy lost in the silicon, and so the pulses may either be treated individually or d-c operation is possible. The theory of both these modes will be discussed and the results compared with experiment. Under pulse operation a sensitive volume of only 0.04 ml permits dose-rate determination down to 10^{-5} rad/min and a study was made of the response to various γ-emitting radioisotopes. The possibility of using the device under approximate wavelength independent conditions will be discussed and the effect of ambient temperature considered. When d-c measurements are carried out under applied bias, difficulty is experienced due to the leakage current, and it will be shown that the device is best used without bias provided long minority carrier lifetime material is used. Here the photovoltaic effect is utilized and the current which flows, when measured under short-circuit conditions, is a linear function of dose rate. Alternatively the voltage generated across the junction may be determined by a high input impedance circuit in which case there is a logarithmic response over a restricted dose-rate range. The current measurements are temperature independent between 0° and 50°C but this is not true for the voltage measurements. Consideration will be given to the wavelength dependence of the device from both a theoretical and experimental standpoint and data will be presented pertaining to the effect of radiation damage in relation to the various modes of use. Comments are presented on our practical experience with these devices and a comparison will be made with other dosimetric systems suitable for *in vitro* studies. The silicon devices are very useful as dose-rate meters in situations where their high sensitivity, small size and ruggedness are advantageous.

472 (EUR 3063.e) ELECTRONIC INSTRUMENTS FOR RADIATION DETECTORS AND SYSTEMS.

Benoit R., De Blust E., Isabella L., Mandl V., Melandrone G. (European Atomic Energy Community, Ispra (Italy). Joint Nuclear Research Center).

1966. 34 p. Dep. mn.

Electronics instruments developed in the Nuclear Chemistry Laboratory of the Chemistry Department are described. They include low-noise amplifiers for solid state detectors and gridded ionization chambers, fast electronics, power systems for the construction of lithium drifted semiconductors and automatic controls for activation analysis and radiochemical separations.

473 (UCRL-14930-T) DETERMINATION OF CHARGE SENSITIVITY OF A TUNNEL DIODE VOLTAGE THRESHOLD DISCRIMINATOR USED IN TIME DIFFERENCE MEASUREMENTS.

Compton P. D. Jr., Johnson W. A. (California Univ., Livermore. Lawrence Radiation Lab.).

Oct. 10, 1966. Contract W-7405-eng-48. 30 p. (CONF-661020-1). Dep. mn. CFSTI $2.00 cy, $0.50 mn.

From 13th Annual Nuclear Science Symposium, Boston, Mass.

The results of an investigation of the delay time variation of a tunnel diode (TD) threshold sensing discriminator are presented. These variations are a function of the square root of the input signal risetime and are accountable in terms of a charge sensitivity of the tunnel diode. A distinction is made between the charge sensitivity due to continuously rising signals and that due to short, low-energy pulses. A simple experimental method ued for measuring the delay time variation as a function of the input signal risetime is described. The method is quite general and may be applied to any type of threshold

discriminator. A theoretical model of the tunnel diode operating in the discriminator mode is developed. An equivalent circuit approach is used in this development by considering three phases of operation; before the TD reaches threshold, during the actual TD switching, and after the TD has fired. The model agrees with the experimental data, and it is concluded that the charge sensitivity model is a usefully valid concept which is applicable to the design and prediction of discriminator time-delay characteristics.

474 (ORO-2401-8) UTILIZATION OF A LOW LEVEL WHOLE BODY COUNTING FACILITY IN THE MEASUREMENT OF ELECTROLYTE COMPOSITION AND METABOLISM IN MAN.

Progress Report, 1966.

Heyssel R. M., Brill A. B., Denman E. D. (Vanderbilt Univ., Nashville, Tenn.).

Oct. 28, 1966. Contract AT(40-1)-2401. 70 p. Dep. mn. CFSTI $3.00 cy, $0.75 mn.

The design and calibration of a whole-body scanner and applications of computer methods in analysis of γ spectra data are described. Applications of the whole-body counter reported include measurements of the whole-body retention of ^{132}Cs in man following ingestion of approximately 2 μc; the simultaneous measurements of body water (using tritiated water), extracellular space (using ^{82}Br); body sodium (using ^{24}Na or ^{22}Na), and body potassium (using ^{42}K) in patients by computer analysis of the γ spectra obtained from the whole-body, plasma, and excretion products; and the determination of blood volume and extracellular fluid volumes in the steady state, non-steady state, and in shocked dogs using ^{35} S, ^{131}I-serum albumin, and ^{51}Cr as tracers. The levels of circulating renin and angiotensin were determined by an indirect method that consists of scintillation measurement of the clearance of subcutaneously injected ^{125}I Na at separate forearm sites when administered with and without angiotensin as compared with the control side, and the subsequent measurement of plasma renin activity. Progress is reported in the evaluation of an instrument designed for measuring bone mineral *in vivo*. The instrument consists of a collimated ^{125}I source of x rays, a holder for the patient's finger, a collimated scintillation detector, and a drive mechanism to permit scanning across the bone. A scintillation detector system consisting of three $2 \times 2 \times 1$ inch NaI crystal and photomultiplier assemblies arranged in an adjustable arc to fit the neck was designed for use in counting low levels of thyroidal ^{131}I. Applications in studies of the effect of lead poisoning on thyroid function in man showed that chronic lead intoxication causes a decrease in thyroidal ^{131}I uptake. The injection of ^{55} Fe and ^{59}Fe in the same individual on the same day gave additional evidence of a circadian rhythm in plasma iron turnover. A method was developed for the simultaneous liquid scintillation counting of ^{55}Fe and ^{59}Fe in biological samples. Progress is reported in the development of tracer methods using ^{55}Fe, ^{59}Fe, ^{51}Cr-labeled red blood cells, and ^{32}P for the diagnosis of iron deficiency and iron deficiency anemia, measurements on the effects of androgens on erythropoiesis, and ferro-kinetic studies on humans. Progress is reported in the radiological dosimetry of ^{75}Se and studies on the effects of age on the distribution of ^{75}Se-methionine in rat tissues. The design and calibration of a lithium-drifted germanium semiconductor detector for use in the analysis of γ spectra are described.

475 RELIABILITY OF COMPONENTS UNDER RADIATION STRESS. PROBLEMS TO BE SOLVED AND SOME EXPERIMENTAL RESULTS.

Blin A., D'Harcourt A., Le Ber J. (CEA, Paris).

Onde Elect., 46: 945-54 (Sept. 1966). (In French).

A method is described which permits the prediction of reliability of electronic circuits and components under radiation stress when the statistical behavior of each component entering the circuit is known. Results obtained by the statistical treatment are given for transistors, resistors, capacitors, condensers, and semiconductors.

476 (AD-641164) RADIATION EFFECTS ON INSULATED GATE FIELD EFFECT (MOS) INTEGRATED CIRCUITS.

Quarterly Report No. 4, April 1 - June 30, 1966.

Long D. M. (Martin Co., Baltimore, Md.).

Oct. 1966. Contract DA-28-043-AMC-01520(E). 85 p. (MND-3264-4; ECOM-01520-4). CFSTI $3.00 cy, $0.75 mn.

Activities in a program to determine the mechanism and extent of the transient and permanent effects of nuclear radiation on insulated-gate field effect metal-oxide-semiconductor (MOS) integrated circuits are reported. The results of the past year's investigation of transient response phenomena in custom-built and commercial MOS transistors and commercial MOS integrated circuits are discussed. It was found that the transient gate current produced in MOS transistors by pulsed ionizing radiation is composed of current leakage from the gate lead to the package through the ionized encapsulated gas, and photovoltaic displacement current resulting from the motion of induced carriers in the transverse electric field beneath the gate oxide. The mechanisms produce a larger response for n-depletion transistors than for p-enhancement transistors. Mechanisms of generally lesser importance include photocurrents of protective gate diodes, gate-drain interaction leakage currents, and variations in gate current due to irradiation history. Charge scattering from the device leads is small, and ionization-induced leakage through the gate oxide is negligible. The components of transient drain current are the photocurrent of the drain-substrate p-n junction, the drain current produced by the g_m amplification of threshold voltage changes (occurs with or without $R_g = O$), and secondary drain current produced by the g_m amplification of gate voltage changes (occurs only for large R_g values). Transient changes in threshold voltage are common for n-depletion devices, and relatively uncommon for p-enhancement devices. Devices of a given type can differ widely in the magnitude of ΔV_T. MOS integrated circuits which are presently available have transient failure thresholds in the range of 1 to 100r for radiation pulse widths less than the resistance-current (RC) time constants of the circuits (typically μ sec). Both substrate currents, which produce turn-on, and secondary

drain currents, which produce turn-off, are instrumental in causing failure in microcircuits. Latch-up or long term recovery processes (greater than a few μ sec) were not observed on any of the circuits tested. It appears that the sensitivity of MOS integrated circuits to transient ionizing radiation could be improved by dielectric substrate isolation, and use of evacuated (rather than gasfilled) packages.

477 (AD-634488) INVESTIGATION OF TRANSIENT RADIATION DAMAGE IN SEMICONDUCTOR MATERIALS.

Quarterly Progress Report No. 2, January 1, Mar. 31, 1966.

Corelli John C., Frederickson A. Robb., Westhead James W. (Rensselaer Polytechnic Inst., Troy., N. Y.).

June 1966. Contract DA-28-043-AMC-01788(E). 25 p. (ECOM-01788-2). CFSTI $1.00 cy, $0.50 mn.

Transient radiation effects induced in Si irradiated at 122°K and 300°K by pulses of 48 MeV electrons were studied using the transient response of resistivity and Hall effect voltages as the measuring probes. Results are given for one ohm-cm P-doped n-type Si and a 100 ohm-cm B-doped p-type sample. In the case of one ohm-cm Si the results clearly show the actual buildup of excess electrons produced by ionization during the time the electron pulse is irradiating the sample. Moreover, the shape of the pulse during buildup is independent of temperature so long as the electron beam pulse is kept constant. Dependence of the number of injected excess carriers on the ionization intensity (total integrated electron flux in the pulse) was found to be linear up to excess carrier concentrations of $10^{17}/cm^3$. The lifetime is found to increase linearly with injection implying that the recombination may be dominated by one defect energy level. The significant "damage mechanism" can be understood by considering only the transient ionization effects, since atomic displacements effects are small and insignificant.

478 (AD-630701) INVESTIGATION OF TRANSIENT RADIATION DAMAGE IN SEMICONDUCTOR MATERIALS.

Final Report, February 1, 1963 - September 30, 1965.

Corelli John C., Frederickson Arthur R., Westhead James W., Lichtenstein Roland M., Willard H. James Jr. (Rensselaer Polytechnic Inst., Troy, N. Y.).

Mar. 1966. Contract DA-36-039-AMC-02165(E). 46 p. CFSTI $2.00 cy, $0.50 mn.

A contactless method was developed for measuring induced photoconductivity in silicon. The method was used to search for transient radiation damage effects in silicon specimens irradiated by short bursts of high-energy electrons. The investigation showed that transient radiation damage in silicon at room temperature is a minor effect when compared with permanent damage if the damage is assessed by way of the decay time of induced photoconductivity. No transient damage (as opposed to permanent damage) survives to 1.3 milliseconds after the instant when the damage is produced. Transient radiation damage experiments indicate that in p-type silicon the transient Hall and conductivity voltages decay in about 20 to 50 microseconds. Relatively long saturation times (about 10 to 100 microseconds) are observed in the transient Hall and conductivity voltage following an electron burst. The saturation time decreases with dose accumulation and also decreases as the irradiation temperature of the sample is decreased. Very similar effects also are observed in n-type silicon samples. In both n- and p-type silicon the Hall and conductivity voltages decay with about the same time constant.

479 (EUR 3071.d) DIE MESSUNG DES ABBRANDZUSTANDES KUGELFOERMIGER BRENNELEMENTE MIT HILFE EINES HOCHAUFLOESENDEN HALBLEITERGAMMASPEKTROMETERS.

(Burnup Measurement on Spherical Fuel-Elements by Means of a High-Resolution Semiconductor Gamma Spectrometer).

Bücker H. (Brown Boveri/Krupp Reaktorbau G.m.b.H., Düsseldorf (West Germany). Kernforschungsanlage, Jülich (West Germany)).

Aug. 1966. 38 p. Dep. mn.

A description is given of a method of measuring the burnup level of spherical fuel elements. A non-destructive and rapid burnup determination is obtained by means of γ spectrometry. The measuring apparatus is a high-resolution photo-peak γ spectrometer equipped with a Li-drifted Ge semiconductor detector. The ^{137}Cs photoline at 662 keV serves as a reference line for measurement. Its intensity provides a measurement of the burnup. The first measurements were carried out on a fuel sample.

480 (BMwF - FBK - 66 - 24) SILIZIUM-OBERFLAECHENSPERRSCHICHT-DETEKTOREN, HERSTELLUNG, TESTMETHODEN, EIGENSCHAFTEN UND EINIGE ANWENDUNGEN.

(Silicon Surface Barrier Detectors: Fabrication, Test Methods, Properties, and Some Applications).

Andersson-Lindstroem G., Zausig B. (Hamburg Univ. (West Germany). I. Institut für Experimentalphysik).

July 1966. 50 p. (In German). Dep. mn.

Investigations were performed on fabrication methods for silicon surface barrier detectors and their correlated properties. The resulting technique currently being applied is presented. The method is based on the use of high resistivity silicon material (10.000 — 30.000 Ωcm). Some special tests and results for several properties are given in detail and examples of application in nuclear experiments are described.

481 (UCRL-14926) U-JUNCTION Ge(Li) DRIFT DETECTORS.

Armantrout Guy A. (California Univ., Livermore. Lawrence Radiation Lab.).

Oct. 15, 1966. Contract W-7405-eng-48. 12 p. (CONF-661020-6). Dep. mn. CFSTI $3.00 cy, $0.65 mn.

From 13th Annual Nuclear Science Symposium, Boston, Mass.

A U-junction drifting configuration was used which permist the fabrication of large volume, low-capacitance detectors in much less time than previously required. For example, it is now possible, with good material, to fabricate in approximately one week an 18-cm^3 diode with 3-pF capacitance. The U-junction structure is partially wrapped around three sides of a parallelepiped of the desired dimensions. The drifting then proceeds toward the remaining side of the detector. At the completion of the drift, only a narrow strip of P-type material remains along one edge. The portion of the lithium junction used for the rapid drift is now lapped off, leaving the low-capitance junction structure for the collection of the charge. No further processing is required, and the diode is ready for mounting. Initial tests on two 6-cm^3 U-junction detectors indicate that the diodes have the expected capacitance of about 2 pF and a relatively thin window. A resolution of 705 eV for the 60-keV gamma ray of ^{241}Am was thus far obtained, and the measured Fano factor of 0.157 is consistent with the currently accepted value.

482 (UCRL-17149) HIGH-RESOLUTION BETA- AND GAMMA-RAY SPECTROMETER.

Elad Emanuel, Nakamura Michiyuki (California Univ., Berkeley. Lawrence Radiation Lab.).

Sept. 27, 1966. Contract W-7405-eng-48. 23 p. (CONF-661020-10). Dep. mn. CFSTI $3.00 cy, $0.65 mn.

From 13th Annual Nuclear Science Symposium, Boston, Mass.

A high-resolution semiconductor beta and gamma spectrometer is described. The spectrometer consists of a silicon or germanium detector, low-noise field-effect transistor pre-amplifier, and a linear amplifier. The requirements for the different sections for high-resolution performance are outlined.

483 ENCAPSULATED LITHIUM DRIFTED GERMANIUM DIODE FOR GAMMA RAY SPECTROMETRY.

Gibbons P. E., Howes J. H., Pyrah S. (Atomic Energy Research Establishment, Harwell, Eng.).

Nucl. Instrum. Methods, 45: 322-4 (1966).

The design and performance of an encapsulated Ge (Li) diode gamma spectrometer are discussed with emphasis on the encapsulation method. The spectrum of ^{153}Gd obtained with the diode is presented also.

484 SOME APPLICATIONS OF SEMICONDUCTOR COUNTERS IN HIGH ENERGY PHYSICS.

Akimov Yu. K. (Joint Inst. for Nuclear Research, Dubna, USSR).

Nucl. Instrum. Methods, 45: 173-7 (Nov.-Dec. 1966).

The small size of semiconductor counters is a considerable limitation for their application to detect high energy particles. However, in experiments on accelerators there is a certain number of special problems where semiconductor counters can be rather effectively used. In particular, good spectrometric properties, nonsensitivity to the magnetic field and the compactness of the semiconductor counter allow to use it for identifying slow protons and deuterons in elastic pp and pd scatterings. In our case the target was bombarded with the 10 GeV internal proton beam of the proton synchrotron of the Joint Institute for Nuclear Research. Semiconductor counters operating in the photodiode regime were applied to measure particle fluxes in other investigations carried out on the synchrocyclotron. Optical characteristics of lithium-drifted silicon counters of the surface-barrier type were studied. Being rather perfect fast photodiodes, the counters can be used also for determination of the spark coordinates in a spark chamber.

485 SETUP FOR MEASURING SENSITIVITY-FREQUENCY CHARACTERISTICS OF PHOTODETECTORS.

Khaykin N. Sh.

Prib. Tekh. Eksp., No. 3, 172-4 (1966). (In Russian).

A method of undesirable-pickup suppression and a setup for measuring sensitivity-frequency characteristics of radiation detectors (photodiodes, photomultipliers) are described. Essentially, the radiation flux modulated by an electrooptical element is once more modulated at $\Omega \geqslant (2—3)\,\Delta\omega$, where $\Delta\omega$ is the passband width of an analyzer that records the photoresponse of the test detector; the second modulation is accomplished by a mechanical (60-kc) modulator. An experimental setup included a Kerr cell and operated satisfactorily within 1 to 120 Mc. It was used for testing a few photodiodes (1 to 35 Mc) and a photomultiplier (1 to 80 Mc).

486 A HIGH-RESOLUTION γ SPECTROMETER WITH Ge(Li) DETECTOR AND FIELD-EFFECT TRANSISTOR PREAMPLIFIER.

Kalbitzer S., Melzer W., Kemmer J., Walther P. (Max Planck-Institut für Kernphysik, Heidelberg).

Z. Naturforsch., 21a: 1178-83 (July 1966). (In German).

The preparation of a high-resolution Ge(Li) detector by different drift methods and the diagram of a fast preamplifier with a field-effect transistor in the input stage are described. The radiation of ^{60}Co was resolved with a 3-keV half value width. A value of 0.20 to 0.25 was given for the Fano factor in the energy range from 300 to 2750 keV.

487 ON THE FORMATION OF SURFACE BARRIER LAYERS OF SILICON DETECTORS.

Bader R., Kalbitzer S. (Max Planck-Institut für Kernphysik, Heidelberg).

Z. Naturforsch., 21a: 1072-4 (July 1966). (In German).

The processes for the formation of surface barrier layers on n-silicon treated with gold vapor was investigated. The thickness of the gold layer, temperature, and oxigen pressure were varied. The delay time between the moment of oxygen introduction and the formation of the barrier layer was measured in all cases. The activation energy of the oxygen diffusion was 0.85 ± 0.04 ev. The delay time is squarely dependent on the gold layer thickness and also shows a pressure dependence.

488 A COMPUTER-CONTROLLED 4096-CHANNEL SEMICONDUCTOR DETECTOR SYSTEM WITH STABILIZATION.

Swierkowski Stefan P., Lafore Robert W. (Univ. of California, Berkeley).

pp. 255-8 of Proceedings of the National Electronics Conference. Vol. XXII. Chicago, National Electronics Conference, Inc., 1966. (UCRL-16814[Rev.]).

The construction and operation of the hardware and software constituting a 4096-channel bistalbilized pulse-height analyzer, data processing, and control system are described. The system was designed for studying mesic x-ray spectra at the 184-inch cyclotron.

489 GASEOUS TARGET SCATTERING CHAMBER OF SMALL VOLUME WITH A DIFFERENTIAL PUMPING SYSTEM.

Gobert G., Mani G. S., Sadeghi A. (Centre d'Etudes Nucléaires, Saclay, France).

Nucl. Instrum. Methods, 42: 250-7 (July 1966). (In French).

An accurate small volume gas scattering chamber installed on the Van de Graaff tandem at C.E.N. Saclay is described. Detailed design factors for the differential pumping system are given. The chamber can have up to 32 detectors. The associated electronics is briefly described. Some experimental data are presented together with a short description of the solid angle calculation.

490 AVERAGE ENERGY PER PAIR IN p-TYPE SILICON WITH 5 MeV ALPHA PARTICLES.

Buys W. L. (Univ. of Ghent).

Nucl. Instrum. Methods, 42: 329-30 (July 1966).

The value of the average energy required per hole-electron pair in p-type silicon was investigated with a diffused junction detector, having a net surface of 5 mm^2, 2 μm diffusion depth and made from 10 to 20 $k\Omega \cdot cm$ p-type silicon and with plane thin (^{233}U, ^{244}Cm) alpha sources.

491 SOLID-STATE DEVICES AS DETECTORS OF COHERENT HIGH-ENERGY INTERACTIONS.

Lander R. L. (Univ. of California, San Diego, La Jolla), Mehlhop W. A. W., Lubatti H. J., Schnurmacher G. L.

Nucl. Instrum. Methods, 42: 261-8 (July 1966). (UCRL-16603).

The possibility of using a solid-state radiation detector as a target is considered in order that the recoil energy of the struck nucleus, as well as any charged nuclear fragments, may be measured. In this way, one can discriminate against those interactions leading of breakup of the nucleus (noncoherent) and can also measure the momentum transfer to the nucleus with considerably better precision than might otherwise be possible. As a first test of such a detector, the distribution in energy deposited in a 1-mm-thick lithium-drifted silicon detector when 730-MeV protons are scattered at small angles by nuclei in the detector were observed. When the protons traverse the silicon without interacting, the characteristic Landau energy-loss distribution is observed. When the protons scatter at small angles, their energies and path lengths in the silicon are practically unchanged. The recoil silicon nucleus, however, deposits most of its kinetic energy, T_{Si}. This energy is added to that from the proton, so the observed energy distribution in the silicon detector is shifted upwards by T_{Si} when the proton scatters. This second peak was observed at proton scattering angles of 4.3, 5.4, and 6.3 deg in the laboratory system and confirm the predicted energy shift. The potential applications of this technique are discussed.

