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Semiconductor detectors for neutron flux measurements

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Abstract

Silicon detectors with ^{235}U converter for neutron flux measurements over a wide energy range (from thermal up to epithemal neutrons) have been developed. The surface-barrier detectors with plastic converters were developed for fast neutron detection.

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1. Introduction

Various types of semiconductor detectors for neutron flux measurements over a wide energy range (from thermal up to fast neutrons) have been developed. The neutron flux measurements are based on registration neutron induced secondary radiation by silicon detectors or by recording the radiation defects created by neutron in the silicon p–i–n dosimeter [1]. The secondary radiation is produced in the interaction of the neutrons with the special converter adjacent to the detector.

2. Results and discussion

Detectors with converter ^{235}U were used for determining the flux of thermal and epithermal neutrons. The ^{235}U oxide–protoxide converter with enrichment up to 99.92%, thickness of 0.15 mm and α-activity of 81 Bq was mounted on an Al-substrate and attached to a silicon barrier-surface detector with an active area 100 mm^2. The silicon detector records the ^{235}U nuclei fission after neutron capture by responding to the fission fragments, which have energy of about 70 MeV. The signals from the fission fragments are easily separated from those due to γ-rays and α-particles making the use of Si–^{235}U sensors advantageous in the mixed reactor γ-neutron fields. The ^{235}U converter itself generates a constant rate signal from the spontaneous α-decay (4.36 MeV). The degradation of the detector sensitivity can be

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estimated by measuring the variations in amplitude of the α-particle signal. The substantial difference of energy between the α-particle and the fission fragment allows one to distinguish these components. The relation between the components (N_f/N_α) defines a reliable neutron flux measurement. Detector degradation under irradiation can be taken into account because the contribution for each component of spectra is the same. The Si–^{235}U sensors were used for measuring the flux of thermal neutrons and epithermal neutrons (effective neutron energy ≈ 10.4 keV).

The intensity of the thermal neutron flux at the out of horizontal channel HB7 of Peten (Netherlands) reactor was also determined by activation of an Au target with diameter 1 cm and equals 5.8636×10^6 n/cm^2 s.

The fission fragment spectrum obtained with the semiconductor detector under the thermal neutron irradiation at the horizontal reactor channel HB7 with Bi filter is shown in Fig. 1(a).

The total number of pulses recorded from converter in the channels ranging from 90 to 1024 equals 1,936,982 pulses per 600 s ($N = 3.23 \times 10^3$ pulses/cm^{2}s). The detector sensitivity defined as ratio between flux of the converter fission fragments detected by sensor to neutron flux is $K_{th} = 5.5 \times 10^{-4}$ pulses/n.

The spectra of the fission fragments and α-particles under irradiation of detector by the epithermal neutron at channel HB 11 without filter are given in Fig. 1(b).

One may see that α-radiation of ^{235}U converter gives ~1110 pulses per 600 s in the channels ranging from 42 to 90, while the fission fragments give 3610 pulses per 600 s. in the channels ranging from 90 to 1024. Since the peak of α-particles is in the low-energy range of the spectrum we may exclude their contribution from the total sum by taking into account only the pulses in the channels ranging from 90 to 1024. The sensitivity of the detector is $K_{epi} = 1.82 \times 10^{-5}$ pulses per neutron.

Surface-barrier detectors with thickness 0.8 mm and sensitive area 24 cm^2 were used as proton-recoil neutron spectrometer for measurements of fast neutron flux with energy up to 10 MeV. The PMMA plastic converter plate with depth 1.5 mm was used. Spectrum of recoil protons from a hydrogenous radiator bombarded with neutrons at energy range 5–10 MeV was obtained for various values of reverse voltage. It was shown that the efficiency of the detector increased at high bias

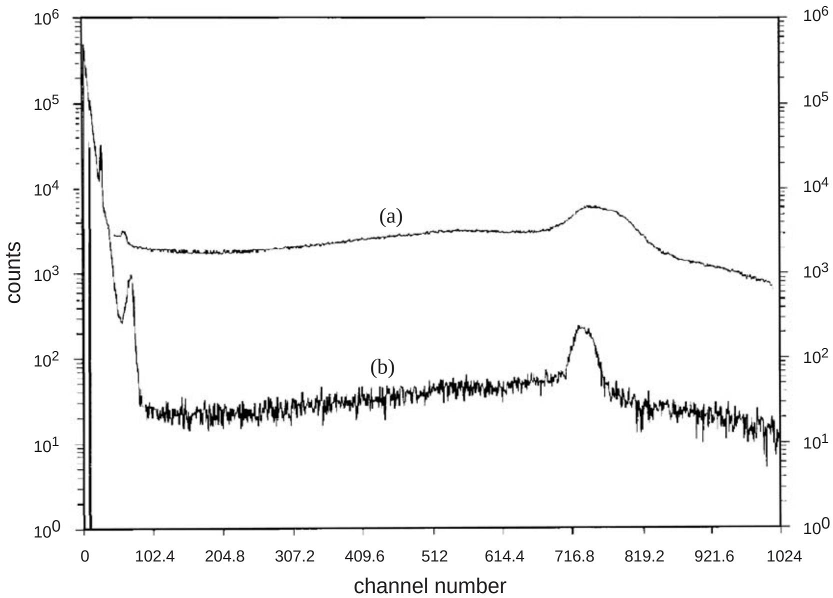

Fig. 1. Fission fragments spectrum from detector with ^{235}U converter irradiated by thermal neutron (a) at channel HB7 and epithermal neutron (b) at channel HB11.

(400 V). The calculated efficiency for this detector with converter is $K_p = 3.19 \times 10^{-3}$ pulses/n.

3. Conclusions

The real-time measurement of neutron flux over a wide energy range can be possible by using semiconductor detectors with suitable converters.

References

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