492 SCATTERING CHAMBER FOR USE WITH COOLED LARGE AREA LITHIUM-COMPENSATED SILICON RADIATION DETECTORS.

Dodge W. R., Coleman J. A., Domen S. R. (National Bureau of Standards, Washington, D. C.).

Nucl. Instrum. Methods, 42: 181-7 (July 1966).

A scattering chamber designed to be used with large area, lithium-compensated silicon radiation detectors was constructed. The chamber has provision for cooling a circular array of detectors to 77°K to achieve shorter charge collection time and better energy resolution than could be obtained with room temperature operation. The apparatus was designed to be used with the NBS 180-MeV synchrotron in photoproton experiments in the 2 to 35 MeV proton energy interval.

493 LOW-ENERGY SPECTRA MEASURED WITH 0.7-keV RESOLUTION.

Elad E., Nakamura M. (Univ. of California, Berkeley).

Contract W-7405-eng-48. Nucl. Instrum. Methods, 42: 315-17 (July 1966). (UCRL-16760).

An improved version of a FET amplifying stage discussed by Elad (Nucl. Instr. and Meth. 37, 327 (1965)) is described. It was used as an input stage of a low-noise preamplifier for semiconductor radiation detectors. The elimination of several noise sources has made possible a spectrometer resolution of 0.7 keV, compared with 1.1 keV resolution achieved with the basic circuit.

494 SEMICONDUCTOR DETECTOR METHOD.

Miller G. L., Wagner S. E. (U. S. Atomic Energy Commission).

U. S. Patent 3,272,668. Sept. 1966.

This patent relates to drifted semiconductor radiation detectors. A method is described by which lithium is drifted into a lithium alloyed p-doped silicon crystal by reverse biasing the crystal with a constant wattage supply while Joule heating generated by the reverse biasing is removed by a vapor phase coolant. In one embodiment, coolant is maintained near its boiling point adjacent to the crystal surface whereby a deep lithium drifting is accomplished efficiently and expeditiously.

495 (AD-641559) EVALUATION OF THE RESPONSE OF SILICON DIODE DOSIMETERS TO FAST NEUTRONS.

Vega Eloy P., Kilminster David T., McNeilly John H. (Army Nuclear Defense Lab., Edgewood Arsenal, Md.).

Oct. 1966. 44 p. (NDL-TM-31). CFSTI $3.00 cy, $0.65 mn.

Conductivity-modulated, silicon p-n junctions of two base widths (10- and 50-mil) were exposed to a burst of fast neutrons. High-level lifetime, reverse-recovery lifetime, and forward voltage at four constant current levels were correlated with fast neutron kerma as measured by threshold detectors. This correlation showed that the sensitivity of the diodes varied with respect to kerma. The curves of high-level lifetime versus kerma and reverse-recovery lifetime versus kerma have two changes in slope, at 10^5 ergs/g and at 10^6 ergs/g. The 10-mil diodes exhibited excellent reproductibility for both lifetime measurements; however, only 55 percent of the forward-voltage measurements were within ± 10 percent of the average. The lifetime measurements of the 50-mil diodes were very poor (only 31 percent of the data was within ± 10 percent) while the forward-voltage measurements were better (84 percent of the data was within ± 10 percent).

496 SUMMARY OF DIODE AND TRANSISTOR RESPONSE TO IONIZING RADIATION.

Rogers S. C. (Bell Telephone Lab., Inc., Whippany N. J.).

Bell Telephone Syst. Tech. Publ. Monograph 5171, 9 p. (1966).

Irradiation of a semiconductor device with ionizing radiation causes ionization and excitation of electrons and the generation of hole electron pairs in the device. These hole electron pairs are free to move under the influence of such local environments as electric, magnetic, or diffusion fields. If any of these carriers traverse a junction before they recombine, a radiation-induced current (photocurrent) will flow at the device terminals. Some theoretical and practical consequences of these phenomena are reviewed to help the design engineer properly view the problems associated with radiation-induced transients in transistors and diodes. The phenomena are described qualitatively in terms of carrier generation and movement and described quantitatively by theoretical models for the responses of diodes and transistors. Practical aspects of predicting response of transistors imbedded in discrete component circuits are discussed and some studies pertaining to the response of monolithic integrated circuits are reviewed. Although the device models are generally accurate enough for radiation effects studies, the determination of the model parameters is difficult and time consuming. Furthermore, the computer programs that must be used to solve for response are limited by their speed, stability considerations, and nonlinear restrictions. In addition, electronic technology is moving in a direction that makes the prediction problem even more complicated; monolithic microcircuits are an example of this. For these devices, the geometry of conduction paths caused by ionizing radiation is clearly three-dimensional. This can be approximated by networks consisting of many loops; however, these additional loops are difficult to specify quantitatively, and the computer is burdened with additional equations which may require significant computing time for solving. Predictions of transistor and circuit response can now be made over a moderate range of radiation intensities with reasonable accuracy.

497 (AECL-2610) PHYSICS DIVISION PROGRESS REPORT, JANUARY 1 - MARCH 31, 1966.

(Atomic Energy of Canada Ltd., Chalk River [Ontario]).

57 p. (PR-P-69). Dep. mn. AECL $1.50.

A number of energy-level transitions in fluorine were observed by measuring the γ rays emitted following inelastic scattering of 14-MeV neutrons. The 6.02-MeV γ transition from the 7.79-MeV level to the 1.77-MeV level in ^{28}Si was observed following excitation by the ^{25}Mg-(α,n)^{28}Si reaction. Gamma decay of the 8.543-MeV level in ^{28}Si was studied from the same reaction. Gamma-ray triple angular correlation measurements were made on levels in ^{28}Si and ^{29}Si to determine spins and multipole mixtures of the radiations. Alpha spectra from the ^{16}O-(^{16}O,α)^{28}Si reaction were measured to determine spin-parity combinations for ^{28}Si levels between 7.38 and 8.94 MeV. Gamma-ray spectra corresponding to the excitation of 13 levels in ^{24}Mg were analyzed, and the branching ratios to lower levels were determined. Mean lines of 0^+ states in ^{140}Ce and ^{144}Sm were studied by conversion electron and proton time correlations. Half-life measurements on isometric ^{127}Xe are reported. Experiments were made using two open-ended cylindrical coaxial Ge(Li) detectors for γ-γ coincidence counting. L-sub-shell intensity ratios are reported for pure E2 transitions in even-even rare-earth nuclei. A half life of 12.31-± 0.13 y for ^{3}H was calculated from 5 absolute measurements on AECL ^{3}H standards dating from April 1953 to March 1966. Studies were made of charge collection times in coaxial Ge(Li) spectrometers. Measurements of the magnetic excitations in UO_2 at temperatures close to the antiferromagnetic transition temperature (28.5°K) were made by neutron inelastic scattering techniques. Measurements of the [$\zeta\zeta\zeta$]L branch of the frequency/wave-vector relation of the normal modes of vibration of the alloy $Nb_{0.44}$—$Mo_{0.56}$ were made on a triple-axis spectrometer. Neutron scattering by liquid K at 73°C was studied using a rotating-crystal spectrometer. No evidence of phonon-like excitations were observed at this temperature. The inelastic scattering of neutrons from phonons in K at 92°K was measured. Pseudo-potentials were developed for electron-ion interaction in K. Single crystals of $NaNO_2$ were grown by slow cooling of a saturated solution containing a seed crystal. Gamma-ray energies were measured for the reaction ^{199}Hg(n,γ)^{200}Hg using a coaxial Ge(Li) detector. Similar studies were made for the ^{54}Fe(n,γ)^{55}Fe reaction using thermal neutrons. Measurements of resonance elastic scattering and self-absorption of γ radiation in natural and radio-lead were performed in the range 5.5 to 8.15 MeV.

A technique is described for increasing the efficiency of Ge(Li) detectors, whereby the Compton photons scattered by the Ge crystal are detected by NaI coincidence counters and suitably added to the results. Preliminary results are reported on semiautomatic shell-model calculations for the structure of ^{28}Si.

498 INVESTIGATION OF FRESH FALLOUT SAMPLES WITH Ge(Li) SEMICONDUCTOR COUNTERS.

Kloes H., May R., Schneider H. (Univ., Giessen, Ger.).

Z. Naturforsch., 21a: 1502-4 (Sept. 1966). (In German).

The γ spectrum of fresh fallout samples from the third Chinese nuclear tests was measured with the Ge(Li) semiconductor counter. The ratio of the ^{95}Zr lines at 723 and 757 keV was determined. The age of the samples was calculated from the zirconium-niobium activity ratio.

499 MODIFIED DETECTION ARRANGEMENT FOR SCANNING ELECTRON DIFFRACTION INSTRUMENT.

Dove D. B., Denbigh P. N. (Bell Telephone Labs., Inc., Murray Hill, N. J.).

Rev. Sci. Instrum., 37: 1687-9 (Dec. 1966).

Modifications to the detection arrangement of a scanning electron diffraction apparatus, described by Grigson (Rev. Sci. Instr., 36: 1587 (1965)), have been carried out to (i) permit rejection of inelastically scattered electrons, (ii) provide measurements of the main beam by Faraday cage, and (iii) provide high sensitivity measurements using a semiconductor detector and modulated beam.

500 (CLOR-52/D) TEMPERATURE DEPENDENCE OF FET AMPLIFIERS USED WITH JUNCTION DETECTORS.

Katkiewicz W. (Centralne Laboratorium Ochrony Radiologicznej, Warsaw [Poland]).

1966. 8 p. Dep.

The energy resolution of the FET input stages of amplifiers used in conjunction with junction detectors was investigated in the temperature range +30 to —70°C. For 2N2500 and 2N3277 input stages the increase in resolution was about 0.5% C^{-1} with decreasing temperature. This was the result of a drop in the thermal channel noise as well as increase of FET transconductance g_m.

501 (AERE-R-5183) DETERMINATION OF THE FAST-NEUTRON SPECTRUM IN THERMAL REACTORS BY USING ^{6}Li AND ^{3}He SEMICONDUCTOR SPECTROMETERS.

Silk M. G. (Atomic Energy Research Establishment, Harwell [England]).

Sept. 1966. 56 p. Dep. BIS $1.20. HMSO 8s.

A ^{6}Li-loaded sandwich type semiconductor neutron spectrometer was used to determine fast-neutron spectra in the low-power reactors DAPHNE, LIDO, and GLEEP. The spectrum from a Pu—Be fast-neutron source has been studied. The resultant spectra are shown to be in good agreement with spectra calculated by Monte Carlo techniques and with spectra obtained by other workers. The sources of error in, and the potential application of, this method of neutron spectrometry are considered.

502 SEPARATION OF ISOTOPIC INTERFERENCES UTILIZING Ge(Li) GAMMA-RAY DETECTORS.

Parker C. V. Jr., Martin T. C., Morgan I. L. (Texas Nuclear Corp., Austin).

Trans. Amer. Nucl. Soc., 9: 599 (Oct.-Nov. 1966).

503 (AD-641843) SILICON DIODE FAST NEUTRON DOSIMETER. PHASE I. EVALUATION OF RESPONSE VERSUS STARTING MATERIAL.

Swartz J. M., Chase B. H., Thurston O. M. (Phylatron Corp., Columbus, Ohio).

Oct. 1966. Contract DA-18-035-AMC-101(A). 45 p. (NDL-TR-83-I). CFSTI $3.00 cy, 10.65 mn.

The results obtained from an investigation of the effects of n-or p-type doping, resistivity, and method of crystal fabrication (pulled or float-zone) on the response of silicon-diode fast-neutron dosimeters are presented. The high-level lifetime, the reverse-recovery lifetime, and the current-voltage characteristic were measured for diodes fabricated from each type of starting material, and these parameters were then followed as the diodes were exposed to various neutron fluences. Preliminary results of isochronal annealing experiments and the effects of maintaining the diodes at low temperatures during irradiation are also presented. It was expected that the high-level damage constant, derived from the high-level lifetime, would be independent of the resistivity of the starting material, and this was demonstrated experimentally. Annealing results suggest that at least seven levels are involved in the degradation of lifetime by fast neutrons, and studies of devices irradiated at 77 and 273°K revealed an increased amount of observed damage.

504 (RT-FI-(66)-17) SEMICONDUCTOR DETECTORS AND SMALL FISSION CHAMBERS FOR FAST NEUTRON SPECTRAL ANALYSIS.

Balducci G., Martini M., Vigo A. (Comitato Nazionale per l'Energia Nucleare, Rome [Italy]).

1966. 21 p. (CONF-650832-2). Dep. mn.

From International Meeting on Nuclear Spectroscopy Instrumentation, Herceg-Novi, Yugoslavia.

In order to evaluate the hystogram of fast neutron spectrum, fission detectors were developed. Surface barrier detectors and small fission chambers were used to measure fission rates of materials with different fission thresholds.

The elements used are ^{235}U, ^{233}U, ^{239}Pu, ^{237}Np, ^{238}U, and ^{232}Th. The solid state detectors are placed in a steel cal with a nickel disk on which a fissionable element was deposited by vacuum evaporation technique. The fission chambers are parallel-plate ionization types with an $A\text{-}A_2$ mixture atmosphere and very high (about 99%) efficiency for the fission products. Both counters are small enough to avoid distortion of neutron flux. The fission counters are calibrated by determining the alpha counters rate or, in a thermal neutron flux, by counting the fission fragments. The results of irradiations (all relative to ^{235}U fission) are well consistent.

505 USE OF THE MINIATURE SILICON DIODE AS A RADIATION DOSEMETER.

Raju M. R. (Univ. of California, Berkeley).

Phys. Med. Biol., 11: 371-6 (1966).

The use of commercially available miniature silicon diodes as dosemeters, with particular reference to their application to biomedical facilities at cyclotrons, is discussed. They are simple and convenient, and their small size makes them ideal for use as beam profile detectors.

506 NUCLEAR RADIATION DETECTION BY SOLID-STATE DEVICES.

Dearnaley G. (Atomic Energy Research Establishment, Harwell, Eng.).

J. Sci. Instrum., 43: 869-77 (Dec. 1966).

The history of the development of solid state devices for nuclear radiation detection is traced from crystal counter to the latest semiconductor detectors. The physical processes which are involved in the detector are then outlined, and the features which are desirable are discussed. Some commonly used procedures for detector fabrication are described, and attention is drawn to certain problems which remain. Finally, some recent and novel applications of these detectors are briefly described.

507 RADIATION ENDURANCE OF LOW RESISTIVITY SILICON DIODES FOR NEUTRON MONITORING.

Epstein L. M., Ferber R. R. (Westinghouse Research Labs., Pittsburgh).

Trans. Amer. Nucl. Soc., 9: 483-4 (Oct.-Nov. 1966).

508 USE OF GaAs LIGHT SOURCES FOR CALIBRATING DEVICES WITH SEMICONDUCTOR NUCLEAR-RADIATION DETECTORS.

Naumov V. I., Omel'yanenko M. N., Rykalin V. I., Titova V. F. (Joint Inst. for Nuclear Research, Dubna, USSR).

Prib. Tekh. Eksp., No. 4, 65-8 (July-Aug. 1966). (In Russian).

The calibration of a telescope consisting of four trays of Si nuclear-radiation detectors by means of a GaAs light source is described. The recombination-light source was made from n-type GaAs that had a majority-carrier concentration of (1 to 3) $\times 10^{17}$ per cm^3 and a mobility of 0.35 m^2/V sec; a plot of light-pulse height vs temperature is shown. The telescope is calibrated by constant-height light pulses simulating the passage of nuclear particles through semiconductor detectors; a simplified light-pulse-generator circuit is supplied. The amplitude characteristic of the generator is stabilized within 10 to 40C; the detectors are electrically shielded.

509 (AD-633774) STUDY OF CHARGE CARRIER COLLECTION FROM INSIDE AND OUTSIDE THE SPACE CHARGE REGION.

Basso Michael J. (Army Electronics Command, Fort Monmouth, N. J.).

Jan. 1966. 43 p. (ECOM-2660). CFSTI $3.00 cy, $0.65 mn.

A theoretical and experimental study of the collection of charge carriers produced within and outside the space charge region of a p-n type solid-state radiation detector by incident energetic alpha particles of 4.98, 4.67, 3.87, 2.98, and 2.31 MeV energy is described. The depth of the space charge region was made smaller by a variable forward bias voltage externally applied. The magnitude of the applied voltage was smaller than the barrier potential. Measurements were made of the number of collected carriers from inside and outside the space charge region as the depth of space charge region was varied over the range of the incident alpha particle. The measured results show agreement with the theoretical considerations. The collection efficiency of the detector was also investigated and is given, independent of the particle energy, as a function of the applied bias voltage.

510 THE EFFECTS OF SPACE RADIATION ON MOSFET DEVICES AND SOME APPLICATION IMPLICATIONS OF THOSE EFFECTS.

Gordon Frederick Jr., Wannemacher Harry E. Jr. (Goddard Space Flight Center, Greenbelt, Md.).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13; No. 6, 262-72 (Dec. 1966).

MOSFET devices and microcircuits were designed and built into flight hardware for use in open operational spacecraft (IMP D&E) by NASA/GSFC. A look at some of the engineering results associated with studying this class of devices for use in these applications is reviewed. In addition, there is a first-cut engineering study for comparison of performance, in a simulated space radiation environment, of two types of MOSFET's and the newer experimental silicon nitrite devices (MNS-FET). The experiments reported upon are application parameter oriented and of limited sample size. Therefore, no attempt is made to draw any far reaching conclusions about MOSFET's in general, nor are any devices physics oriented interpretations included.

511 A RADIATION-INDUCED INSTABILITY IN SILICON MOS TRANSISTORS.

Dennehy W. J., Brucker G. J., Holmes-Siedle A. G. (David Sarnoff Research Center, Princeton, N. J.).

IEEE (Inst. Elec. Electron. Eng.), Trans. Nucl. Sci., NS-13: No. 6, 273-81 (Dec. 1966).

Data are presented on a room-temperature instability which was observed in certain types of MOS systems after bombardment with ionizing radiation. This instability can cause the transfer characteristic of an irradiated MOS transistor to shift rapidly when bias is applied. The shift can be as much as 3 volts for a unit that has been bombarded with 10^{15} 1 MeV electrons/cm^2. In order to explain this effect it is postulated that the ionizing radiation introduces a number of surface trapping sites in the oxide which can exchange charge very slowly with silicon. Shifts in transfer characteristic under bombardment, due to immobile charge accumulation in oxide were also observed. The shifts observed were unusual in that they indicate negative charge buildup, which is contrary to the usual finding.

512 RADIATION EFFECTS ON ELECTRONIC SYSTEMS.

Olesen, Henning Lind.

New York, Plenum Press, 1966. 245 p. $16.50.

The effects of nuclear radiation on electronic and electrical equipment is discussed. Topics included are radiation effects on semiconductors and other materials, passive and active radiation shielding, and recommended experimental methods and simulation facilities for design testing.

513 (ORNL-P-2515) RADIATION EFFECTS IN SEMICONDUCTORS.

Crawford James H. Jr. (Oak Ridge National Lab., Tenn.).

[1966]. Contract W-7405-eng-26. 44 p. (CONF-660923-3). Dep. mn. CFSTI $3.00 cy, $0.65 mn.

From Solid State Conference on Interaction of Radiation With Solids, Cairo, Egypt.

The correlation between high-energy radiation damage to crystal lattices in semiconductors and the presence of imperfections in their crystalline structure was investigated. The nature of radiation defects, particularly in the systems of Ge and Si, was studied, as was the influence of these defects on the behavior of semiconductors. A result of the investigation was a better understanding of the complexities involved in the identification of the imperfections responsible for the acceptor and donor states in Ge, Si, and other semiconductors.

514 (NYO-2098-1) NUCLEAR REACTIONS IN LIGHT NUCLEI AND MOESSBAUER STUDIES.

(Johns Hopkins Univ., Baltimore, Md. Dept. of Physics).

Nov. 1966. Contract AT(30-1)-2028. 237 p. Dep. mn. CFSTI $6.00 cy, $1.25 mn.

The effect of Coulomb excitation on Moessbauer spectra of ^{57}Fe in Fe and F_2O_3 was investigated; and Moessbauer experiments were performed on ^{164}Dy, ^{168}Er, ^{155}Gd, ^{156}Gd, ^{158}Gd, ^{160}Gd, and ^{174}Yb using Coulomb excitation. Ratios of quadrupole moments were obtained for the even-even isotopes of Gd. Well-resolved magnetic hyperfine structure was observed in ^{164}Dy and ^{168}Er, and estimates of the magnetic energy splitting were obtained. Unresolved quadruple structure was observed in ^{174}Yb, and the quadrupole interaction energy was determined. Moessbauer levels were observed in ^{172}Yb, ^{174}Yb, and ^{176}Yb following the population of the first excited states by Coulomb excitation; the quadrupole energy splittings and relative quadrupole moments were determined for each isotope. The electric field gradient at the nucleus and the asymmetry parameter for Yb in Yb_2O_3 were obtained from Coulomb excitation cross-section data. In addition, the magnetic moment and spin of the second excited state of ^{57}Fe was determined by observing the Moessbauer effect of the 136.4-keV decay. Moessbauer measurements on ^{155}Gd gave a lower limit for the lifetime of the first excited state and indicated a spin of ½ for the second excited state as well as a quadrupole splitting of 9.3×10^{-7} eV for the ground state. Hyperfine interaction energies of ^{170}Yb in Yb_2O_3 and $YbCl_3 \cdot 6H_2O$ were also measured using Moessbauer techniques. Equipment was developed for Moessbauer studies at high and low temperatures, and experiment was prepared for the observation of polarization from the reaction ^{56}Fe(d,p)^{57}Fe, using the Moessbauer effect. The polarization of the ^{12}B recoil nuclei from the reaction ^{11}B(d,p)^{12}B was investigated as a function of deuteron energy, recoil angle, and the types of recoil stopping material-angular distributions and excitation functions for the reaction ^{19}F(d,n)^{20}Ne were measured in the energy range from 0.9 to 2.7 MeV; the angular distributions were analyzed in terms of a dual-mode plane-wave theory that incorporates exchange and interference terms. Li-drifted Ge gamma detectors were fabricated and tested, and a magnetic spectrometer was developed for Moessbauer studies. A prototype of a large-area neutron detector using slabs of scintillator was also constructed.

515 (AD-635088) RADIATION DAMAGE IN SOLIDS: COMPILATION OF ABSTRACTS.

Andrushis J., Shishkevish C. (Library of Congress, Washington, D. C., Aerospace Technology Div.).

Apr. 18, 1966. 194 p. (ATD-66-43; TT-66-61659). CFSTI $5.00 cy, $1.00 mn.

Radiation damage to semiconductors, metals and alloys, polymers, low-molecular-weight compounds, lubricants, ceramics, alkali halides, ruby, calcium fluoride, Rochelle salt, quartz, glycine sulfate, devices and components, and insulating materials is covered in this compilation.

516 (KFK-426) ELEKTRONISCHE SICHERUNG MIT μA-ANZEIGE FUER HALBLEITER-DETEKTOREN.

(Electronic Safety Devices with μA Readings for Semiconductor Detectors).

Kind Joachim (Kernforschungszentrum, Karlsruhe (West Germany). Institut für Experimentelle Kernphysik).

Mar. 1966. 15 p. (In German). Dep. mn.

The operation of semiconductor detectors requires a slow and steady rise of the current up to the final value as well as continuous control of the set current in the operating range, since exceeding the permissible current, which in many cases is only a few microamperes, may destroy the expensive semiconductor detectors. An electronic protective device is described. This equipment allows the separate simultaneous connection up to four semiconductor detectors. A time constant takes care of a slow and steady rise of the set currents to the ultimate value. Four separately adjustable electronic fuses protect the semiconductor detectors. The supply currents can be read from installed instruments.

517 ARRANGEMENT AND CALIBRATION OF A Ge:Li GAMMA DETECTOR.

Prieels R., Vlieghe P. (Univ., Louvain, Herverle, Belg.).

Ann. Soc. Sci: Brux. Ser. I, 80: 277-88 (Dec. 28, 1966). (In French).

The installation and standardization of a gamma detection system with high energy resolution is described. The detector was a Ge : Li crystal with a nominal thickness of 2 mm in the adjusted zone. A typical width at half maximum of 4.5 to 122, 6.7 to 1333, and 9.5 to 2614 keV was obtained. In the detection of pair production events the width at half maximum obtained was 8 keV for a gamma ray of 2614 keV. The factors affecting the resolution and the pulse height are discussed in detail. Experimental values for the efficiency for photoelectric and Compton effects and pair production are compared with theoretical values calculated for a 2-mm detector.

518 SEMICONDUCTOR RADIATION DETECTORS FOR AEROSPACE APPLICATION.

Trice James B. (General Electric Co., Philadelphia).

pp. 88-101 of Radioisotopes for Aerospace. Part. I. Dempsey John C., Polishuk Paul (eds.). New York, Plenum Press, 1966.

The physical and functional characteristics of contoured amplifying detectors developed over the past four years are described. Applications of these detectors to several aerospace requirements of an engineering and scientific nature are presented in terms of those specific contributions that can be made to missile and satellite instrumentation. The achievements made possible through these sensors are: high speed and time resolution that approaches a nanosecond; the ability to measure x-ray energies as low as one kilovolt or less; and the major reduction in size or elimination of preamps and amplifiers.

519 (UCRL-16924) LITHIUM-DRIFTED SILICON DETECTOR USED AS A PULSE DOSIMETER.

Raju Mudundi R., Lampo Edward J., Curtis Stanley B., Sperinde Johnie M., Richman Chaim (California Univ., Berkeley. Lawrence Radiation Lab.).

Sept. 27, 1966. Contract W-7405-eng-48. 10 p. (CONF-661020-15). Dep. mn. CFSTI $3.00 cy, $0.65 mn.

From 13th Annual Nuclear Science Symposium, Boston, Mass.

A lithium-drifted silicon detector used as a pulse radiation dosimeter is described. It is used to measure the depth-dose distribution of pion beams in water. The fractional dose due to energy depositions above a particular energy in the detector can also be measured. Such measurements yield information on the distribution of ionization density. Preliminary results of the pion-beam dosimetry using this pulse dosimeter are given.

520 EFFECTS OF TRAPPED RADIATION ON ELECTRONIC DEVICES.

Brown W. L. (Bell Telephone Labs., Inc., Murray Hill, N. J.).

pp. 757-92 of Radiation Trapped in the Earth's Magnetic Field. McCormac Billy M. (ed.). New York, Gordon and Breach Science Publishers, 1966.

The consequences of the geophysics of the magnetically trapped radiation, together with the solid-state physics of materials and devices, to the hardware of unmanned vehicles in space are considered. The different classes of important radiation effects are discussed, and their effects on semiconductor devices are considered. Information is included on the Telstar satellite experiments.

521 (ORO-2843-11) NUCLEAR CHEMISTRY GROUP PROGRESS REPORT, 1966.

(Florida Univ., Gainesville).

Contract AT(40-1)-2843. 15 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

Angular correlations of ternary fission and of fission-fragment scattering were investigated, and preliminary experiments were carried out on the characteristics of the ternary fission of ^{252}Cf, ^{240}Pu, ^{242}Pu, ^{234}U, and ^{236}U. A time-of-flight fission-fragment mass spectrometer was developed, as was a six-parameter multichannel analyzer and position-indicating solid-state detectors.

522 (IS-1478) NUCLEAR SPECTROSCOPIC STUDIES WITH A SEMICONDUCTOR DETECTOR COINCIDENCE SYSTEM.

Englert Thaddeus Joseph, Everling F., Eakins G. W., Hatch E. N. (Ames Lab., Iowa).

Nov. 1966. Contract W-7405-eng-82. 89 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

A coincidence spectrometer has been constructed which utilizes the properties of semiconductor detectors and sodium-iodide scintillation detectors. Measurements of relative intensities of conversion electrons from ^{207}Pb and ^{175}Lu were determined using this system and the values found are in good agreement with measurements made with magnetic spectrometers. To demonstrate further its versatility, the coincidence system was used to study the Compton effect using the 570- and 1064-keV gamma rays from ^{207}Pb. The problem of obtaining a pure electron spectrum with semiconductor detectors when

the electrons are being emitted in the presence of a photon spectrum was studied and two methods of suppression of the photon background were investigated. Electron-electron coincidence measurements using semiconductor detectors and electron-gamma coincidence measurements using a sodium-iodide scintillation counter in conjunction with a semiconductor detector were made to study the decay scheme of ^{175}Lu following the electron capture decay of ^{175}Hf.

523 GERMANIUM p-i-n DETECTOR.

Ryndina E. Z., Uhrin Janos.

ATOMKI (At. Kut. Intez.) Kozlem., 8: 238-43 (Sept. 1966). (In Russian).

A detector of 3-mm sensitive layer and 1.9-cm^2 surface was made. Spectra of ^{203}Hg, ^{137}Cs, ^{60}Co, ^{151}Gd, and ^{153}Gd are presented. In the case of ^{60}Co the resolution is 5.5 keV.

524 A Ge(Li)-SPECTROMETER WITH PLASTIC ANTICOINCIDENCE MANTLE FOR GAMMA ANALYSIS OF FUEL ELEMENTS.

Hasselgren Arne (Chalmers Univ. of Technology, Goteborg).

Nukleonik, 8: 443-6 (Nov. 1966).

A lithium drifted germanium detector 5 mm × 4.0 cm^2 was used in anticoincidence with a 24 cm diameter by 31 cm long NE 102A plastic scintillator for measuring gamma radiation from reactor fuel elements. The spectrometer reduces and smooths the Compton distribution and is a cheap and simple instrument for simplifying the response function of a Ge(Li)-detector.

525 DIRECT OBSERVATION OF SEMICONDUCTOR DETECTORS CURRENT PULSES.

Vacher J. (CEN, Grenoble, France).

Bull. Inform. Sci. Tech. (Paris), No. 108, 89-97 (Oct. 1966). (In French).

A device is described which permits the observation of the form of current pulses produced, in semiconductor-detectors, by the α particles of UO_2 which renders the junction sensitive to neutrons. Due to the rapidity of these pulses a sampling oscilloscope must be used. The amplitude of the pulses to be observed is however smaller than the noise amplitude of obtainable oscilloscopes. To eliminate this noise, series of circuits were constructed which restore the mean value of the samples in numerical form. These samples are then fed to a multichannel analyzer used as a multiscaler which reconstructs the form of the pulses point by point.

526 (UCOL-535-561) TECHNICAL PROGRESS REPORT [ON NUCLEAR PHYSICS].

(Colorado Univ., Boulder. Dept. of Physics and Astrophysics).

Nov. 1, 1966. Contract AT(11-1)-535. 70 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

The optical-model potential was investigated using ^{3}He scattering by medium-weight nuclei. Angular distributions for the reaction ^{12}C(He-3,α)^{11}C and for ^{3}He elastic scattering by ^{12}C at 43.7 MeV were analyzed using the optical model and the DWBA formalism. Angular distributions for proton inelastic scattering by ^{92}Zr and ^{94}Zr were fitted using distorted-wave theory and shell-model form factors. Angular distributions for the ^{96}Zr(p,d)^{95}Zr reaction and for proton inelastic scattering by ^{96}Zr at 19.4 MeV were measured and were calculated. spectroscopic factors were obtained by a distorted-wave analysis of the ^{96}Zr(p,d)^{95}Zr reaction. Level density fluctuations in ^{56}Fe were investigated using proton inelastic scattering, and proton elastic and inelastic scattering by ^{42}Ca and ^{44}Ca at 22.9 MeV was studied experimentally and theoretically. Energy levels in ^{35}Ar, ^{36}K, and ^{37}K were investigated using the reaction ^{36}Ar(p,d)^{35}Ar, ^{36}Ar(He-3,t)^{36}K, and ^{36}Ar(He-3,d)^{37}K. The Coulomb energy systematics of isobaric triplets in the mass region $22 \leqslant A \leqslant 40$ were also investigated experimentally. The proton elastic scattering cross section of ^{58}Ni was calculated using a modified optical theorem, and optical-model parameters were investigated using proton elastic scattering by ^{40}Ar, ^{209}Bi, ^{208}Pb, ^{58}Ni, ^{14}N, ^{16}O, ^{116} Sn, and ^{96}Zr. Information on the level structure of ^{88}Sr and ^{89}Y was obtained from angular distributions for proton scattering by ^{88}Sr and ^{89}Y at 19.5 MeV and for the reaction ^{88}Sr(He-3,d)^{89}Y at 37.7 MeV. Proton elastic and inelastic scattering by ^{56}Fe, ^{57}Fe, and ^{58}Fe at 22.5 MeV was also investigated; experimental angular distributions were fitted using the optical model. The (d,p), (p,d), and (He-3,d) reactions on ^{40}Ca were investigated using optical-model wave functions obtained from proton are deuteron elastic scattering by ^{40}Ca; previously unreported levels of ^{39}Ca and ^{41}Sc were observed. Previously unreported levels of ^{57}Ni, ^{88}Y, and ^{89}Zr were observed in a study of the reactions ^{58}Ni-(He-3,α)^{57}Ni, ^{89}Y(He-3,α)^{88}Y, and ^{90}Zr(He-3,α)^{89}Zr. A method of measuring the half lives of long-lived radioisotopes was developed; the half lives of ^{36}Cl and ^{41}Ca were measured. Techniques for the fabrication of Ge(Li) detectors were also investigated.

527 (AECL-2639) PHYSICS DIVISION.

Progress Report, July 1 - September 30, 1966. (Atomic Energy of Canada Ltd., Chalk River (Ontario). Chalk River Nuclear Labs.).

71 p. (PR-P-71). Dep. mn. AECL $2.00.

The cross sections for excitation of energy levels in ^{19}F by the scattering of 14-MeV neutrons were measured. The anisotropy of fission fragments from ^{235}U(d,pf) and ^{239}Pu(d,pf) near threshold was investigated. Studies were made of ternary fission of ^{252}Cf in which a long range α-particle accompanies the emission of the two large fragments. The ^{12}C(^{12}C,$\alpha\gamma$)^{20}Ne reaction at a ^{12}C ion energy of 21.35 MeV was used to study the 10.65-MeV level in ^{20}Ne. Lifetimes of levels in ^{28}Si were obtained by Doppler-shift attenuation measurements. In preparation for use with the MP tandem accelerator, the broad-range magnetic spectrograph was modified to permit the study of particles emitted at 180° with respect to the incident beam direction, in addition to the usual angular range of 0 to 165°. An experiment based on the (d,pγ) reaction was conducted to investigate statistical aspects of

the gamma spectra of a number of medium and heavy elements. The L subshell rasios of the 162.65-keV transition in ^{140}La are being investigated with a $\pi\sqrt{2}\beta$ spectrometer. The properties of the 57- and 350-keV states in ^{143}Pr are being studied. Magnetic moments of excited states in ^{169}Tm are being investigated by γ—γ cascade angular-correlation measurements. To aid in the interpretation of these measurements, the conversion-electron spectrum of ^{169}Yb is being studied in the $\pi\sqrt{2}\beta$ spectrometer at resolutions of 0.03 to 0.1% in momentum. Extensions to the efficiency tracing method for eliminating self-absorption errors in $4\pi\beta$ counting were studied. Neutron counters filled with ^{3}He up to 8 atm of pressure were developed. Studies were made of the performance of large-volume coaxial Ge(Li) detectors operated with low-noise field-effect-transistor-type amplifiers. The performance of planar-type Ge(Li) detectors was investigated at different temperatures ranging from 4.2 to 150°K. The normal modes of vibration in large $NaNO_2$ crystals are being studied. Measurements were made of the magnetic excitations of UO_2 in the [111] direction of propagation from nuclear lattice points. The ferroelectric and semiconducting properties of SnTe-GeTe alloys are being investigated with the possibility of developing new electromechanical transducers. A triple-axis crystal spectrometer was used to measure magnetic excitations between the lowest two electronic states of the Co^{++} ion in CoF_2. Measurements were made of the energy distribution of 2.3 Å neutrons scattered from a powdered sample of Er metal at room temeprature using a rotating-crystal spectrometer. Calculations are being made of the widths and shifts of phonons in K as a function of temperature. The anharmonic coefficients which determine these quantities are obtained from a pseudopotential fitted to phonon frequencies at 9°K. Gamma energies from ^{96}Mo and ^{98}Mo following the reactions ^{95}Mo(n,γ)^{96}Mo and ^{97}Mo(n,γ)^{98}Mo were measured using a coaxial Ge(Li) detector. Resonance scattering measurements on natural lead were made using the Compton scattered 8.99-MeV neutron capture γ rays of nickel for excitation. An energy range of 6.6 to 8.0 MeV was investigated. A relation was found between cold-neutron scattering by simple molecular liquids and the corresponding infrared and Raman spectra of these substances. For liquids in which statistical correlations between the rotational and translational motion are negligible, the contribution of the rotational motion to the cold-neutron scattering cross sections can be obtained from the infrared and Raman rotational-vibrational line shape functions. Coherent scattering of neutrons by liquids was theoretically investigated. A study is being made of the effect of pairing forces on the energy of the ground-state band in ^{20}Ne. The structure of states in ^{28}Si was studied by including a spin-orbit force in the Hartree-Fock treatment of the nucleus. Using the three-body formalism of Faddeev and a separable-potential approximation to the two-body interactions, several three-body nuclear systems are being investigated. The electro- and photodisintegration of ^{3}He was theoretically investigated.

528 NUCLEONIC TWO PHASE HYDROGEN QUALITY GAUGING SYSTEM.

Fornadley Frank D. (General Nucleonics Corp., Claremont, Calif.).

pp. 177-84 of Radioisotopes for Aerospace. Part. 2. Dempsey John C., Polishuk Paul (eds). New York, Plenum Press, 1966.

A nucleonic gauging system for accurately measuring the mass of flowing two-phase hydrogen is described. Beta emitting sources were mounted in a fixed configuration in the hydrogen flow pipe. Ten solid state detectors were arrayed outside the flow pipe. The output of the detectors is combined electronically to give an integrated output which is an accurate measure of the hydrogen flow under all conditions of liquid and gaseous states and is insensitive to bubbles in the flow. Laboratory tect verified theoretical predictions for the system, and showed that liquid cryogenics can be gauged by nucleonics techniques to detect accurately changes of 0.05 lb/ft^3 with a time response of less than 10 milliseconds.

529 (AD-641654) DEVELOPMENT OF A HIGH-INTENSITY SOLID-STATE GAMMA-RAY DOSIMETER SYSTEM.

Final Technical Report.

Fletcher C. L. (General Dynamics, Fort Worth, Tex.).

July 18, 1966. Contract N228(62479)67947. 63 p. (USNRDL-TRC-53). CFSTI $3.00 cy, $0.65 mn.

Design, construction, and testing of an integrating gamma-ray dosimeter for high dose rates are discussed. The sensor is a silison surface-barrier detector operating as a current device. The detector output current is integrated on a capacitor. When the voltage on the capacitor rises to a predetermined level corresponding to 10 rad-equivalent-air of gamma-ray dose, the capacitor is discharged and the instrument produces an output pulse to signal the event. The number of output pulses indicates integrated dose, and the pulse repetition rate idicates dose rate. The detector proper is cooled with a thermoelectric cooler to minimize and stabilize leakage current. The instrument is designed for operation in the dose-rate range of 10 to 100,000 rad-equivalent-air per second. The detector is constructed to make it function as a Bragg-Gray device over the gamma-ray energy range of 80 kev to 12 Mev. The detector is reasonably isotropic; cumulative errors due to all causes are less than plus or minus 30%. The electronics are insensitive to gamma-radiation transients for dose rates as high as 1,000,000 rad per second. Results of tests with radioactive sources, a fast-burst reactor, and bremsstrahlung pulses are given.

530 (CLOR-57/D) BETA DOSE RATE MEASUREMENT WITH SILICON COUNTER.

Roman J., Sawicka B. (Centralne Laboratorium Ochrony Radiologicznej, Warsaw [Poland]).

1966. 11 p. Dep.

The use of silicon surface-barrier detector, as an extrapolation parallel plate ionization chamber, in measuring of beta radiation dose rate was investigated. The detector response was compared to the surface absorbed dose rate in tissue, measured with an extrapolation air ionization chamber. It was found that the correlation is sufficiently good and that the extrapolation silicon counter is suitable for the use under laboratory, as well as field conditions. The beta radiation dose rate range from few milirads to few hundred rads can be covered.

531 (N-66-24954) [FUNDAMENTAL STUDIES ON SEMICONDUCTOR RADIATION DETECTORS].

Annual Status Report No. 2, March 1, 1965 - February 28, 1966.

Casper Karl J. (Western Reserve Univ., Cleveland, Ohio).

[1966]. 53 p. (NASA-CR-74766). CFSTI $3.00 cy, $0.65 mn.

A summary is presented on research progress on studies of the response functions of lithium drifted silicon detectors to monoenergetic electrons, a preliminary investigation of the temperature dependence of the resolution of lithium drifted silicon detectors, fabrication of large volume lithium drifted silicon detectors, studies of the internal Compton effect using a superconducting magnet beta ray spectrometer, ohmic contacts to silicon detectors, and studies of high Z semiconductors for radiation detectors.

532 (N-66-25000) THEORETICAL AND EXPERIMENTAL STUDIES OF RADIATION-INDUCED DAMAGE TO SEMICONDUCTOR SURFACES AND THE EFFECTS OF THIS DAMAGE ON SEMICONDUCTOR DEVICE PERFORMANCE.

Semiannual Progress Report No. 4, September 1, 1965 - February 28, 1966. (North Carolina State Univ., Raleigh, Semiconductor Device Lab.).

[1966]. 44 p. (NASA-CR-74733; SDL-4-588-1). CFSTI $3.00 cy, $0.65 mn.

Accomplishments are presented in related projects dealing with surface recombination velocity investigations, surface studies of metal oxide semiconductor capacitors, the measurement of surface recombination velocity as a function of surface potential, and deep lying centers in germanium. Relative to the surface recombination investigations, emphasis is placed on determining the effects of ^{60}Co gamma irradiation (approximately 1.3 MeV) on both the bulk and surface properties of silicon. In the surface studies, progress is reported in examining silicon surface state density changes induced by gamma radiation. The surface potential area presents experimental determinations of the effects of surface potential on the surface recombination velocity of an oxide-silicon surface and its variation with gamma radiation. The studies concerned with deep lying centers in germanium emphasize both theoretical and experimental lifetime variation effects in diodes.

533 (ORO-2972-25) ANNUAL REPORT OF THE ACCELERATOR LABORATORY FOR 1966.

(Texas Univ., Austin, Accelerator Lab.).

Dec. 1966. Contract AT(40-1)-2972. 74 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

The polarization of protons elastically scattered from ^{4}He was measured between 6.0 and 11.6 MeV; a phase-shift analysis of the data was performed. The differential cross sections and absolute polarizations for proton elastic and inelastic scattering by ^{9}Be were measured in the energy range from 7.0 to 11.0 MeV. The energy levels of ^{13}N were investigated using the polarization of protons elastically scattering by ^{12}C at 4 to 10 MeV. Neutron resonances were also observed in neutron elastic and nonelastic scattering by C at 13.5 to 24.5 MeV. Alpha angular distributions and yields from the reaction ^{12}C(d,α)^{10}B at 5 to 9.5 MeV were measured, as were differential cross sections for the reaction ^{13}C(d,α)^{11}B at 10 to 12 MeV. An attempt was also made to observe alpha cluster structure of ^{15}O using proton reactions and scattering on ^{14}N. The energy levels of ^{32}S were investigated using the reaction ^{31}P(p,^{2})$^{8\alpha}$Si at 1 to 5.7 MeV. Differential cross sections and yields for the reaction ^{31}P(d,α)^{28}Si at 5.5 to 12.0 MeV were measured, as were excitation functions for the (p,α) reaction on ^{35}Cl and ^{37}Cl at 4 to 7 MeV. The measurement of nuclear level spins using proton polarization from scattering was investigated; the polarization of protons scattered elastically by ^{90}Zr was measured. An experimental observation of the coupling of the (d,n) and (d,p) reaction channels was made by observing deuteron reactions with zirconium at 5 to 10 MeV. Isobaric analog states were observed in proton elastic scattering by ^{124}Te, ^{126}Te, ^{128}Te, and ^{130}Te; parameters were determined for a number of the analog resonances observed. Similarly, analog states in ^{209}Bi were investigated using proton scattering by ^{280}Pb. The effect of the electromagnetic interaction on isospin selection rules in nuclear reactions was studied theoretically, as was the polarization of protons from (d,p) reactions. Also, finite-range calculations were carried out for knockout reactions using the distorted-wave formalism. A facility for the production of Si surface-barrier detectors was put into operation, as was a computer system for on-line use with pulse analyzers at the tandem and 4-MeV Van de Graaff accelerators.

534 SPECTROMETRIC ALPHA SOURCES AND THEIR APPLICATION IN DETERMINING THE BASIC PARAMETERS OF SPECTROMETERS AND SEMICONDUCTOR DETECTORS.

Stepanov E. K., Tyutikov N. V.

Vienna, International Atomic Energy Agency, 1966, Preprint No. SM-79/74, 16 p. (In Russian). (CONF-661012-44). DTIE.

From IAEA Symposium on the Standardization of Radionuclides, Vienna.

The use of alpha sources for determing the basic parameters of spectrometers and semiconductor detectors is discussed. The spectrometric characteristics of the sources are defined and their values determined for the measurement of a given spectrometer parameter. The investigations were carried out with ^{233}U, ^{239}Pu, ^{241} Am and ^{210}Po alpha sources and with ^{226}Ra and RaTh(^{228}Th) radon-free sources, the radionuclides being prepared by different methods. The spectra of the sources were recorded by means of an alpha spectrometer with a semiconductor and having a total energy resolution of 20—25 keV.

535 (N-67-10874) BASIC RESEARCH IN SEMICONDUCTOR DETECTOR-DOSIMETER CHARACTERISTICS, AS APPLIED TO THE PROBLEMS OF WHOLE BODY DOSIMETRY.

Annual Progress Report.

Crawford George W. (Southern Methodist Univ., Dallas, Tex.).

Sept. 1966. 82 p. (NASA-CR-79718). CFSTI $3.00 cy, $0.65 mn.

The preparation of lithium-drifted semiconductor nuclear particle detectors is discussed in detail. The associated theory is reviewed, including basic material, diffusion, p-n junctions, drift, and operation, and the preparation and experimental results of the detector are presented. It was concluded that preparation and use of the detector are both feasible and desirable. It was pointed out that excellent agreement can be obtained between experimental and theoretical determinations of stopping power, average excitation energy, and electron hole pair formation energy for silicon. Summary reports are also included on other phases of basic research in semiconductor detector-dosimeter characteristics, including charge-pulse response of silicon detectors, detector lifetime behavior studies, stopping power measurements, and correlation between biological response and dose measurement.

536 SOLID-STATE ALPHA COUNTERS: A REPLACEMENT FOR NUCLEAR TRACK COUNTING IN BIOASSAY PROCEDURES.

Butler H. L., Splichal W. F. Jr. (E. I. du Pont de Nemours and C., Aiken, S. C.).

Contract AT(07-2)-1. Health Phys., 12: 1627-39 (Nov. 1966). (DPSPU-65-30-6).

The advantages of using solid-state alpha detectors over nuclear track counting for monitoring bioassay samples are considered. The results of monitoring uranium and plutonium-230 in urine by each method are statistically analyzed.

537 (MIT-905-81) CHEMISTRY PROGRESS REPORT.

(Massachusetts Inst. of Tech., Cambridge. Lab. for Nuclear Science).

Dec. 31, 1966. Contract AT(30-1)-905. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

Developments are reported for studies in: nuclear chemistry; instrumental chemistry; uses of organic isotopes; and physical chemistry.

538 (BNL-10863) GAMMA-RAY SPECTROSCOPY IN VAN DE GRAAFF RESEARCH.

Alburger David E. (Brookhaven National Lab., Upton, N. Y.).

[1966]. Contract AT-30-2-GEN-16. 43 p. (CONF-670103-1). Dep. mn. CFSTI $3.00 cy, $0.65 mn.

From International Conference on Low Energy Nuclear Physics, Dacca, East Pakistan.

A review is presented of the techniques used by the Brookhaven Van de Graaff group in the study of gamma rays from the excited states of light nuclei. The topics include the determination of multipolarities with a magnetic pair spectrometer, studies of gamma rays from short-lived activities, gamma-ray angular distributions and correlations, and various methods using lithium-drifted germanium detectors. The operating characteristics of the Brookhaven Van de Graaff accelerator are also described briefly.

539 (CLOR-60/D) PRZEDWZMACNIACZ LADUNKOWY I WZMACNIACZ IMPULSOWY DO DETEKTOROW POLPRZEWODNIKOWYCH.

(The Charge-Sensitive Preamplifier and Linear Pulse Amplifier for Semiconductor Detectors).

Glowacki St. (Centralne Laboratorium Ochrony Radiologicznej, Warsaw [Poland]).

1966. 15 p. (In Polish). Dep.

A charge sensitive preamplifier and linear pulse amplifier with resolution of 3.5 keV fwhm are described. The output signal level is 8 V for 200 keV of beta particle energy lost in a silicon detector. The expander of gain of 10 V/V in the amplifier is provided, owing to the fact that the accuracy of measurement is magnified. The amplifier is developed for direct driving of the pulse-to-time converter of a multichannel analyser.

540 POSSIBILITY OF ABSOLUTE CALIBRATION OF SEMICONDUCTOR DETECTORS FOR FISSION FRAGMENTS.

Kashukeev N. (Inst. of Physics, Bulgarian Academy of Sciences).

Compt. Rend. Acad. Bulg. Sci., 19: 579-82 (1966). (In Russian).

A method is suggested for absolute calibration of silicon detectors used for measuring the energy of fission fragments. The method can be utilized even under conditions when other methods fail, for instance, when the fissioning isotope standard is not available, when it is impossible to obtain heavy ions of certain energies, and when detectors have poorly developed plateaus or are working beyond the plane part characteristics. The method was tested with ^{252}Cf and compared with the data offered by H. W. Schmitt et al. (Phys. Rev. 137, B837 (1965).

541 (AECL-2659) PHYSICS DIVISION PROGRESS REPORT, OCTOBER 1-DECEMBER 31, 1966.

(Atomic Energy of Canada Ltd., Chalk River (Ontario). Chalk River Nuclear Labs.).

76 p. (PR-P-72). Dep. mn. CFSTI $3.00 cy, $0.65 mn. AECL $2.00.

Levels in ^{25}Mg up to 4 MeV and in ^{26}Mg to about 6 MeV were excited by inelastic scattering of protons from the MP tandem accelerator. Proton bombarding energies between 3.8 and 8.3 MeV were chosen to populate the state under study directly without gamma cascades from higher states. The gamma rays were detected in a 25-cm^3 (Ge(Li) spectrometer, and lifetimes were measured by observing attenuated Doppler shifts at angles between 20 and 160°. Information on decay schemes was

also obtained. Measurements on the first four levels in both ^{25}Mg and ^{26}Mg were completed, and further measurements on higher levels in both nuclei are continuing. A three-crystal pair spectrometer consisting of a 25-cm^3 Ge(Li) detector surrounded by two NaI(Tl) scintillation detectors was constructed for studies using the tandem accelerator. A single peak is obtained for a high-energy γ ray by selecting pulses in the Ge(Li) detector which are in triple coincidence with the 511-keV annihilation peaks in the NaI(Tl) detectors. The apparatus was tested using collimated RdTh (2.62 MeV) and ^{88}Y (1.836 MeV) γ-ray sources. Approximately 20% of the "double-escape" peaks in the Ge(Li) spectrum are recorded in triple coincidence, and the remaining part of the spectrum is greatly reduced giving an improvement in the peak value to background ratio of about 50. The C5 triple-axis neutron spectrometer was used in a program to investigate the temperature dependence of the anharmonic shifts and half-widths of phonon frequencies in a single crystal of potassium. Measurements were made at 9, 92, 215, and 299°K. In all, 150 modes were studied, and for some of them the shifts and half-widths at high tempeartures were an appreciable fraction of the frequency at 9°K. Theoretical calculations of the anharmonic shifts and widths of phonons in potassium as a function of temperature were also made. The processes causing these anharmonic effects are as follows: A phonon may be scattered into two other phonons due to third order terms in the potential between atoms in the potassium metal; this gives rise to a lowering of the phonon frequency and width due to the finite lifetime of the phonon. A phonon may interact with any other phonon present in the crystal through the fourth order potential; this gives rise to a frequency shift which may be either positive or negative. Finally, a lowering of the frequency is produced by a uniform strain in the lattice arising from the thermal expansion. The anharmonic coefficients required for the calculation were obtained from a total potential of a pseudo-atom model fitted to the phonon frequencies at measurements of 9°K. For several phonons there is good agreement between theory and experiment for the shifts up to 215°K, but not at room temperature where it is known that many vacancies are present in the crystal and where multi-phonon scattering becomes appreciable. Agreement is generally poor for the phonon half-widths, and this probably indicates an inadequacy in the model used in calculations. Lattice vibrations were shown to influence the electronic band structure of crystals. Within the pseudopotential model, the leading correction to normal band structure calculations with fixed ions is to multiply the pseudopotential coefficients by the appropriate Debye-Waller factors. This tends to reduce the effect of the crystal structure on the electron bands, so that solids will tend to be more free-electron-like at high temperatures, in agreement with measurements of the Hall effect in metals. These effects will be particularly marked in those crystals for which the electron bands are greatly influenced by the crystal structure, such as transition metals and narrow band gap semiconductors. The effects might be seen in detail by a change with temperature in the Fermi surface shape or the position of the Kohn anomaly. Detailed calculations based on a published pseudopotential model were made of the temperature dependence on the band gap in Ge and Si. The results are 4.3×10^{-4} eV/°K and 4.1×10^{-4} eV/°K, respectively, whereas published measurements give 3.9×10^{-4} eV/°K and 2.4×10^{-4} eV/°K. The agreement reflects limitations in the assumed model. A triple axis crystal spectrometer was put into operation at the hole C4 of the NRU reactor. The in-pile collimator contains a 5 in. single crystal quartz filter cooled to liquid nitrogen temperature to provide an improved ration of slow to fast neutrons. The spectrometer is designed with a fixed monochromator angle but a good selection of incident neutron energies may be obtained by using different monochromator crystals and crystals planes. Due largely to the lower neutron flux at C4, the intensity of monochromatic neutrons incident on the specimen in this spectrometer is about 1/8 that in the C5 spectrometer. However, with its low background rate this spectrometer will be an important supplement to the C5 spectrometer. Modifications were made to both G-20 and 3100 operating systems to have the first pass of the APEX compiler executed by the 3100 before the program is submitted to the G-20. Programs were written for use in the G-20 computer as follows: a program for drawing PERT networks on a CALCOMP plotter, a program which compares the decay of irradiated foils with the decay curve of a standard foil, a program to analyze body monitor data and to plot contour and relief pictures of the scanned body, a program to calculate the matching of charged particle beams with magnetic transport systems consisting of certain symmetric arrangements of quadrupole lenses, and a program to calculate a geometric factor for the self-absorption in a two-shell cylindrical fuel element.

542 MEASURING FISSION SPECTRA WITH SEMICONDUCTOR DETECTORS.

Gordon Glen E., Harvey John W., Nakahara Hiromichi (Massachusetts Inst. of Tech., Cambridge).

Nucleonics, 24: 62-6 (Dec. 1966).

Detailed investigations were made of the γ-ray spectra of gross fission products at various times following neutron irradiations using high-resolution Ge(Li) detectors. Methods were also developed for determining the ranges in aluminum and the yields of about 20 of these fission products. Typical spectra are given for ^{235}U following thermal-neutron induced fission, and ranges and yields are presented for fission products from ^{233}U.

543 SEMICONDUCTOR DETECTORS FOR IONIZING RADIATION.

Hofker W. K. (Philips Research Labs., Amsterdam).

Philips Tech. Rev., 27: 323-36 (1966).

Germanium and silicon counters with p-n and p-i-n configurations are extremely useful for detecting and measuring the energy of gamma quanta and high-energy charged particles. Except with very heavy particles, these semiconductor detectors are highly linear and have a particularly high resolution (about 20 keV for α-radiation, only a few keV for β- and γ-radiation). The pulse height depends only on the quantum energy (particle energy) E and not on the nature of the radiation. With extremely thin detectors it is possible to measure dE/dx and thus indentify unknown heavy particles. The construction of the device is readily adaptable to specific requirements; to measure directional distributions, for example, a detector can be divided into numerous subdetectors (checkerboard counter). The resolution is higher for larger values

of the charge carrier life compared with the transit time in the counter, and for lower bias current. A p-i-n detector combines a large detection volume with a weak bias current.

544 RISE TIME IN SOLID-STATE DETECTORS.

Alberigi Quaranta A. (Univ., Bologna).

Nuovo Cimento (1), 4: Suppl., 631-46 (1966).

The research performed on various factors effecting the rise time of semiconductor detectors is reviewed. The topics discussed are the equivalent circuit, plasma time, and charge-collecting time in semiconductor detectors. Applications to the physics of semiconductors are also considered.

545 SEMICONDUCTOR SPECTROMETERS OF PENETRATING NUCLEAR RADIATIONS DEVELOPED IN THE INSTITUTE OF NUCLEAR RESEARCH.

Chwaszczewska Janina, Dakowski Miroslaw, Przyborski Wincenty, Sowinski Mieczyslaw, Stegner Adolf (Inst. of Nuclear Research, Polish Academy of Sciences, Swierk).

Nukleonika, 11: 703-12 (1966).

The semiconductor spectrometers of penetrating nuclear radiation developed in recent years in the Institute of Nuclear Research are reviewed. The review includes guard-ring surface-barrier detectors, silicon and germanium lithium drifted detectors, and windowless silicon surface-barrier lithium drifted detectors. The trends of development of the methods of semiconductor spectrometry are pointed out.

546 INVESTIGATION OF THE INFRARED ABSORPTION SPECTRUM OF NEUTRON- IRRADIATED SILICON.

Lotkova E. N.

Tr. Fiz. Inst., Akad. Nauk SSSR, 37: 102-48 (1966). (In Russian).

The infrared absorption spectrum of multicrystalline silicon, irradiated with fast reactor neutrons was investigated. The current theories on the effect of neutron irradiation on semiconductors were examined, and a review of the basic works on the effects of neutron irradiation on silicon was given. The methods used in the present study on neutron-irradiated silicon were described. The results showed that as a result of the irradiation, absorption bands, connected with the local level of the radiation detectors, appeared. The bands were tabulated and their origin was discussed.

547 (UCRL-16969) I. THE MEASUREMENT OF INTERNAL CONVERSION COEFFICIENTS UTILIZING SEMICONDUCTOR DETECTORS. II. DECAY SCHEME STUDIES OF THE ODD-MASS GOLD ISOTOPES.

Haverfield Arthur Judd (California Univ., Berkeley. Lawrence Radiation Lab.).

Nov. 10, 1966. Contract W-7405-eng-48. 196 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

Thesis.

The application of semiconductor detectors to measurements of internal conversion coefficients is extensively discussed, with particular emphasis being placed upon a spectrometer employing both Si(Li) and Ge(Li) detectors for the simultaneous observation of conversion electrons and gamma rays. The construction, calibration, and use of such a spectrometer are described. Possible improvements in this system are also discussed. It is found that this type of spectrometer is best suited for ICC measurements of transitions following electron-capture decay, but may still be useful in cases of beta or positron decay. The level schemes of the odd-mass Au isotopes of mass 199, 197, 195 and 193 were examined from the decay of the respective odd-mass platinum and mercury isotopes. The measurement of numerous internal conversion coefficients permitted the assignment of spin and parity values to many of these levels. The systematic trends of many of the nuclear phenomena associated with these isotopes were examined as a function of neutron number. The experimental data were compared to the various theoretical approaches applicable to this region of nuclei. The internal conversion process is discussed along with the various experimental methods of ICC measurement. The calibration of semiconductor detectors for energy and intensity measurements is discussed. Extensive tables of standards for these calibration procedures are presented.

548 NEW TYPE OF DETECTOR FOR SLOW NEUTRONS.

Rauch H., Grass F., Feigl B. (Oesterreichische Hochschule, Vienna).

Nucl. Instrum. Methods, 46: 153-6 (1967). (In German).

A neutron-detection method with several marked advantages over current methods is described. The method is based on the measurement of the conversion electrons formed during neutron capture in Gd. The conversion electrons are determined by means of surface barrier detectors. This method enables a detection probability of up to 70%. The main advantage of this detector system is its small size, rendering a low weight detector shielding system and the exact measurement of the place of the possible neutron absorption. This may be of interest for time-of-flight measurements.

549 PULSE SHAPE DISTRIBUTIONS FROM GAMMA-RAYS IN LITHIUM DRIFTED GERMANIUM DETECTORS.

Strauss M. G., Larsen R. N., Sifter L. L. (Argonne National Lab., Ill.).

Nucl. Instrum. Methods, 46: 45-54 (1967).

Pulse shape distributions resulting from the interaction of γ-rays in planar germanium detectors were studied as a function of field intensity, γ-ray energy, and detector width. It was observed that at 2300 V/cm the initial rate of charge collection approached 10 nsec/mm. Due to a slow component the total charge collection was about 30% longer. At 1000 V/cm the collection time was somewhat longer, and at 250 V/cm it was considerably longer. These observations appeared to be independent of γ-ray energy in the range of 0.6 to 3 MeV and detector widths of 3 to 11 mm. Events interacting near the center of the detector result in fast rising pulses and those interacting near one of the electrodes have a risetime which is approximately twice as long, thus giving rise to a distribution of pulse shapes. With low energy γ-rays all shapes occur with equal probability, but at higher energy the pulses tend to have a more uniform shape. Due to the spread in risetimes, signals from monoenergetic γ-rays do not cross a given pulse height level at the same time and therefore produce timing uncertainties. With a 1 cm detector timing uncertainties of more than 30 nsec were observed at the 50% level, and less than 5 nsec at the 5% level. It therefore appears that for accurate timing of all signals, the timing discriminator should be set at the lowest level consistent with the system noise. The variations in risetime can also affect the energy resolution. If a 1 cm detector is used in conjunction with a pulse shaping network consisting of a 1 μsec RC differentiator and integrator, the variations in risetimes may cause an amplitude spread on the order of 0.03%. At γ-ray energies of 10 MeV this is comparable to the spread due to statistics.

550 FAST PULSE PICKOFF WITH SEMICONDUCTOR RADIATION DETECTORS.

Quaranta A. Alberigi, Martini M., Ottaviani G. (Univ., Bologna).

Nucl. Instrum. Methods, 47: 10-12 (Jan. 1967).

The problem is investigated of extracting a fast signal at the same time of the energy signal from a solid state detector. The effect of the charge amplifier on this waveform is accounted for. A new method is suggested for achieving fast timing with this kind of detectors.

551 ARRAY DETECTORS AND EXTENDED SOURCE USED IN A DOUBLE FOCUSING BETA SPECTROMETER.

Nilsson O., Karlsson S.-E., Andersson I., Nordling C., Siegbahn K. (Uppsala Univ.).

Nucl. Instrum. Methods, 47: 13-22 (Jan. 1967).

The 50-cm iron-free beta spectrometer at Uppsala has been furnished with an array of close-lying semiconductor detectors and an extended source arrangement. The combined detector and source system increases the amount of information per time-unit more than 100 times. A description of the detector and source arrangements is given together with some applications.

552 FABRICATION OF GERMANIUM Li-DRIFTED DETECTORS.

Cappellani F., Fumagalli W., Henuset M., Restelli G. (CCR-EURATOM, Ispra, Italy).

Nucl. Instrum. Methods, 47; 121-4 (Jan. 1967).

A detailed description of the procedures used in constructing GeLi detectors is given. Planar and coaxial type detectors with active volumes up to 5 cm^3 and 18 cm^3 respectively have been obtained. Optimum resolutions for 120 keV and 1.330 keV gammas were: 3 keV and 4 keV for a planar 2 cm^3 detector and 4 keV and 7 keV for a coaxial 18 cm^3 detector, using a tube type preamplifier.

553 SCATTERING CHAMBER USING SEMICONDUCTOR DETECTORS.

Haque M. A. (Atomic Energy Center, Dacca, Pakistan), Holzer O. H., Hossain A., Sabir A., Siddiq A. K. M.

Nucl. Instrum. Methods, 47: 137-40 (Jan. 1967). (AECD /EP-14).

The design and construction of a 24″ dia scattering chamber which will be used primarly for angular distribution studies of neutron induced reactions are presented. Five semiconductor detectors can be used at a time to detect charged nuclear reaction products at different angles and at different distances with respect to the incident beam. The detectors are mounted on a rotating table which is graduated in degrees and is rotated externally. A liquid air trap is used in the vacuum system to prevent deposition of pump oil on the surface of the detectors.

554 NEW DOUBLE DELAY LINE AMPLIFIER USING ONE LINE ONLY.

Gorni S. (Hebrew Univ., Jerusalem).

Nucl. Instrum. Methods, 47: 74-6 (Jan. 1967).

A new double delay line amplifier is described. The double delay line bi-polar shaping is accomplished by one line only. The noise of the amplifier was better than that of the ordinary double delay line amplifier. The pulse width used in our amplifier was 50 ns and the rise time 10 ns. The amplifier was used as the second stage after the solid state charge sensitive amplifier.

555 DUAL ELEMENT, COAXIAL, Ge (Li) GAMMA RAY SPECTROMETER.

Lalovic B. (Univ. of Toronto).

Nucl. Instrum. Methods, 47: 173-5 (Jan. 1967).

A method which allows the assembly of germanium gamma spectrometers with sensitive volumes much larger than those of existing spectrometers is described. This method consists of stacking two or more coaxially drifted germanium diodes and using them as a single detector. The energy dependence of the photopeak and second escape peak efficiences of the dual element germanium spectrometer and of the constituent counters are shown. The absolute intrinsic efficiencies and the effect of increased solid angle are compared with the sum of the efficiencies of the individual counters.

556 MOBILITY OF ELECTRONS AND HOLES AT 77 DEG K IN LITHIUM-COMPENSATED GERMANIUM.

Kuchly J. M., Stab L., Henck R., Siffert P., Coche A. (Centre de Recherches Nucléaires, Strasbourg).

Nucl. Instrum. Methods, 47: 148-50 (Jan. 1967). (In French).

The drift mobility of electrons and holes was measured at 77°K. The observed minority carrier mobility is less than the mobility calculated from scattering by phonons and impurity atoms. The discrepancy, which is greater than a factor of 5 in some cases, has been attributed to collisions with substitutional oxygen (which has been measured by lithium precipitation).

557 TIME DEPENDENCE OF COAXIAL-DRIFT PROCESS.

Rezanka I. (Inst. of Nuclear Research, Czechoslovak Academy of Sciences, Rez).

Nucl. Instrum. Methods, 47: 181-2 (Jan. 1967).

Time dependence of intrinsic region formation is derived in the approximation of great t for two limiting of coaxial drift processes.

558 PHOTOPEAK AND DOUBLE-ESCAPE PEAK EFFICIENCIES OF GERMANIUM LITHIUM DRIFT DETECTORS.

De Castro Faria N. A., Levesque R. J. A. (Univ., Montreal).

Nucl. Instrum. Method, 46: 325-32 (1967).

Theoretical calculations by the Monte Carlo method of the intrinsic efficiencies, photo and double-escape fractions of Ge(Li) drift detectors for parallel beams of gamma rays in the range of energy from 100 keV to 10 MeV. For the photopeak efficiencies the calculations were made from 100 keV to 1.5 MeV and for the double-escape peak efficiencies, they were carried for energies greater than 1.5 MeV. The detectors considered were cylinders having 18 mm dia. and depletion depths of 2, 3.5, 4, 5, 6, 7, 8, 9, and 10 mm. The results are compared with the experimental values obtained by Ewan et al. with an 18×3.5 mm detector, for both the photopeak and the double-escape peak efficiencies and with a 5 $cm^2 \times 8$ mm for the full energy peak efficiency.

559 FINITE SOLID ANGLE CORRECTIONS TO ANGULAR CORRELATIONS FOR SQUARE Ge(Li) GAMMA DETECTORS.

Avida R., Atzmony U., Unna I. (Hebrew Univ., Jerusalem).

Nucl. Instrum. Methods, 46: 350-4 (1967).

Geometrical corrections for angular correlation measurements with square Ge(Li) detectors and extended linear sources are calculated.

560 CALCULATION OF ANGULAR CORRELATION ATTENUATION FACTORS AND EFFICIENCIES FOR LITHIUM DRIFTED GERMANIUM DETECTORS.

Black J. L., Gruhle W. (Stanford Univ., Calif.).

Nucl. Instrum. Methods, 46: 213-22 (1967).

Angular correlation attenuation factors and efficiencies were computed for eleven Ge(Li) detectors with sensitive volumes in the range 0.3 cm^3 to 8.0 cm^3. The calculations were carried out for eight source-detector separations in the range 1.0 to 10.0 cm.

561 A MINIATURE COOLING SYSTEM FOR Ge(Li) SOLID-STATE DETECTORS.

Williamson C. F., Alster J. (Univ. of Washington, Seattle).

Nucl. Instrum. Methods, 46: 341-3 (1967). (RLO-1388-4).

A cooling system using a Joule-Thompson cryostat is described for the convenient use of a Ge(Li) solid-state detector in a vacuum chamber or in an anticoincidence annulus.

562 GENERATION-RECOMBINATION NOISE AND ITS INFLUENCE ON THE ENERGY RESOLUTION OF DIFFUSED SILICON p-n JUNCTION RADIATION DETECTORS.

Deshpande R. Y. (Atomic Energy Establishment, Trombay, India).

Nucl. Instrum. Methods, 46: 255-60 (1967).

A basic mechanism limiting the energy resolution of p-n junction nuclear radiation detectors is proposed. Shockley-Read-Hall statistics are applied to determine the time constant of the charge-fluctuation at the generation-recombination centers. Some factors governing this time constant are discussed. A specific case of diffused silicon p-n junction detectors, for which information about the generation-recombination centers is available, is then worked out. The charge-fluctuation time constant is used as a normalizing parameter to evaluate the noise-power spectrum of the detector-amplifier system. Finally, some design considerations of the system are presented.

563 ANALYSIS OF GAMMA-RAY SPECTRA FROM NaI(Tl) AND Ge(Li) SPECTROMETERS. COMPUTER PROGRAMS.

Helmer R. G., Heath R. L., Schmittroth L. A., Jayne G. A., Wagner L. M. (Phillips Petroleum Co., Idaho Falls, Idaho).

Nucl. Instrum. Methods, 47: 305-19 (1967).

Descriptions are given of two computer programs that are used in the analysis of gamma-ray spectra from NaI(Tl) scintillation spectrometers. The programs can be used to determine the contributions to an experimental spectrum from either a set of isotopes or a set of monoenergetic gamma rays. In the former case, both the intensities and gains of the components can be varied to

obtain the best fit. In the latter case both the intensities and energies can be varied. Examples of fits to experimental spectra are presented for both NaI(Tl) and Ge(Li) spectrometers.

564 METHOD FOR GENERATING SINGLE GAMMA-RAY SHAPES FOR THE ANALYSIS OF SPECTRA.

Heath R. L., Helmer R., Schmittroth L. A., Cazier G. A. (Phillips Petroleum Co., Idaho Falls, Idaho).

Nucl. Instrum. Methods, 47: 281-304 (1967).

A method is described for the calculation of pulse-height distributions which represent the response of a NaI scintillation spectrometer to monoenergetic photons. The method is based upon an interpolation between experimental spectra for sources emitting only one gamma ray. A description of the experimental procedures used to accumulate input data is given. This discussion includes the analysis of photopeak shapes, detector efficiency, and the nonlinear relationship between energy and pulse-height NaI. The interpolation method is described. To illustrate the quality of the resulting calculated gamma-ray shapes, they are compared with input and other simple spectra. The application of this method to spectra obtained with germanium detectors is discussed.

565 DETERMINATION OF FISSION FRAGMENT ENERGIES USING SOLID-STATE DETECTORS.

Forgue V., Kahn S. (Aerojet-General Nucleonics, San Ramon, Calif.).

Nucl. Instrum. Methods, 48: 93-102 (Feb. 11, 1967).

A method of correcting for the pulse height defect of fission fragments in silicon surface barrier detectors is described. Loss of energy in the gold window and by elastic collisions in the silicon are considered as well as loss of pulse height from incomplete charge collection in the detector. The method gives identical results for the degraded energies of fission fragments passing trough a given amount of gas when the total defects of the detectors used differ by 15 MeV.

566 TRAPPING IN DEFECT STATES AS A SOURCE OF THE PULSE HEIGHT DEFECT IN SILICON SURFACE BARRIER DETECTORS.

Eisler P. L. (Div. of Mineral Chemistry, Port Melbourne, Australia).

Nucl. Instrum. Methods, 48: 103-8 (Feb. 11, 1967).

The evidence from charge collection efficiency measurements is considered in the light of the various processes which limit the speed of transient response in silicon surface barrier detectors. This establishes that trapping is predominantly responsible for the apparent inefficiency of the charge collection process. A method of measuring the energy difference between a trapping level and the edge of the appropriate vacant energy band was devised in terms of a simple theoretical model. In the case of a detector for which this model was suitably accurate, this energy difference was 0.23 eV.

567 A PARTICLE IDENTIFICATION SYSTEM FOR USE WITH 30 MeV ^{3}He PARTICLES.

Broadhurst J. H., Pyle G. J. B. (Univ. of Birmingham, Eng.).

Nucl. Instrum. Methods, 48: 117-24 (Feb. 11, 1967).

A particle identification system is described which is based on a fast multiplication of signals proportional to dE/dx and E from a silicon surface barrier counter telescope. This system is compared with others already in use which generate a similar product for particle identification. The performance of the system for identification of ^{3}He and α-particles in the 10 to 40 MeV energy region is shown as an illustration of the capability of the system.

568 IONIZATION FLUCTUATIONS AND RESOLUTION OF IONIZATION CHAMBERS AND SEMICONDUCTOR DETECTORS.

Alkhazov G. D., Komar A. P., Vorobev A. A. (Ioffe Inst. of Physics and Tech., Leningrad).

Nucl. Instrum. Methods, 48: 1-12 (Feb. 11, 1967).

The Fano factor F determining the variance of ionization fluctuations is calculated by Fano's approximate method for a variety of gases and for Si and Ge. The calculated Fano-factor for He, Ne, Ar, He+0.5% Ar; Ne+0.5% Ar; Ar + 0.5% C_2H_2 equals to 0.17; 0.17; 0.17; 0.055; 0.05; 0.075 respectively. Ionization fluctuations in semiconductors are calculated using Shockley's and Hodgkinson's models of the ionization process in solids. Both models give fairly close results: $F_{Si} = 0.05 + 0.1$; $F_{Ge} = 0.1 - 0.2$. The Fano factor is measured for Ar and Ar — 0.5% C_2H_2 in a gridded ionization chamber. The fwhm (for $E_{alpha} = 5.68$ MeV) is 13 keV; F_{exp} is 0.19 for Ar and $\leqslant 0.09$ for Ar + 0.5% C_2H_2, being in good agreement with the calculations. The ultimate fwhm of gas ionization chambers may be 7 keV at an α-particle energy of $E_{alpha} =$ 6 MeV. The ultimate resolution of semiconductor γ- and β-detectors is about 1 keV at $E_{beta, gamma} = 600$ keV, whereas that of semiconductor α-detectors is probably 5—6 keV.

569 SEMICONDUCTOR DETECTOR AS A FAST NEUTRON SPECTROMETER.

Miller R. G., Kavanagh R. W. (California Inst. of Tech., Pasadena).

Nucl. Instrum. Methods, 48: 13-27 (Feb. 11, 1967).

Silicon semiconductor detectors have been used to measure the energies of 6 to 17-MeV neutrons to a precision of 5 to 15 keV by utilizing (n,α) and (n,p) nuclear reactions in the active volumes of the detectors. Criteria for the selection and use of a detector are given. Various combinations of cross sections for the most important detection processes, ^{28}Si(n,α)^{25}Mg and ^{28}Si(n,p)^{28}Al, are presented for reactions leading to the first four states of both residual nuclei for neutron energies from 7.2 to 16.4 MeV, facilitating the use of the detector for determination of neutron flux. Resolution and pulse-height anomalies associated with the recoil ^{25}Mg and ^{28}Al ions are described. Methods of data analysis are discussed.

570 HIGH TEMPERATURE BEHAVIOR AND LONG-TERM STABILITY OF LITHIUM DRIFTED SILICON SURFACE-BARRIER DETECTORS.

Tuzzolino A. J., Perkins M. A., Kristoff J. (Univ. of Chicago).

Nucl. Instrum. Methods, 48: 33-41 (Feb. 11, 1967).

Lithium-drifted silicon surface-barrier detectors were fabricated which exhibit stable electric and α-particle characteristics under conditions of prolonged aging and repeated exposure to thermal-vacuum environments. The detectors will operate at a temperature of 85°C and high vacuum for several days and at a temperature of 100°C and high vacuum for several hours, with no evidence of noise instability. The operating characteristics of such detectors were studied over a period of fourteen months. These studies included measurements of their electric and α-particle characteristics taken before, during and after extended thermal-vacuum testing at 50 and 85°C and short-term testing at 100°C. Degradation in electric and α-particle characteristics resulting from such testing and aging was found to be negligible over the fourteen month time period. The α-particle measurements at 100°C indicate that the fractional change in the mean energy per ion pair in going from room temperature to 100°C is approximately —1.8%. The results of these studies are reported.

571 (ORNL-4039) ANALYTICAL CHEMISTRY DIVISION ANNUAL PROGRESS REPORT FOR PERIOD ENDING OCTOBER 31, 1966.

Raaen Helen P. (comp. and ed.) (Oak Ridge National Lab., Tenn.).

Jan. 1967. Contract W-7405-eng-26. 168 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

Developments are reported for research on: analytical instrumentation; effects of radiation on analytical methods; analytical chemistry for reactor projects; special analytical methods; analytical biochemistry; x-ray and spectrochemical analyses; mass spectrometry; optical and electron microscopy; nuclear and radiochemical analyses; inorganic and organic preparations; mass spectrometric analyses; spectrochemical analysis laboratory; and process analysis. The ORNL master analytical manual is appended.

572 IMPROVEMENT OF ALPHA-PARTICLE RESOLUTION OF SILICON SURFACE-BARRIER DETECTORS BY COOLING.

Engelkemeir D. (Argonne National Lab., Ill.).

Nucl. Instrum. Methods, 48: 335-7 (1967).

It is shown that the alpha-particle resolution of surface-barrier Si detectors may be significantly improved by cooling to about —30°C. This improvement is due principally to the reduction of leakage currents which contribute to preamplifier noise. Cooled detectors of 1 cm^2 area typically give line widths of 13—15 keV fwhm for 5.5 MeV alpha particles.

573 MOUNTING PROCEDURE FOR Ge(Li) DETECTORS.

Adams F. (Ghent Univ.).

Nucl. Instrum. Methods, 48: 338-40 (1967).

A method for mounting lithium-drifted germanium detectors is described. The method consists of etching in a 3—1 mixture HNO_3 70%—HF 50% at 80°C immediately after the clean-up drift, quenching in bidistilled water, application of Ga—In contacts, and immersion in 30% H_2O_2 for 30 min. The detector is then dried on filter paper in a clean atmosphere of 48—50% relative humidity, installed in a cryostat, and brought under a vacuum.

574 SPECTROMETRY OF LOW-ENERGY γ- AND X-RAYS WITH Ge(Li) DETECTORS.

Drexler G., Perzl F. (Gesellschaft für Strahlenforschung mbH, Munich).

Nucl. Instrum. Methods, 48: 332-4 (1967).

The efficiency of lithium-drifted germanium detectors for gamma-ray and x-ray spectrometry is discussed.

575 PULSE SHAPE DISCRIMINATION CIRCUIT FOR LITHIUM-DRIFTED GERMANIUM DIODES.

Tamm U., Michaelis W., Coussieu P. (Kernforschungszentrum, Karlsruhe, Ger.).

Nucl. Instrum. Methods, 48: 301-5 (1967).

A pulse-shape discrimination circuit was developed which is sensitive to a slow time-constant component in the charge carrier collection of lithium-drifted germanium detectors. Preamplifier output pulses containing such a component are rejected. By this method the spectrum shapes can be improved considerably. In high-energy gamma-ray spectra the background under the peaks is reduced by a factor of up to 3. The resolution of the spectra is not affected. The attenuation of the peaks is certainly less than 10%.

576 USE OF CRYSTAL DIFFRACTION WITH Ge DIODE DETECTOR FOR HIGH RESOLUTION GAMMA-RAY SPECTROSCOPY.

Smither R. K., Namenson A. I. (Argonne National Lab., Ill.).

Rev. Sci. Instrum., 38: 52-65 (Jan. 1967).

The Argonne 7.7 m bent crystal gamma-ray spectrometer is combined with a lithium drifted Ge diode detector to perform high resolution gamma-ray spectroscopy on complicated neutron capture gamma-ray spectra. The system combines the energy precision of the bent crystal spectrometer with the high resolution of the Ge diode. The system is most useful in the 1—3 MeV energy range where both the precision and energy resolution obtained by the combined system frequently are from 3 to 10 times those of either the bent crystal or the Ge diode used

individually. A 50-fold improvement in the signal-to-background ratio is obtained through the use of the combined system. The use of the system is illustrated by $^{113}Cd(n,\gamma)^{114}Cd$ spectra. The Argonne system is compared with other possible crystal diffraction arrangements and with coincidence and anticoincidence techniques for improving the quality of the (n,γ) measurements. The application of the Argonne system to the comparison of (n,γ) transitions with gamma transitions following radioactive decay is discussed. New values for the strong gamma transition associated with the decay of ^{137}Cs and ^{60}Co are quoted along with a more precise value (1294.35 ± 0.30 keV) for the gamma ray associated with the decay of ^{41}A. Improvements in the Argonne system are described and a proposed extension of the system for precision energy measurements in the 2—5 MeV range is discussed.

577 SIMPLE CONTACTLESS METHOD FOR MEASURING DECAY TIME OF PHOTOCONDUCTIVITY IN SILICON.

Lichtenstein R. M., Willard H. J. Jr. (Rensselaer Polytechnic Inst., Troy, N. Y.).

Rev. Sci. Instrum., 38: 133-4 (Jan. 1967).

A method is described for measuring decay time of photoconductivity in silicon. The technique is to induce eddy currents in a silicon disk by means of an alternating magnetic field and to monitor the power absorbed by the sample.

578 (UCD-CNL-74) DIRECTIONAL CORRELATION ATTENUATION COEFFICIENTS WITH Ge DETECTORS.

Carlson George A. (California Univ., Davis. Crocker Nuclear Lab.).

Jan. 23, 1967. Contract AT(11-1)-Gen-10. 32 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

Methods are presented for finding accurate attenuation coefficients for a rectangular Ge detector. The coefficients and the corresponding ones for a cylindrical NaI detector are used in the Legendre polynomial series representing the directional correlation function for the finite solid angles subtended by the detectors. Examples are given for particular cases, and the computer program used in the calculation is included.

579 LEAKAGE CURRENT AND NOISES IN SURFACE BARRIER PARTICLE DETECTORS.

Masuda M. (Tokyo Inst. of Tech.), Takeda S., Chisaka H.

Nucl. Instrum. Methods, 49: 77-85 (Mar. 1967).

In order to obtain better semiconductor particle detectors, an investigation to understand the problems of surface effects was undertaken using planar type surface barrier detectors. The diode capacitance, the diode V-I characteristics and the noises were measured as a function of temperature in many detectors. The dominant reverse current was not correlated with the noises. The planar type detector was easy to perform and the surface phenomena were easy to understand.

580 AUTOMATIC APPARATUS FOR α-γ ANGULAR CORRELATION MEASUREMENTS.

Lewis A. R., Morris J. P. (Massachusetts Inst. of Tech., Cambridge).

Nucl. Instrum. Methods, 49: 61-70 (Mar. 1967).

Automatic equipment for the measurement of α—γ angular correlations is described. The circuitry for automatic operations is given in detail. Detectors used in the system are a coaxial Ge(Li) crystal for γ-rays and a silicon surface barrier detector for α particles. A simple method of determining the relative efficiency of the Ge(Li) detector as a function of energy is outlined. The electronics used for coincidence has a resolving time of $\sim$5 nsec.

581 CHARGED PARTICLE SPECTROMETER FOR SPACE EXPERIMENTATION.

Rinehart M. C., Winslow R. G. (Philco Corp., Palo Alto, Calif.).

Nucl. Instrum. Methods, 49: 125-44 (Mar. 1967).

The design and some test results for a near-earth satellite-borne solid state detector spectrometer intended to provide useful data on the directionality, spectral intensity, and time fluctuations of the natural and artificial trapped radiation belts, solar flare proton- and alpha emissions, and primary cosmic ray protons and alphas are discussed. The objectives of the intended experiment translate into requirements of instrument performance which are concerned with the identification of the particle types in the environment and the simultaneous measurement of the spectral intensity of each, with sufficient directional time, and energy resolution to allow the data to be related to current models of trapped belt structure and flare proton propagation. The significant performance characteristics of the electronic modules under pulser excitation are described, and the response of the solid state detectors to electrons and protons of various energies is displayed. Particular attention is given to the particle mass and energy resolution achievable with the chosen technique over a wide energy range characteristic of space radiation.

582 (AECL-2637) APPLICATION OF SOLID STATE AMPLIFYING RADIATION DETECTORS IN HEALTH PHYSICS.

Jones A. R. (Atomic Energy of Canada Ltd., Chalk River [Ontario]).

Jan. 1967. 20 p. Dep. mn. CFSTI $3.00 cy, $0.50 mn. AECL $0.50.

To assess amplifying radiation detectors for use in health physics, measurements were made on five samples. The properties measured were: dependence of noise on applied voltage, gain on applied voltage, sensitivity of gamma rays on energy, sensitivity to gamma rays on voltage, and sensitivity to gamma rays on temperature. The results of these measurements are presented and suggest that the detectors would be suitable for measuring exposures, or doses, and their rates over a wide range of energies (0.03-1.25 MeV) and over a wide range of exposure rates (background up to $\sim$1000 Roentgens/hour).

583 EFFECTS OF OXIDATION ON SURFACE-BARRIER DETECTORS.

Chisaka Haruo (Tokyo Metropolitan Isotope Research Center), Morita Eiichi, Takeda Shigeru, Masuda Masayoshi.

Jap. J. Appl. Phys., 6: 542-3 (1967).

An investigation was undertaken in order to find the best surface treatment for surface barrier detectors. The leakage current, noises, and photoresponses were measured for various surface treatment and a correlation between these factors was also investigated.

584 NOVEL LITHIUM DRIFT CONTROL METHOD FOR SILICON AND GERMANIUM RADIATION DETECTORS.

Schueler W. A. (Oak Ridge Technical Enterprises Corp., Tenn.).

Rev. Sci. Instrum., 38: 539-41 (Apr. 1967).

A method and an apparatus are described which allow a non-destructive indication of the progress of the drifting operation. While drifting, pulsed light is shone onto the face opposite the lithium diffused layer of the device. The photosensitivity of the detector is used to obtain a signal whose amplitude is inversely proportional to the window thickness, i.e., the thickness of the undrifted region. A charge sensitive amplifier and a peak rectifier convert the pulses into a dc signal which is used for window thickness indication.

585 FABRICATION OF SURFACE-BARRIER NUCLEAR PARTICLE DETECTORS FROM p-TYPE SILICON.

Mathew P. J. (Univ. of Wellington, New Zealand), Chapman N. G., Coote G. E.

Nucl. Instrum. Methods, 49: 245-7 (1967).

A simple method is described by which surface barrier detectors of excellent performance can be constructed from p-type silicon of resistivity up to at least 5000 ohm · cm. The rectifying front electrode is a vacuum evaporated aluminium film and the rear electrode is a similar film of gold. An important feature of the method is that the silicon surface is prepared by gradually quenching the CP4A etchant with concentrated nitric acid, followed by slow decanting with deionized water. Unencapsulated detectors show excellent long term stability in both air and vacuum. For detectors of area 20 mm^2 typical energy resolution (fwhm) for 5.5 MeV alpha particles is 30 keV. Thin totally depleted detectors were successfully made in this way and the surface preparation technique appears to have advantages in the fabrication of conventional surface barrier detectors from n-type silicon.

586 DETECTION OF 160 MeV PROTONS BY A LITHIUM-DRIFTED GERMANIUM COUNTER IN A SIDE-ENTRY ORIENTATION.

Gruhn C. R. (Michigan State Univ., East Lansing), Kuo T., Gottschalk B., Kannenberg S., Wall N. S.

Phys. Lett., 24B: 266-7 (Mar. 20, 1967).

A lithium-drifted germanium counter was constructed and used to measure the energy of 180-MeV protons with a resolution of 650 ± 50 keV (f.w.h.m.).

587 ENERGY DEPENDENCE OF PULSE HEIGHT DEFECT WITH FISSION FRAGMENTS IN A SILICON SURFACE BARRIER DETECTOR.

Andritsopoulos G. (Univ. of Reading, Eng.).

Nucl. Instrum. Methods, 50: 177-8 (1967).

An energy dependence of pulse height defect is observed above 100 MeV for fission fragments of the same mass. The method used involves the measurement of the correlated energies and velocities of the fission fragments from ^{235}U, by using a time-of-flight technique with Si-surface barrier detectors for the fragment detection.

588 INFLUENCE OF THE ENTRANCE WINDOW ON THE ENERGY RESOLUTION OF SURFACE BARRIER SEMICONDUCTOR DETECTORS.

Fabri G., Karolyi J., Svelto V. (Laboratori CISE, Milan).

Nucl. Instrum. Methods, 50: 50-2 (1967).

The energy straggling due to the gold layer of the semiconductor surface barrier detector was calculated and measured. This effect on the linewidth is appreciable in the case of α particles and heavier ions and sets a limit to the resolution. The contribution to the linewidth due to the gold layer is for the usual thicknesses about 10-14 keV in fwhm for 6-MeV α particles.

589 CARRIER MULTIPLICATION IN SEMICONDUCTOR DETECTORS.

Ogawa I. (Rikkyo Univ., Tokyo).

Nucl. Instrum. Methods, 49: 325-33 (1967).

On the basis of a slightly modified version of the Townsend-Miller theory of electron avalanches accompanied by β-mechanism, it is shown that the observed dependence of the multiplication factor M in an internally amplifying semiconductor detector upon the position x_0 of the formation of primary electron-hole pairs should be attributed primarily to the marked difference in ionization coefficient between electrons and holes in the material and not to the non-uniformity of the electric field within the depletion region. A formula for $M(x_0)$ is presented together with its simplified forms in particular cases. Expressions and estimations are also given of the intrinsic fluctuation of avalanche sizes.

590 LINEARITY OF A Ge(Li) DETECTOR IN THE RANGE 0.5 TO 10 MeV.

Levy A. J., Ritter R. C. (Univ. of Virginia, Charlottesville).

Nucl. Instrum. Methods, 49: 359-60 (1967).

The linearity of an annular germanium lithium-drifted gamma detector was measured to be $<0.046\%$ over a range of 0.5 to 10 MeV.

591 FIRST RESULTS ON PROTON DEUTERON DISCRIMINATION WITH A SINGLE SEMICONDUCTOR DETECTOR.

Alberigi Quaranta A., Martini M., Ottaviani G., Zanarini G. (INFN, Bologna).

Nucl. Instrum. Methods, 50: 169 (1967).

An experiment is described whereby the charge collection time in semiconductor detectors can be determined by measuring the amplitude of the output current pulse.

592 ELECTRICAL DOMAINS IN SEMICONDUCTORS WITH HOT ELECTRONS.

Bonch-Bruevich V. L.

Soviet Physics - Solid State, Vol. 8, No. 2, Feb. 1966, p. 290-296.

We have considered the steady-state nonlinear problem of the charge density and electric field intensity distributions in cases where heating of the electron gas may lead to the creation of negative differential conductivity σ. We describe the conditions under which electric domains (regions of high and low field intensity) arise. We show that hysteresis may occur under certain conditions: domains are formed or not formed depending on the creation of a state with a given value of σ.

593 COLD FINGER CRYOSTATS FOR LITHIUM-DRIFTED GERMANIUM DETECTORS.

Buhler S., Marcus L. (Institut de Physique Nucléaire, Orsay, France).

Nucl. Instrum. Methods, 50: 170-2 (1967).

Cold finger type cryostats of different shapes with self-containing vacuum are described. Very long cold fingers need internal liquid nitrogen circulation in order to shorten the cool-down period and to get lower temperatures of the detector. Conditioning and performances of such cryostats are described.

594 IMPROVEMENTS RELATING TO SOLID STATE DEVICES.

Freck David Vernon, Rouse Robert Lindsay, Wakefield James (Associated Electrical Industries Ltd.).

British Patent 1,058,753. Feb. 15, 1967. Filed Nov. 2, 1962.

A method of manufacturing solid state p-i-n junction devices comprising a first stage in which lithium is diffused into a p-type semiconductor material so as partially to compensate the acceptors without changing the conductivity type of the semiconductor material, a second stage in which further lithium vapor is diffused part of the way through the semiconductor so as to change the conductivity type of the semiconductor material and form a p-n junction and a third stage in which a reverse bias is applied across the junction while heated to form an intrinsic region between the opposite conductivity type zones. The semiconductor material being is silicon or germanium.

595 IMPROVEMENTS RELATING TO SOLID STATE RADIATION DETECTORS.

Wakefield James, Waters Derek George, Pope Rex Anthony (Associated Electrical Industries Ltd.).

British Patent 1,058,754. Feb. 15, 1967. Filed May 2, 1963.

Improvements to silicon and germanium radiation detectors are described, which reduce the Compton effect arising in the detection of x and gamma radiation.

596 DOPPLER BROADENING OF ANNIHILATION RADIATION.

Murray G. (Univ. of Manchester, Eng.).

Phys. Lett., 24B: 268-9 (Mar. 20, 1967).

The Doppler broadening of annihilation radiation was observed using a Ge(Li) detector. It is pointed out that detailed information on the motion of the annihilating positron-electron pairs may readily be obtained using such detectors.

597 SOLID STATE ALPHA MONITOR (ENGINEERING MATERIALS).

(Oak Ridge National Lab., Tenn.).

(CAPE-1495).

1 drawing.

The instrument was designed to monitor the position of elution peaks during the separation of transplutonium elements by an ion exchange column. The instrument is comprised of a solid-state detector, a charge-sensitive preamplifier, a main amplifier, and a count-rate meter. (For details see TID-4100 Suppl. 37).

598 (MIT-952-3, pp 349-402) INSTRUMENTATION TECHNIQUES AND NUCLEAR GEOCHEMISTRY.

(Massachusetts Inst. of Tech., Cambridge. Dept. of Physics).

The following instrumentation techniques are described: low-noise charge-sensitive preamplifiers for semiconductor detectors; data processing; electronic equipment for alpha-gamma coincidence spectroscopy; automatic alpha-gamma angular correlation apparatus; ^{227}Ac thin source preparation; and contoured diffused-junction detectors. The following studies in nuclear geochemistry are reported: three-dimensional electrical analog studies of pressure-induced interstitial flow in underground mine environments and the application of lithium-drifted germanium detectors to neutron activation analysis.

599 FAST PULSE AMPLIFIER (ENGINEERING MATERIALS).

(Oak Ridge National Lab., Tenn.).

(CAPE-1470).

1 drawing.

A nanosecond high-gain pulse amplifier with a rise time of 1 nsec at a current gain of 270 is used with an accelerator beam probe and connected with 150 ft of high quality coaxial cable. The amplifier is also suitable for application with semiconductor detectors and fast ionization chambers. (For details see TID-4100 Suppl. 38).

600 (ORNL-4007, pp 171-210) RADIATION DOSIMETRY.

Auxier J. A. (Oak Ridge National Lab., Tenn.).

Progress is reported in the evaluation of γ and neutron doses received by residents of Hiroshima and Nagasaki exposed to the effects of atomic explosions and the effects of various shielding parameters on the radiation doses. The design of a semiconductor absolute neutron dosimeter is described and results of performance tests are reported. A series of equations based on stopping-power theory were developed to predict radiation injuries after exposure of biological systems. A transistorized fast neutron dose integrator was built for use in the presence of severe environmental conditions. Neutron cross sections are presented for the production of γ rays in air by the $^{14}N(n,\gamma)^{15}N$; $^{14}N(n,\alpha)^{11}B$; $^{40}Ar(n,\gamma)^{41}Ar$; $^{16}O(n,n')^{16}O$; $^{16}O(n,\alpha)^{13}C$; or $^{16}O(n,p)^{16}N$ reactions that show that ^{14}N is the dominant γ producing source in air with most of the γ rays coming from the inelastic scattering of neutrons by ^{14}N and ^{16}O. Work is reported in progress to determine neutron cross sections for elements in tissue for use in calculations of depth dose in tissue-equivalent phantoms. The distribution of ionization during recombination in ionization chambers was used to study ionization induced by γ or neutron sources. Typical values are presented for linear energy transfer of keV per micron in unit density tissue. The possible use of silver-activated methaphosphate glass and a fluoroglass reader for personnel monitoring is discussed. Neutron-energy threshold detector units employing solid-state nuclear tract detectors were improved by replacing the conventional fissile foils with fissile radiators and nuclear track detectors. Results are reported from an intercomparison of nuclear accident dosimetry systems in which 7 groups participated. A Monte Carlo digital computer code simulating various physical experimental situations was used to study depth dose as a function of energy in a man-equivalent phantom composed of H, C, N, and O in the proportions found in soft tissue and depth dose and LET spectra were computed for 10 different monoenergetic neutron beams ranging from 0.025 eV to 2.5 MeV. Neutron depth dose studies were also made in a 30-cm-diameter × 60-cm cylindrical water phantom. The sensitivity of cellulose acetate butyrate for use in solid-state α particle track detection was evaluated. Plastics were irradiated with helium ions and deuterons using the DOSAR low-energy accelerator and the design is described of a deflection chamber for use with a pair of beam deflection plates on the target end of DOSAR during the irradiation. A technique was developed for the correction of readings from the Radsan neutron-dosimetry system taken in radiation fields of unknown spectra. The final endurance testing of the 150-keV positive-ion accelerator (HPRR) was completed and the accelerator was shipped to the Nevada Test Site and the installation is described. Containers for shipping accelerator targets were designed and fabricated. The Health Physics Research Reactor was operated for a total of 271 hr. Minor design modifications to improve reproducibility of burst yield are reported.

601 (UCRL-50007-66-1, pp 15-21) SOLID STATE BETA SPECTROMETER.

Prevo C. T., Cate J. L. (California Univ., Livermore, Lawrence Radiation Lab.).

The use of Li-drifted silicon detectors as a means of measuring β spectra is investigated. A simple analytical method that allows fairly rapid identification of Emax (with accuracies of circa $\pm$ 5%) and the resolution of up to 3 or 5 superimposed spectra is described.

602 (ANL-7029, pp 4-8) THE 7.7-m BENT CRYSTAL SPECTROMETER.

Smither R. K., Namenson A. I. (Argonne National Lab., Ill.).

A combination gamma spectrometer which makes use of a Ge-diode gamma-ray detector in conjunction with the Argonne 7.7-m bent-crystal spectrometer is described. This combination spectrometer takes advantage of superior energy resolution (above 1 MeV) of the Ge diode while retaining the high signal-to-noise ratio and energy precision of the bent-crystal spectrometer. Examples of its performance are presented.

603 (UCRL-13272) FURTHER DEVELOPMENT OF SEMICONDUCTOR DETECTORS FOR GAMMA TRANSIENT DETECTION.

Final Report.

(Solid State Radiations, Inc., Los Angeles, Calif.).

[nd]. Contract W-7405-eng-48. 61 p. Dep. mn. CFSTI $3.00 cy, $0.65 mn.

For California Univ., Livermore. Lawrence Radiation Lab.

The fabrication of semiconductor detectors for gamma transient detection is discussed. Germanium, gold-doped silicon, gallium arsenide, as well as silicon diodes were fabricated and evaluated. Methods of optical dry running of semiconductors were investigated and a pulsed xenon flash lamp was designed for field use. Finally, prototype silicon diodes suitable for application in a high-vacuum photodiode were designed and fabricated.

604 RADIATION DOSIMETRY. SECOND EDITION. VOLUME II. INSTRUMENTATION.

Attix Frank H., Roesch William C. (eds.).

New York, Academic Press, 1966. 475 p. $20.00.

The instrumentation used in radiation dosimetry is discussed. Topics include ionization chambers, Geiger-Mueller and proportional counters, scintillation detectors, chemical dosimetry, solid-state integrating dosimeters, solid-state electric conductivity dosimeters, dosimetry with photographic emulsions, and calorimetry.

605 RESOLUTION LIMITATION OF SOLID STATE RADIATION DETECTORS FOR HEAVY PARTICLES.

Siffert P., Coche A., Hibou F.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 225-230.

The resolutions of semiconductor detectors were measured for protons, deuterons, α particles and $^4He^+$ ions at different energies between 20 keV and 5.5 MeV. We obtained limits of the Fano factor and evaluated the contribution of nuclear collisions to the half-maximum width of the α particle peaks. The latter result is compared with LINDHARD and NIELSEN'S calculations. Moreover we measured differences between electron-hole pair creation energies for the different particles.

606 A LOW BACKGROUND SEMICONDUCTOR COUNTER TELESCOPE FOR NEUTRON REACTION STUDIES.

Lalovic B., Ajdacic V., Pai H.L., Petrovic B.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 221-224.

A telescope system is described, in which coincidence or anticoincidence of associated alpha particle pulses from the $H^3(d,n)He^4$ reaction with pulses produced in the counters is required in order to reduce the background in investigations of 14 MeV neutron induced reactions. By using current pulse transformers with surface barrier semiconductor counters and fast electronics, coincidence resolving time between neutron induced pulses in the counters and associated alpha particle pulses of 1.6 ns is reduced by an order of magnitude. The same method may be employed for studies using lithium-drifted germanium counters, both with 14 MeV neutrons and neutrons produced in the $H^2(d,n)He^3$ reaction.

607 THE CHECKER BOARD COUNTER: A SEMICONDUCTOR dE/dx DETECTOR WITH POSITION INDICATION.

Hofker W. K., Oosthoek D. P., Hoeberechts A. M. E., van Dantzig R., Mulder K., Oberski J. E. J., Koerts L. A. Ch., Dieperink J. H., Kok E., Rumphorst R. F.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 208-213.

As part of an extensive design study for a cyclotron project containing a few hundred semiconductor detectors of different types, we have developed a new version of the (dE/dx) detector as used in (dE/dx x E) telescopes. This checker board counter delivers, besides the ΔE signal, also information about the position of the incident particles. With this detector the angular distributions of charged reaction products can be measured with high angular accuracy in a large solid angle, while slit scattering is eliminated. The checker board counter is essentially a dE/dx detector, which is subdivised in a large number of sensitive fields. These are obtained by placing counter electrodes in the form of parallel strips on each side of the detector in such a way that the back and front side patterns are perpendicular to each other, together forming a rectangular coordinate system. In our case a checker board counter with 88 sensitive fields of $1.37 \times 1.37\ mm^2$ maintaining an angular accuracy of 1 degree with an 88-fold increase in solid angle was chosen. Some aspects of the electronic read-out system of the detector are given.

608 EFFECTIVE CHARGE CARRIER LIFETIME IN SILICON p-i-n JUNCTION DETECTORS.

Coleman J. A., Swartzendruber L. J.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 240-244.

An estimate of the effective charge carrier lifetime can be obtained from a determination of the collection efficiency as a function of the transit time for charge carriers produced by incident short-range radiation in a p-i-n junction detector. The results of this method have the advantage of being independent of both the charge carrier mobility and the depletion depth of the detector. Effective lifetimes as low as a few microseconds (τ_e) for electrons produced by natural alpha particles have been observed in several 2 mm thick lithium-compensated silicon detectors operating at room temperature. No significant bias dependent windows which might cause misleading interpretation of the results were observed. Window effects were investigated by measuring the changes in pulse height of detector output signals initiated by natural alpha particles incident on the detectors at angles up to 45 degrees. The electron lifetimes were observed to decrease when the detector was operated at liquid nitrogen temperature. The short effective lifetimes that can occur in lithium-compensated silicon set a lover limit on the field strengths that must be maintained for efficient charge collection in thick p-i-n junction detectors. Effective hole lifetimes can also be obtained using this technique but with the present geometry of lithium-compensated silicon detectors this measurement is more difficult if short-range particles are used. The effects of charge carrier lifetime and amplifier pulse rise and fall times on the observed radiation-induced pulse shapes are discussed.

609 OBSERVATIONS ON THE ENERGY RESOLUTION OF GERMANIUM DETECTORS FOR 0.1-10 MeV GAMMA RAYS.

Mann H. M., Bilger H. R., Sherman I. S.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 252-264.

The ratio of variance to yield was studied for γ-rays at energies up to 10.080 MeV in lithium-drifted germanium detectors. With detectors of thickness up to 14 mm this ratio was found to be as low as 0.13 ± 0.02 at 122 and 356 keV. At energies between 1 and 10 MeV the ratio was found to be 0.16 ± 0.01, corresponding to a detector contribution of 4.8 ± 0.1 keV (FWHM) at 10 MeV. Investigation of the dependence of the ratio of variance to yield on electric field intensity resulted in acceptance of $F = 013 \pm 0.02$ as the best experimental estimate of the Fano factor, and $F = 0.16$ is interpreted as an upper limit for γ-rays at energies between 1 and 10 MeV.

610 PULSE SHAPE DISTRIBUTIONS FROM GAMMA-RAYS IN LITHIUM DRIFTED GERMANIUM DETECTORS.

Strauss M. G., Larsen R. N., Sifter L. L.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 265-273.

Pulse shape distributions resulting from the interaction of γ-rays in germanium detectors were studied as a function of field intensity, γ-ray energy, and detector width. It was observed that at 2300 V/cm the initial rate of charge collection approached 10 nsec/mm. Due to a slow component the total charge collection was about 30% longer. At 1000 V/cm the collection time was somewhat longer, and at 250 V/cm it was considerably longer. These observations appeared to be independent of γ-ray energy in the range of 0.6 — 3 MeV, and detector widths of 3 — 11 mm. Events interacting near the center of the detector result in fast rising pulses and those interacting near one of the electrodes have a risetime which is approximately twice as long, thus giving rise to a distribution of pulse shapes. With low energy γ-rays all shapes occur with equal probability, but at higher energy the pulses tend to have a more uniform shape. Due to the spread in risetimes, signals from monoenergetic γ-rays do not cross a given pulse height level at the same time and therefore produce timing uncertainties. With a 1 cm detector timing uncertainties of more than 30 nsec have been observed at the 50% level, and less than 5 nsec at the 5% level. It therefore appears that for accurate timing of all signals, the timing discriminator should be set at the lowest level consistent with the system noise. The variations in risetime can also affect the energy resolution. If a 1 cm detector is used in conjunction with a pulse shaping network consisting of a 1 μsec RC differentiator and integrator, the variations in risetimes may cause an amplitude spread on the order ot 0.03%. At γ-ray energies of 10 MeV this is comparable to the spread due to statistics.

611 DETECTION OF HIGH ENERGY PROTONS BY THIN-WINDOW LITHIUM-DRIFTED GERMANIUM COUNTERS.

Pehl R. F., Landis D. A., Goulding F. S.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 274-278.

Recent developments in producing thin-window Li-drifted germanium detectors have enabled us to investigate their response to 29- and 40-MeV protons. The window is of negligible thickness for long-range particles, probably about 0.5 μ, although a precise measurement has not been made. Resolutions of 28 and 44 keV (FWHM) were obtained on 29- and 40-MeV protons, respectively. After subtracting nondetector contributions, mainly the energy spread in the cyclotron beam, the resolutions obtained approach the theoretical limit for a Ge detector. A brief discussion of the response of a 0.5 cm thick, high-voltage li-drifted silicon detector is also presented. Although extensive measurements have yet to be performed, these devices appear to be capable for a resolution approximately equal to that for Ge detectors for 29-MeV protons.

612 A TOTAL-ABSORPTION DETECTOR FOR 60-MeV PROTONS USING LITHIUM-DRIFTED GERMANIUM.

Bertrand F. E., Peelle R. W., Love T. A., Fox R. J., Hill N. W., Todd H. A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 279-284.

A lithium-drifted germanium diode has been used for total-absorption detection of 59-MeV protons from the Oak Ridge Isochronous Cyclotron. The detector is 1.9 cm in diameter, has a depledepth of 6 mm, is cooled to less than 85°K, and is sealed in an aluminum can with a 0.0026-in.-thick window. The diode was oriented so that the protons entered in a direction parallel to the detector junction. The energy resolution attained for 59-MeV protons was 150 keV (FWHM), uncorrected for energy straggling in windows of 76 keV, for approximately 60 keV of beam resolution, and for electronic noise. The peak-to-total ratio, determined by using an anticoincidence collimator, was a high as 0.94, which is comparable to 0.96 observed elsewhere for NaI. When the collimator was moved along a line parallel to the junction and perpendicular to the beam, the energy resolution and peak-to-total ratios remained constant within the experimental accuracy over a 10-mm scanned distance. As the collimator was moved in a direction perpendicular to the junction and toward the depleted material, the peak-to-total ratio decreased, as was expected from multiple scattering calculations. When the diode was connected by a 125-ohm terminated coaxial cable to a fast amplifier, a rise time of 4-5 nsec was observed. Since the protons entered the detector parallel to the junction, pictures obtained show the superposition of nearly rectangular current pulses arising from hole and electron collection. The length of the pulses is correlated with the point of incidence of the collimated beam. The mobilities of the charge carriers as calculated from the measured collection times and a knowledge of the location of proton incidence are 13,000 cm^2/Vsec for the electrons and 9,800 cm^2/Vsec for holes for a detector bias of 500 volts. With detector biases of 200 and 700 V, the mobilities are 60% higher and 30% lower, respectively.

613 IMPROVEMENTS IN LARGE VOLUME COAXIAL GERMANIUM SPECTROMETERS.

Malm H. L.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 285-296.

Large volume (16-54 cm^3) germanium lithium drift diodes coaxially drifted with one open end have shown excellent performance as γ-ray spectrometers. However limitations have been found in the coincidence resolving times possible with short coaxial diodes due to large variations in charge collection times which result from the nonuniformity of the electric field-especially in the closed end portion. Leading edge time distributions as a function of axial position were made on a longer (6.6 cm) coaxial diode with one open end using 511 keV γ-rays. In an attempt to improve the electric field uniformity, the closed end was cut off to produce a double open-ended detector 4.2 cm long, and a single open ended detector 2.1 cm long. Both diodes were excellent spectrometers.

In the 4.2 cm detector (C = 55 pF) the full width at tenth maximum $W_{0.1}$ of the leading edge time distributions varied from 34 nsec to 19 nsec due to a large variation in core size along the axis. In the 2.1 cm detector (C = 34 pF) $W_{0.1}$ varied from 17 nsec in the coaxial region to 30 nsec at the closed end. A 6.1 cm long coaxial diode was made with two open ends, a circular cross-section, and a circular core cross-section nearly uniform along the length. $W_{0.1}$ of the leading edge time distribution for this improved diode was 19 nsec for the whole detector, and varied by less than 2 nsec from end to end. Improved γ-ray resolutions using a field effect transistor preamplifier instead of a tube preamplifier have been observed. An energy resolution of 3.4 keV (fwhm) for ^{60}Co (1333 keV) was obtained with a 15 cm^3 coaxial detector.

614 THEORETICAL AND EXPERIMENTAL RESULTS ON THE RESOLVING TIME OF P.I.N. DETECTORS IN γ-γ COINCIDENCE EXPERIMENTS.

Pigneret J., Samueli J. J., Sarazin A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 306-314.

A calculation of the resolving time one can obtain by the delayed coincidence method with a P.I.N. detector, is developed. The results show that submillimicrosecond time resolution can be obtained with a 2 mm thick detector. Experimental results lead to 1.1 ns (FWHM) with a Co^{60} source and 2.8 ns with a Na^{22} source. The broadening of the prompt spectrum is explained in term of the electronic system noise.

615 A FABRICATION TECHNIQUE FOR SIGNIFICANTLY REDUCING THE CAPACITANCE OF LARGE-VOLUME Ge LID DETECTORS.

Armantrout G. A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 328-335.

Practical drift depths for Ge LID detectors are limited to less than 15 mm so that large-volume detectors have a relatively high capacitance because of their increased junction area. A fabrication technique has been developed and evaluated which significantly reduces this capacitance by increasing the effective thickness of the intrinsic material between the junction and decreasing the junction area. In making a large-volume, low-capacity detector, a conventional Ge diode is first drifted to a depth greater than 1 cm. The original junctions used for the drifting operation are then removed and new junctions are applied to the compensated material in a more favorable geometry. A number of these detectors have been fabricated with a contact structure consisting of a gold surface-barrier P-type contact and a diffused-lithium N-type contact. The diodes that were made had an active volume of 4.5 cm^3 and a final capacity of less than 2 pF as compared to their original capacity of 9 pF. The detector performance with a preamplifier and a source confirmed the improvement in resolution that would be expected for this decrease in the diode capacitance without a significant reduction in the active detector volume. This technique may be extended to large detectors and would make possible the fabrication of a 30-cm^3 Ge LID detector with a capacitance less than 5 pF.

616 PREPARATION OF LARGE VOLUME PLANAR GERMANIUM DETECTORS AND RESULTS OF THEIR USE IN NUCLEAR PHYSICS EXPERIMENTS.

Mann H. M., Janarek F. J., Helenberg H. W.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 336-350.

Improved performance of germanium detectors, prepared by use of lithium-drift techniques, was obtained by means of measurements of diode properties and surface resistivity during preparation. A compensated thickness of 16 mm was obtained for several detectors in a single drift operation. For these and other detectors the provision of a negligible (i.e. $< 10\,\mu$) dead layer on one side allowed the detector to be useful from 10 keV to 10 MeV. An electric field intensity of 50 to 175 volts/mm was sufficient to give satisfactory energy resolution (i.e., 3.0 — 4.5 keV ⊙ 1.333 MeV) and full counting efficiency for detectors of thickness up to 16 mm. The preparation of 2 — 3 cm thick detectors by use of a dual-drift procedure, wherein two adjacent diode structures are caused to merge, is described. The joint use of coaxial and planar techniques, and their relative advantages, are discussed. It is concluded that the preparation of germanium detectors of area 25 cm^2 and thickness 1.5 — 3.0 cm is feasible with present techniques, but limited by the quality of the crystals utilized. The results of application of these detectors to muonic x-ray studies, neutron-capture gamma-ray experiments, charged-particle induced reactions involving gamma rays, and isotopic analysis of materials such as uranium are presented. An advantage of a reduction in sensitive volume for some measurements at energies in the range 5-10 MeV is shown.

617 ENCAPSULATED GERMANIUM GAMMA-RAY SPECTROMETERS. PERFORMANCE CHARACTERISTICS AND OPERATIONAL EXPERIENCE.

Webb P. P., Green R. M., Fowler I. L., Malm H. L.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 351-358.

Hermetically sealed Ge(Li) diodes for gamma-ray spectroscopy have now been manufactured and under study for approximately two years. During this time, 'planar' drifted encapsulated diodes have been increased in size from 2 $cm^2 \times 2$ mm deep (0.4 cm^3) to $\sim$ 8 $cm^2 \times 10$ mm deep (8 cm^3). Coaxially drifted diodes of 25 to 30 cm^3 volume have also been encapsulated. Encapsulation details of both types of detector are given, together with performance characteristics. Measured intrinsic full-energy peak efficiency curves are given for four detector sizes. For a 8 cm^3 planar diode this efficiency is 1.1% at 7 cm for 1 MeV gamma-rays. The corresponding efficiency for a 27 cm^3 coaxial diode is 3.1%. Voltage ratings of 1000 V/cm with leakage currents $\leqslant$ 1 nA at operating voltage are achieved. Resolutions of 3.4 and 5.5 keV (fwhm) at 1173 keV gamma-ray energy have been

obtained with a 2 cm^3 (5 mm deep) planar diode and a 27 cm^3 coaxial detector respectively. Mounting and general application details are discussed.

618 A LOW-NOISE CHARGE SENSITIVE PREAMPLIFIER FOR SEMICONDUCTOR DETECTORS USING PARALLELED FIELD-EFFECT-TRANSISTORS.

Smith K. F., Cline J. E.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 468-476.

The use of a 2N3823 or a 2N3819 (the Silex equivalent of the 2N3823) field-effect transistor (FET) has led to the design of an improved charge sensitive preamplifier. The amplifier has provisions for paralleling FET's in the input stage which gives considerable improvement in the resolution vs capacitance slope over single FET'S. Measured resolution of the amplifier at room temperature was 0.53 keV(Ge) + 0.046 keV/pF with a single FET in the input stage and 0.91 keV + 0.023 keV/pF with four paralleled FET's in the input stage. Cooling the FET's to 140°K gave 0.36 keV(Ge) + 0.030 keV/pF with a single FET and 0.62 keV(Ge) + 0.017 keV/pF with four paralleled FET's. Theoretical computations of the expected resolution gave excellent correlation with the results from the measured circuit.

619 THE FABRICATION OF LITHIUM-DRIFTED GERMANIUM PIN DETECTORS FOR HIGH-RESOLUTION GAMMA-SPECTROSCOPY.

Eichinger R. I. P., Köpp F.

Kerntechnik, vol. 8 (1966), No. 7, p. 297-300.

The production of lithium-drifted pin-junctions in germanium turned out to be more difficult than in silicon. This is mainly due to the instability of the germanium-lithium system, which is discussed in detail. Contrary to the methods of other authors the lithium-drift process is carried out with the diode immersed in boiling pentane. This liquid is specially suitable due to its zero dipole moment which causes small surface currents of the germanium crystal during the drift process. In germanium crystals with a surface of 1 to 2 cm^2, i-regions of 8 mm depth could be achieved in 160 h. The energy resolutions of such detectors had an average value of 3,0 keV at the gamma-energy of 122 keV, and of 6,5 keV at the gamma energy to Co^{60}.

620 RECENT DEVELOPMENTS IN SPARK CHAMBERS.

Wenzel W. A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 34-45.

The parallel developments of a variety of spark-chamber schemes have produced many workable systems with success in experimental applications. Major efforts have developed several methods for direct electrical readout of spark-chamber data. These include the use of magnetic cores for direct digitizing of information from wire spark chambers, as well as the use of Vidicon cameras to observe sparks, and of current division and acoustic transit time in analogue devices to measure spark position. For such systems the on-line use of computers, and (or) the construction of significant electrical interfacting circuitry, are important considerations in efforts to maximize the event rate. Conventional spark-chamber systems using film to record data have benefited from the continued development of automatic off-line scanning and measuring systems. There are also many experiments that will use the unique capabilities of wide-gap spark and streamer chambers.

621 HYBRID PHOTOMULTIPLIER TUBES USING INTERNAL SOLID STATE ELEMENTS.

Wolfgang L. G., Abraham J. M., Inskeep C. N.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 46-53.

A new family of photomultiplier tubes has been developed using silicon diodes and transistors as multiplying elements. For applications requiring low and medium gains these tubes offer several advantages over tubes utilizing ordinary dynode multiplication. These include ease of fabrication, mechanical ruggedness, reduced sensitivity to magnetic field, and fast response. Diode structures have provided normal gains up to the theoretical maximum and have exhibited very short response times. In a few cases anomalously high diode gains have been observed, apparently as the result of induced avalanching near the diode front surface. Much greater gains have been obtained from various transistor structures with some sacrifice in the response time.

622 A PHOTOTUBE USING A SEMI-CONDUCTOR DIODE AS THE MULTIPLIER ELEMENT.

Kalibjian R.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3. June 1966, p. 54-62.

A phototube has been developed with a semiconductor diode as the multiplier element. The tube has an electron gain of 1200 at 5 keV and has a linear output current in the 6-A range with a dynamic range between 10^7 and 10^8. A description is given of the fabrication of the shallow-diffused p-n junction diodes and their use in sealed envelopes with a cesium-antimonide photocathode. Also included is a discussion of the electrostatic lens for focusing the photoelectron beam to the window of the diode, and of the overall operation of the tube.

623 PHOTOCATHODES USED IN PHOTOMULTIPLIER TUBES FOR SCINTILLATION COUNTERS — CHARACTERISTICS AND EFFECT ON PERFORMANCE.

Stanley V. A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 63-71.

In recent months a variation of the caesium antimony cathode has been developed with a quantum efficiency up to 30%. The characteristics of this "super" S-11 cathode are compared with the caesium potassium bialkali cathode, the trialkali cathode and other variants of the caesium antimony cathode. The parameters dealt with are quantum efficiency, spectral response, dark current at various temperatures and the resolution for gamma rays of both low and high energy.

624 MULTIPLE REFLECTION EFFECTS OBSERVED FOR S-1, S-11, AND S-20 PHOTOCATHODES.

Gumnick J. L., Hollish C. D.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 72-76.

A simple optical model has been used to describe the influence of light trapping on the performance of photocathodes. The model is based on the assumption that light trapping occurs as a result of total internal reflection in the faceplate-photocathode structure. The analysis based on the model predicts that successive light photocathode interactions are related through a geometric progression, and the ratios of light intensities and photoelectric yields associated with successive light photocathode interactions equal to the common ratio of the progression. Experiments on S-1, S11, and S-20 type photocathodes tend to confirm three predictions based on the analysis: that the logarithm of the photocurrent for a specific interaction is a linear function of the number denoting the interaction; that successive photocurrents and light intensities have the same ratio denoted K, and that the ratio of the total photocurrent to that of the first interaction approaches $\frac{1}{1-K}$.

625 PERFORMANCE OF A PHOTOMULTIPLIER WITH A POROUS TRANSMISSION DYNODE.

Smith H. M., Ruedy J. E., Morton G. A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 77-80.

The root-mean-square deviation in number of secondary electrons from a normal secondary emitter increases with the square root of the secondary-emission ratio. The constant of proportionality is slight greater than unity. The pulse-height resolution of a multiplier is therefore improved by the use of a high-gain first dynode. The secondary-emission ratio from a porous potassium chloride transmission dynode has a much higher value than that from conventional dynodes. Ratios of fifty to a hundred are easily obtained. If the statistics of emission obeys the same laws as for conventional secondary emission, porous dynodes would be advantageous as the first stage of a photomultiplier for scintillation counters used for energy resolution. A multiplier incorporating a porous transmission first dynode was built and tested. The pulse-height resolution was poor compared with that of a normal photomultiplier. The pulse-height resolution can be expressed in terms of FWHM as follows:

$$\text{FWHM} = 2.35 \frac{1}{\sqrt{N_e}} \sqrt{1+M}$$

where N_e is the average number of photoelectrons per pulse and M is the degradation of resolution by the multiplier structure. A conventional photomultiplier operated at normal gain has an M value in the neighborhood of 0.5. A multiplier with a normal first dynode of gain 30 would have an M value of 0.06. The porous-dynode multiplier with a gain of 30 for the first stage had an M value of the order of 4.3. The poor statistics of porous secondary emission may be a serious limitation to its application in electron devices whose threshold should be determined by the noise in the signal, such as photomultiplier, image intensifiers, and television camera tubes.

626 THE RECTIFICATION PROCESS AT METAL-SILICON SURFACE BARRIERS.

Walter F. J., Boshart R. R.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 189-197.

Published explanations for the rectification at metal-semiconductor contacts have ranged from those which attribute the establishment of the diffusion potential (V_d) entirely to work function differences to those which presume a major role for absorbed gases and surface states. By making direct (differential capacitance) measurements of the barrier height (V_d) and E-I characteristics during fabrication, and as a function of ambient and surface treatment, it is shown that it is possible to rank the variables for the type of etched silicon surface commonly used for radiation detector fabrication in the following order of importance: (1) surface treatment, (2) adsorbed gases, (3) work function. It is also shown that the high reverse currents observed in Au-Si structures before exposure to air are directly correlated with a small V_d and that the V_d associated with various surface treatments agrees with the results of Buck. Preliminary work with liquid metal contacts supports the assumption of a secondary role for the work function. A theoretical model based on surface states and interfacial layers of finite thickness is presented to explain the behavior of metal contacts on etched silicon surfaces, including the fact that many metals (e. h., Al) have been observed to form both rectifying and non-rectifying contacts on etched Si.

627 THERMAL CYCLE DEGRADATION OF CHARGE CARRIER LIFETIME AND RESISTIVITY IN SILICON.

Walter F. J., Bates D. D.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 231-239.

Numerous published examples of high temperature induced changes in the properties of semiconductors indicate that thermal degradation of charge carrier lifetime may be responsible for excess current and noise in diffused junction radiation detectors. By comparing the noise and current in surface barrier diodes made from silicon which had been subjected to a thermal cycle to

the properties of similar diodes made from uncycled material, it is demonstrated that there can be severe degradation of the original material. The relationship between charge carrier lifetime and noise in semiconductor radiation detectors is discussed. Detailed information on changes in resistivity and etch pit density for both p- and n-type silicon from several manufactures as a function of original resistivity and thermal cycle is presented. Information on excess diode current and noise is available only for the n-type samples. The results are consistent with the previously observed strong dependence on both maximum temperature and rate of temperature change. Large increases in diode current and noise have been observed for cycles with peak temperatures as low as 500°C.

628 DRIFT RATE AND PRECIPITATION OF LITHIUM IN GERMANIUM.

Henck R., Stab L., Lopes da Silva G. (Mme), Siffert P., Coche A.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 245-251.

Dcring the study of P-I-N Ge (Li) junctions to be used for gamma-ray spectrometers, it appeared that the drift process of Li^+ ions is strongly depending on the nature of the raw materials: in similar conditions, the maximum width of the compensated region can change from less than 1 mm to more than 5 mm. The influence on drift rate of several factors is studied: resistivity nature of acceptors (Ga, In, Zn), lifetime of minority carriers, copper diffusion. Attention is given to lithium precipitation. Using different thermoelectric probes (described) the concentration of Li^+ ions and the rate of precipitation can be measured. The effect of lithium precipitation on drift rate is discussed.

629 WIDE-BAND LOW-NOISE CHARGE SENSITIVE PREAMPLIFIER.

Blalock T. V.

IEEE Transactions on Nuclear Science, Vol. NS-13, No. 3, June 1966, p. 457-467.

This paper presents the design considerations and experimental characteristics of a transistorized charge-sensitive preamplifier that has a noise line-width significantly lower than that of the best vacuum-tube preamplifiers, and a high gain-bandwidth product which allows stabilization of the charge gain against detector capacitance fluctuations over a wide range of pulse-shaping time-constants. The open-loop gain of both the input charge-sensitive section and the output cable driver section is sufficiently stabilized against temperature fluctuations by compensating elements to allow the feedback capacitor in the charge-sensitive section to control the gain drift of the entire preamplifier. The input device is a new type of *n*-channel field-effect transistor (2N3823) that has excellent gain characteristics and an unusually low noise output. The measured gain and noise characteristics of the device are presented in this paper as functions of frequence (500 Hz to 750 kHz), temperature (—200°C to +25°C), and bias point. The maximum signal-to-noise ratio for the best devices occurred when the case temperature was about —110°C. The charge-sensitive input section of the preamplifier has a midband open-look voltage gain of about 3700, a low-frequency 3-db point less than 100 Hz and a high-frequency 3-db point at about 500 kHz. This high gain-bandwidth product (1.85 GHz) was obtained by developing a new type of input cascode circuit. The new circuit employs a single-stage shunt fedback current amplifier connected between the first and second stages of the conventional cascode circuit. The design of the new cascode circuit allows stabilization of the input section against closed-loop oscillations and open-loop voltage gain changes caused by temperature fluctuations. The input capacitance excluding the detector biasing network is 8.5 pf (device capacitance = 6 pf, wiring capacitance = 1,5 pf, feedback capacitance = 1 pf). The output section of the preamplifier is a cable driver which will linearly drive ± 22 ma into a 93-ohm load with a 10-90% rise time of 20 nsec with negligible overshoot. The voltage gain of the driver is 5.5 when the output is terminated by a 93-ohm load. The open-loop gain-bandwidth product of the driver is 350 MHz. The equivalent noise voltage is sufficiently low to allow the charge-sensitive input section to control the noise performance of the preamplifier. A preamplifier noise line-width (external capacitance = O) of 0.82 kev fwhm (2.8 ev/ion pair Ge) and a slope of 0.6 kev/pf were measured for the field-effect transistor at room temperature with an RC-RC filter. With the field-effect transistor at —110°C, a large feedback resistor (100,000 megohms), and a small feedback capacitor (0.22 pf), the noise line-width was 0.38 kev fwhm Ge with a slope of about 0.05 kev/pf. The line-width of the 122 kev gamma ray of 57-Co was 1.2 kev (external capacitance = 13 pf).

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COLLE Ph.	1964	128
COLLINS G.B.	1964	132
COLORADO UNIV.	1966	526
COLUMBIA UNIV.	1966	359
COMPTON P.D., Jr.	1966	473
CONZETT H.E.	1964	175
CORBE G.	1964	137
CORBIN T.R.	1966	382
CORELLI J.C.	1966	478
	1966	477
CORNELL T.	1966	199
COUSSIEU P.	1967	575
COVA S.	1965	111
	1965	97
CRAWFORD E.W.	1965	237
	1966	535
CRAWFORD J.J., Jr.	1966	513
CRIFO J.J.	1965	306
CSAKANY A.	1965	240
CURTIS S.B.	1966	519
CZULIUS W.	1963	63

Author	Year of publ.	Number in context	Author	Year of publ.	Number in context
DABROWSKI A.		10	ELAD E.	1965	247
	1965	319		1966	493
DAKOWSKI M.	1965	231		1966	482
	1965	233	EL-SHISHINI M.M.	1966	413
	1965	449	EMERY F.E.	1965	82
	1966	545		1965	249
DALEY H.L.	1965	300		1966	248
DANIELS J.M.	1965	235	ENDT P.M.	1964	135
DAVIES D.E.		238	ENGELKEMEIR D.	1967	572
DEARNALEY G.	1966	424	ENGELMANN J.	1966	422
	1966	506	ENGLERT T.J.	1966	522
DE BLUST E.	1966	472	EPSHTEIN M.I.	1966	456
DE CAROLIS M.	1964	59	EPSTEIN L.M.	1966	507
DE CASTRO FARIA N.V.		430	ERGINSOY C.	1964	168
	1967	558	ERRAMUSPE H.J.	1966	250
DECKERS H.	1964	128	ESCUDIE B.	1965	41
DEGTYAREV Yu. G.	1966	379	EVANS R.D.	1965	330
DE LEEUW S.	1964	128		1966	329
DEME S.	1965	27	EVERLING F.	1966	522
	1965	240	EWAN G.T.	1965	251
DENBIGH P.N.	1966	499		1965	262
DENMAN E.D.	1966	474		1966	377
DENNEHY W.J	1966	511		1966	463
DERUYTTER A.J.	1964	136			
	1964	145			
DESHPANDE R.Y.	1967	562	FABJAN C.W.	1965	252
DESSERT R.A.	1965	241	FABRE R.	1965	448
de VRIES H.	1965	242	FABRI G.	1965	39
DEWAN J.T.	1964	115		1967	588
D'HARCOURT A.	1966	475	FACETTI J.F.	1964	367
DICKSON J.M.		9	FALK K.	1965	84
DIEPERINK J.H.	1966	607	FEDOSEEVA O.P.	1965	224
DODGE W.R.	1965	1	FEIGL B.	1967	548
	1966	492	FEFILOV B.V.	1962	71
	1966	415		1964	152
DOMEN S.R.	1965	1	FELSTEINER J.	1965	235
	1966	492	FERBER R.R.	1963	192
	1966	415		1965	6
DONOVAN P.F.		243		1966	392
	1965	371		1966	507
	1966	123	FERGUSON A.T.G.	1965	253
DOVE D.B.	1966	499	FERTIN J.	1966	383
DREXLER G.	1964	244	FIEDLER H.J.	1966	254
	1967	574	FINSTERWALDER L.	1965	255
DUBOIS J.	1965	81	FISCHER E.	1965	202
	1965	223	FLETCHER C.L.	1966	529
DUCHENE J.	1964	76	FLORIDA UNIV.		521
DUNAITSEV A.F.	1964	153	FORD J.L.C., Jr.	1965	317
DUNHAM Ch. L.	1966	222	FORGUE V.	1967	565
DYACHENKO P.P.	1965	245	FORNADLEY F.D.	1966	528
			FORSYTH R.S.	1966	460
			FOWLER I.L.	1964	161
EAKINS G.W.	1966	522		1964	365
EASTERDAY H.T.	1965	122		1965	112
EGOROV A.A.	1964	164		1965	28
EICHELBERGER J.F.	1964	8		1965	293
	1965	16		1966	292
	1965	246		1966	617
EICHINGER P.	1966	394		1966	463
EICHINGER R.I.P.		619	FOX R.J.	1965	118
EISLER P.	1966	418		1965	43
EISLER P.L.	1967	566		1966	612

Author	Year of publ.	Number in context	Author	Year of publ.	Number in context
FOX R.J.	1966	443	GOURDON J.-P.	1964	76
FRANKEL R.B.	1964	91	GOYOT M.	1966	403
FRECK D.V.	1965	196	GRAHAM R.L.	1965	262
	1966	256		1966	377
	1966	410	GRASS F.	1967	548
	1967	594	GREEN R.M.	1966	617
FREDERICKSON A.R.	1966	478	GREW G.R.	1965	2
	1966	477	GRI N.J.	1966	342
FREEMAN J.M.	1966	411	GRIFFIN D.A.		207
FREINDL L.	1966	426	GROTOWSKI K.	1964	185
	1966	232	GROVE G.R.	1964	8
FRIDDELL K.D.	1964	288		1965	16
FRIEDLAND S.S.	1965	30		1965	246
	1965	119	GRUHLE W.	1967	560
FRYZYBORSKI W.	1966	232	GRUHN C.R.	1967	586
FUJIBAYASHI K.	1965	257	GUENTHER P.	1965	263
FUMAGALLI W.	1965	212	GUMMEL K.	1963	68
	1965	228	GUMNICK J.L.	1966	624
	1967	552	GUZZI G.	1965	35
GABBE J.D.	1963	67			
GALANTER L.	1964	101	HAINES E.L.	1966	264
GALINA L.S.	1966	376	HAITZ R.H.	1966	20
GARLICK G.F.		193	HALEY J.T.	1966	382
GEHM H.	1965	258	HALLOWES K.H.		266
GEIGER K.W.	1966	320	HAMILTON G.N.	1965	6
GENERAL ELECTRIC Co.	1965	360		1966	392
	1966	391	HAMILTON J.H.		338
GETOFF N.	1966	466	HANNA R.C.		9
GIBBONS D.	1965	370	HANNESTAD G.	1964	59
GIBBONS J.F.	1965	259	HANSEN N.J.	1964	173
GIBBONS P.E.	1965	260		1966	390
	1966	381	HANSEN W.L.	1964	124
	1966	483	HAQUE M.A.	1967	553
GIBSON W.B.	1965	50	HAREUX F.	1965	22
GIBSON W.M.	1964	168	HARPSTER J.W.	1966	308
	1965	11	HARRIS J.A.		90
	1965	371	HARRISON S.	1965	277
	1966	116		1966	295
GIERTS G.	1964	128	HARVEY J.W.	1966	542
GILLY L.	1966	435	HASHIZUME A.	1965	22
GIRARDI F.	1965	35	HASHMI S.Z.R.	1965	64
GIRAULT B.	1964	117	HASSELGREN A.	1965	201
GLOWACKI S.	1965	10		1966	524
	1966	539	HATCH E.N.	1966	522
GOBERT G.	1966	489	HAVERFIELD A.J.	1965	122
GOLDSWORTHY W.W.	1967	151		1966	547
GOLOVIN B.M.	1965	224	HAYASHI I.		433
GOLOVINA N.V.	1966	374	HEATH R.L.	1966	265
GONDI P.	1966	211		1966	409
GOOTE G.E.	1967	585		1967	563
GORDON F., Jr.	1966	510		1967	564
GORDON G.E.	1966	542	HELENBERG H.W.	1966	616
GORNI S.	1967	554	HELLSTROEM S.	1965	81
GORODETZKY S.	1966	405		1965	223
GOTOH S.	1964	165	HELMER R.G.	1967	563
GOTTSCHALK B.	1967	586	HELMER R.	1967	564
GOULDING F.S.	1965	310	HEMMENDINGER A.	1964	182
	1966	261	HENCK R.	1966	628
	1966	380		1967	556
	1966	611	HENDEE C.F.	1966	78
	1966	406	HENUSET M.	1965	212

Author	Year of publ.	Number in context
HENUSET M.	1967	552
HERBST L.J.		301
HEUGHEBAERT J.	1964	131
HEYSSEL R.M.	1966	474
HIBOU F.	1966	605
HICK H.	1966	267
	1966	225
HILBERT J.W.		434
	1966	205
HILL N.W.	1966	612
HIRSHFELD A.T.	1965	1
HODGSON A.E.M.		266
HOEBERECHTS A.M.E.	1966	607
HOFKER W.K.	1966	543
	1966	607
HOLLANDER J.M.		90
	1965	122
	1965	268
	1966	408
	1966	419
HOLLISH C.D.	1966	624
HOLM D.M.		89
HOLMES-SIEDLE A.G.	1966	511
HOLZER O.H.	1967	553
HOOD J.S.	1965	50
HOPPES D.D.	1965	1
HOSOE M.	1965	56
HOSSAIN A.	1967	553
HOTZ H.P.	1965	269
HOWES J.H.	1966	483
HUBER O.	1965	38
HUGHES L.B.	1966	254
HUNT S.E.	1965	196
	1965	270
HURLEY J.P.	1965	269
	1965	297
HURST G.S.		347
HUTH G.C.	1964	160
	1965	88
	1966	373
	1966	271
	1966	398
HYDE E.K.	1966	220
IFEROV G.A.	1966	374
IMINOV I.	1965	286
INSKEEP C.N.	1966	346
	1966	621
ISABELLA L.	1966	472
ISRAEL ATOMIC ENERGY COMMISSION		356
JAGUSZTYN M.	1965	10
JAMINI M.A.	1966	464
JANAREK F.J.	1966	616
JARED R.C.	1966	220
JARRETT B.V.	1964	124
	1965	310
	1966	261
JASKOLA M.	1965	14
JAYNE G.A.	1967	563
JENKIN J.G.	1966	411
JOHN HOPKINS UNIV.	1966	514
JOHNSON N.R.		338
JOHNSON P.B.	1965	107
JOHNSON W.A.	1966	473
JONES A.	1965	36
JONES A.R.	1966	273
	1967	582
JONES E.O.	1964	272
JONES K.W.	1965	229
JONES L.V.	1964	8
	1965	246
	1965	16
JOSEPH W.F.	1966	344
JUNGCLAUSSEN H.	1965	274
JUPITER C.	1965	282
KAHN S.	1967	565
KALBITZER S.	1966	486
	1966	487
KALIBJIAN R.	1966	622
KALININ A.I.	1964	103
	1965	17
KANNENBERG S.	1967	586
KARCZ W.	1966	232
	1966	426
KARLSSON S.-E.	1967	551
KAROLYI J.	1967	588
KARWOWSKI M.	1965	275
KASHUKEEV N.	1966	540
KASHY E.		428
	1966	210
KATKIEWICZ W.	1965	227
	1966	500
KATZENSTEIN H.S.	1965	119
	1966	385
KAUFMANN C.	1964	26
KAUFMANN K.	1966	388
KAVANAGH R.W.	1967	569
KAZARINOV N.M.	1964	181
KAZARINOVA M.I.	1966	379
KEDEM D.	1965	110
KEIL G.	1966	470
KELLER E.L.	1963	192
KELLETT C.	1965	277
KELLEY M.A.	1966	208
KEMMER J.	1966	486
KEMNITZ P.	1964	26
KENAWY M.	1965	252
KENNETT T.J.	1966	254
	1966	396
KERN H.E.		433
KEYWELL F.		69
KHACHATURYAN M.N.	1964	103
	1965	17
KHAYKIN N. Sh.	1966	485
KHVASHCHEVSKA Ya.	1964	191
KIEFER H.	1965	276
KIEHN R.M.	1964	62
KILMINSTER D.T.	1966	495

Author	Year of publ.	Number in context
KIM Ki-Hyon	1966	465
KIND J.	1964	60
	1966	516
KING W.J.	1965	277
	1966	295
KLEMA E.D.	1965	46
	1966	278
KLOEPPER R.M.	1965	279
	1965	296
KLOES H.	1966	498
KNOLL G. F.	1965	5
	1966	416
KOBAYASHI H.	1964	187
	1965	56
KOCH L.	1966	422
KOEHL G.	1965	263
KOEPP F.	1966	394
KOERTS L.A. Ch.	1966	607
KOK E.	1966	607
KOLACHEV B.A.	1962	437
KOLPAKOV I.F.	1964	154
KOMAR A.P.	1965	195
	1967	568
KONADOR G.	1965	449
KÖPP F.		619
KOWALSKI L.	1964	93
KRAMER G.	1966	280
KRANER H.W.	1965	330
	1966	329
KRAUSE M.O.		207
		431
KRISTOFF J.	1965	337
	1967	570
KROGUL'SKI T.	1964	191
	1965	14
KUCHCINSKI A.	1965	281
KUCHLY J.M.	1966	417
	1967	556
KUCKUCK R.W.	1965	4
	1965	282
KUHLMANN W.R.	1966	283
KUHN A.	1966	423
KUHN L.	1966	378
KUO T.	1967	586
KUZMINOV B.D.	1965	245
LAFORE R.W.	1966	488
	1966	384
LALOVIC B.	1966	606
	1967	555
LAMPO E.J.	1966	519
LANDER R.L.	1966	491
LANDIS D.A.	1965	310
	1966	611
LANDSMAN A.P.	1965	224
LANGLEY R.A.		431
LANGMANN H.J.	1965	86
	1965	303
	1966	302
	1966	414
LARSEN R.N.	1966	610
	1967	549
LAUBER A.	1964	157
LAUGHLIN J.S.	1965	284
	1966	397
LAUTERJUNG K.H.	1966	283
LAW C.A.	1965	74
LAWRENCE J.H.		285
LAWRENCE RADIATION LAB.		357
	1966	364
LAZAREVIC V.	1963	66
LEBAILLY J.	1964	117
LEBER J.	1966	475
LECOMTE J.L.	1964	139
LEE J. Chong	1965	4
LEGRAND J.	1965	22
LEMAITRE G.	1964	130
	1964	131
LENCHENKO V.M.	1965	286
LEVENTHAL E.A.	1965	42
LEVESQUE R.J.A.		430
	1967	558
LEVY A.J.	1967	590
LEWIS A.R.	1967	580
LICHTENSTEIN R.M.	1966	478
	1967	577
LIPPERT J.	1965	120
	1965	94
LOCKER R.J.	1965	88
	1966	287
LONG D.M.	1966	476
LOPES DA SILVA G. Mme	1966	628
LOTHROP R.P.		87
	1966	380
LOTKOVA E.N.	1966	546
LOVE T.A.	1966	612
LOWREY A.R.	1964	288
LUBATTI H.J.	1966	491
LUDWIG E.J.	1965	50
LUKASHOV A.A.	1964	164
LYUBIN V.M.	1966	468
MACCABEE H.D.	1965	290
	1966	102
	1966	453
McCASLIN J.B.	1965	289
McGOWAN F.K.	1965	317
McINTYRE H.	1965	74
MacKENZIE I.K.	1965	262
	1966	377
McKENZIE J.M.	1965	53
McKINNEY R.A.	1964	160
	1965	88
McNEILLY J.H.	1966	495
MADAKBAS M.	1965	84
MADDOCK A.G.	1965	291
MAKSIMENKO B.P.	1965	219
MAKSIMOV Yu. S.	1966	457
MALM H.L.	1965	28

Author	Year of publ.	Number in context
MALM H.L.	1965	293
	1966	292
	1966	613
	1966	617
	1966	463
MALMBERG P.R.	1963	192
MALSKY S.J.	1965	33
MANCHESTER K.E.	1965	294
MANDL V.	1965	23
	1966	472
MANI G.S.	1966	489
MANN H.M.	1965	57
	1966	609
	1966	616
MARCUM A.I.	1966	194
MARCUS L.	1967	593
MARSHALL J.H.	1964	440
MARTIN F.	1965	277
MARTIN F.W.	1966	295
MARTIN J.A.	1965	279
	1965	296
MARTIN T.C.	1966	502
MARTINI M.	1965	40
	1965	121
	1965	83
	1966	504
	1967	591
	1967	550
MASSACHUSETTS INST. OF TECH.		598
	1965	358
	1966	537
MASUDA M.	1967	583
	1967	579
MATHEW P.J.	1967	585
MATHIESEN J.M.	1965	269
	1965	297
MATILE G.		206
MATVEEV O.A.	1964	441
MATVEEV V.V.	1962	114
MAURENZING P.	1965	218
MAUSBERG W.	1964	134
	1965	298
MAUSHART R.	1965	276
MAY R.	1966	498
MAYER J.W.	1965	299
	1966	407
MEDFORD L.V.	1963	68
MEDNIKOV A.K.	1964	155
	1966	375
MEDVED D.B.	1965	300
MEHLHOP W.A.W.	1966	491
MELANDRONE G.	1966	472
MELZER W.		301
	1966	486
MENES J.	1964	132
MERDINGER J.C.	1966	405
MESSIER J.	1965	31
MEYER H.	1966	170
MEYER J.P.	1966	422
MEYER N.I.	1965	259
MEYER O.	1965	86
MEYER O.	1965	303
	1966	302
	1966	414
MICEK S.	1964	185
MICHAELIS W.	1966	387
	1967	575
MICHALOWICZ J.	1965	234
MIEHE J.A.	1966	401
MIKHALEVA T.N.	1966	375
MILLER G.L.	1963	68
	1965	371
	1966	494
MILLER R.G.	1967	569
MILNER W.T.	1965	317
MINER C.E.	1965	80
MITCHELL J.P.	1965	444
MIYASHITA K.	1963	158
	1965	257
MOAT A.	1964	182
MOLL J.L.	1965	259
MONCASTER M.E.	1965	304
MOORE J.A.	1964	145
MORGAN I.L.	1966	502
MORITA E.	1967	583
MORITZ J.	1964	129
MORLEY B.J.	1966	471
MORRIS J.P.	1967	580
MORTON G.A.	1966	625
MORY J.	1965	305
MOZER F.S.	1965	306
MUGGLETON A.H.F.	1965	307
	1966	420
MULDER K.	1966	607
MULLER A.C.	1964	101
MURRAY G.	1967	596
MURRAY H.M.	1966	308
NAKAHARA H.	1966	542
NAKAKADO T.	1964	167
NAKAMOTO A.	1965	56
NAKAMURA M.	1966	493
	1966	482
NAKAYAMA Y.	1964	167
NAMENSON A.I.		602
	1967	576
NAUMOV V.I.	1966	508
NEILER J.H.	1965	11
NELSON L.C., Jr.	1966	461
NEUERT H.	1966	469
NEWTH J.A.	1964	187
NIEWODNICZANSKI H.	1964	185
NIKITIN V.A.	1964	103
	1965	17
NILSSON O.	1967	551
NISHIU S.	1964	167
NITOCHKINA E.V.	1964	164
NORDLING C.	1967	551
NORMAN A.		434
NORTH CAROLINA STATE UNIV.	1966	532

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NORTHROP D.C.	1965	304
	1966	424
NOWLIN C.H.	1966	9
NURMIA M.	1966	455
NYBAKKEN TW.	1965	108
NYGAARD K.	1966	462
OAK RIDGE NATIONAL LAB.		432
		436
		597
		599
	1960	361
	1966	372
OBERSKI J.E.J.	1966	607
OGAWA I.	1967	589
OLESEN H.L.	1966	512
OMEL'YANENKO M.N.	1966	508
OOSTENS J.	1964	131
	1964	132
OOSTHOEK D.P.	1966	607
OPHIR D.	1966	208
OSIPENKO B.P.	1965	224
OSTERTAG E.	1966	401
OSTRETSOV L.A.	1966	376
OTTAVIANI G.	1965	40
	1965	121
	1965	83
	1967	591
	1967	550
PAI H.L.	1966	606
PANDOLFI F.P.	1964	156
PANTUYEV V.S.	1964	103
	1965	17
PAPADAKIS A.C.	1966	309
PARKER C.V., Jr.	1966	502
PARKER R.P.	1963	438
	1966	471
PARKINSON E.R.	1965	44
PARISI P.L.	1965	234
PARTOLIN O.F.	1966	376
PASSE S.	1964	117
PATKO J.	1964	98
PATWARDHAN P.K.	1964	174
PAULY J.	1965	35
PAWLOWSKI Z.	1965	275
PEDRINI A.	1965	23
PEELLE R.W.	1966	612
PEHL R.H.	1965	310
	1966	611
PEREL J.	1965	300
PERKINS M.A.	1965	337
	1967	570
PERLMAN I.	1966	419
PERSSON B.	1965	106
PERZL F.	1967	574
PETROVIC B.	1966	606
PHILIPPINE ATOMIC ENERGY COMMISSION	1965	369
PIGNERET J.	1966	614
	1966	403
		338
PINAJIAN J.J.	1966	126
PIROUE P.A.	1966	169
PLAVITU C.N.	1966	278
PLEASONTON F.	1966	328
	1965	311
POENARU D.	1965	312
	1967	595
POPE R.A.	1965	74
POPOFF D.R.	1966	254
PRESTWICH W.V.	1965	304
PRETTY W.E.		601
PREVO C.T.	1966	517
PRIEELS R.	1966	452
PRIKHOD'KO V.I.	1966	379
PROTOPOPOV V.N.		90
PRUSSIN S.G.	1964	37
PRZYBORSKI W.	1964	52
	1965	231
	1965	233
	1966	426
	1966	459
	1966	545
PUEHLHOFER F.		301
PURDUE RESEARCH FOUNDATION	1966	386
PYLE G.J.B.	1967	567
PYRAH S.	1966	483
†QUARANTA A.A.	1965	40
	1965	121
	1965	83
RAAEN H.P.	1967	571
RABSON T.A.	1965	82
	1965	249
	1966	248
RADEKA V.		313
RAINES J.A.	1965	304
RAJU M.R.	1965	290
	1965	314
	1965	451
	1966	505
	1966	102
	1966	519
RAMAYYA A.V.		338
RANKOWITZ S.	1966	208
RAO E.V.R.	1966	454
RAUCH H.	1965	252
RAUCH R.	1967	548
RAY J.A.		207
		431
RAYMOND J.P.	1965	331
RECHENMANN R.V.	1964	125
REINITZ K.	1966	315
RESTELLI G.	1965	109
	1965	212
	1965	228

Author	Year of publ.	Number in context
RESTELLI G.	1967	552
REYNOLDS J.	1965	106
REZANKA I.	1967	557
RICHMAN C.	1965	314
	1966	519
RIEDLER W.		316
RINEHART M.C.	1967	581
RISTINEN R.A.	1965	54
	1965	229
RITTER R.C.	1963	24
	1965	447
	1967	590
RIZZO F.X.	1964	101
ROACH M.D.		87
ROBERT A.	1966	435
ROBERTSON G.D.	1964	166
ROBINSON L.B.	1964	175
ROBINSON R.L.	1965	317
RODGERS A.L.		199
RODGERS J.W.		433
RODIONOV Yu. F.	1966	457
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ROTONDI E.	1966	320
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ROUSE R.L.	1967	594
ROUX G.	1965	95
RUEDY J.E.	1966	625
RUGE I.	1964	322
	1966	470
	1966	394
RUMPHORST R.F.	1966	607
RUMPOLD K.	1966	225
RYDIN R.A.	1965	323
	1966	324
RYKALIN V.I.	1966	508
RYNDINA E.Z.	1966	523
RYVKIN S.M.	1964	441
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SADEGHI A.	1966	489
SAMUELI J.J.	1966	614
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SCHNEIDER H.	1964	189
	1966	498
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SEIFFERT A.M.	1966	250
SEL'DYAKOV Yu. P.	1962	114
	1963	99
SEN S.K.	1965	55
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SHAIKH M.S.	1963	192
SHATZKES M.	1965	279
	1965	296
SHERMAN I.S.	1966	216
	1966	609
SHIMIZU J.	1963	158
SHIMIZU S.	1964	167
SHIRLEY D.A.	1964	171
	1965	73
SHISHKEVISH C.	1966	515
SIBLEY C.B.	1965	294
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SIDOROV A.I.	1964	103
	1965	17
	1966	456
SIEGBHAN K.	1967	551
SIFFERT P.		332
	1964	142
	1964	143
	1964	144
	1965	47
	1966	605
	1966	628

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SIFFERT P.	1966	417
	1967	556
SIFTER L.L.	1966	610
	1967	549
SILBERT M.G.	1964	182
SILK M.G.	1966	501
SILVESTROVICH S.I.	1962	437
SLAPA M.	1964	61
	1965	10
	1966	426
	1966	232
SLIZ J.	1964	185
SMITH H.E.		87
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	1967	594
	1967	595
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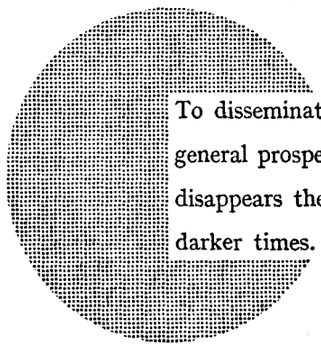

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