SEMICONDUCTOR DETECTORS FOR DETERMINATION OF RADIONUCLIDE CONTAMINATION IN THE SUBSTANCES AFTER THE CHERNOBYL ACCIDENT

P.G.Litovchenko, L.I.Barabash, P.E.Berdnichenko, S.V.Berdnichenko,
V.I.Kutz, T.I.Kibkalo, A.P.Litovchenko, S.V.Djurenko,
A.N.Rudenko, V.M.Pugatch, Yu.N.Pavlenko

Institute for Nuclear Research, Kiev, Ukraine

1. INTRODUCTION

The development of rapid and sensitive devices for the monitoring systems of α-radinuclides in the environment is of a paramount importance, especially after Chernobyl accident. Alpha-spectrometry methods based on Si-semiconductor detectors proved to be among the most reliable ones up to now. Different kind of detectors have been developed and fabricated by authors for that purpose by means of the surface-barrier as well as of the planar technology. The description is presented for the Multichannel-Alpha-Radiometer-Spectrometer ("MARS-16") designed on the basis of the developed detectors for rapid measurements of the concentration of alpha-radionuclides in the environment (soil, fluids, air) and food. Strip-detector option of the "MARS-16" could be used for the high accuracy position determination of the alpha-radioactive contamination.

2. EXPERIMENTAL RESULTS

To provide alpha-spectrometry systems with high quality semiconductor detectors different technologies for the fabrication of the planar detectors were studied. The main physics-technology limitations for the production of silicon planar detectors with different topological configurations were determined.

The detectors were fabricated on the base of n-type silicon plates with diameter of 3 inch, <100> orientation and ~ 1 kOhm·cm resistivity. The plates were oxidized in water vapour with an addition of the 3-chlorine-ethylene at the temperature of 850-1000°C. Vapour-borned Si-oxide as well as a many layer dielectric with a Si-nitride were used for dielectric layers.

p^+-n junction was made by ion implantation of boron at energy E = 40 keV, ohmic contact on the rear side was made by implantation of phosphorus at energy 60 keV. The rear side and p^+-n junction of the detectors were metalized by 0.3 μm thick Al.

Planar detectors on the base of high resistivity silicon with area of 1 cm^2, 16 cm^2 and passive-mosaic detectors with total area of 24 cm^2 were developed. The application of passive-mosaic structures allows to produce the detectors with large active area for integral alpha-activity measurements. The energy resolution of fabricated detectors with area of 16 cm^2 and sensitive layer thickness of 250 μm for 5.5 MeV α-particles was 70-90 keV at the bias voltage of 50 V and leakage current of 60-100 nA. For the detectors with area of 1 cm^2 the energy resolution was 25-30 keV at bias voltage 20-60 V and leakage current 20-40 nA. Such detectors were used for express analysis of radionuclides in samples from various regions contaminated during Chernobyl accident.

In particular, large area Si-detectors (up to 16 cm^2) have been used in the Multichannel-Alpha- Radiometer-Spectrometer ("MARS-16") designed mainly for rapid measurements of the concentration of alpha-radionuclides. 16 Si-detectors are housed in a vacuum chamber equipped by special preamplifiers with low noise for detectors with large capacitance. The vacuum chamber is inserted into a crate CAMAC together with amplifiers, strobe mixer, analog unit and crate controller linked to PC IBM-486. The developed software allows for analysis of spectra to extract values of alpha-concentrations by means of thin and thick samples methods (1). Fig.1 represents the example of the alpha-spectrum measured by one of "MARS-16" channels for the thin probe prepared by means of radiochemical separation of Pu-isotopes using ^{236}Pu as a tracing element.

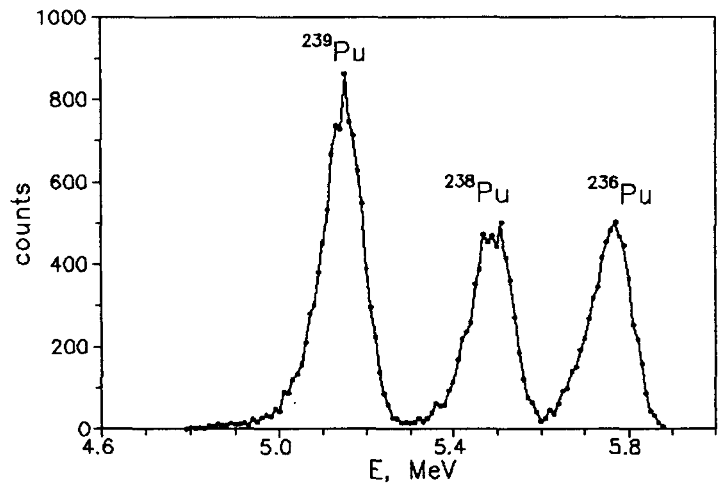

Fig.1. Alpha-spectrum measured for the thin probe prepared by means of radiochemical separation of Pu-isotopes.

The remarkable feature of "MARS-16" is an ability to provide selective alpha-radioactivity monitoring avoiding time consuming and expensive procedure of radiochemical preparation of samples. Fig.2 represents the example of an alpha-spectrum measured by "MARS-16" directly from the contaminated soil sample (histogram). Dashed lines show the contribution of various alpha-emitting isotopes, while the solid line represents their sum, as it follows from the Monte-Carlo simulation. We could easily reach the sensitivity to ^{238,239}Pu concentrations (at 20% statistical error) up to 20 Bk/kg without radiochemical sampling procedure and measuring time ~ 20 hours. Results obtained by means of thin and thick sample methods generally are in a good agreement , although in some cases the thick sample method gives higher concentration values.

Earlier unknown features for alpha-radiometry are introduced by strip-detectors widely used in high energy physics. Extremely good energy resolution (up to few keV for minimum ionizing particles) combined with high position determination accuracy even at very high counting rates

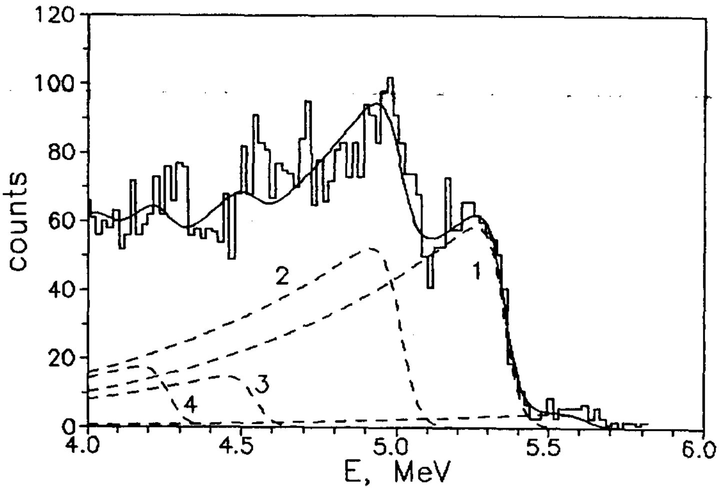

Fig.2. Alpha-spectrum measured for thick sample of soil. Dashed lines correspond to the contributions of different isotopes with distinguished energy of α-radiation: 1 - ^{238}Pu; 2 - ^{239}Pu; 3 - ^{234}U; 4 - ^{238}U. Solid line is their sum.

(up to hundred kHz for the total area of strip-detector) characterizes a strip-detector as an exceptional device for alpha-radiometry.

The design of the 128-channel Si strip-detector with submicron position sensitivity for alpha-radiometry purposes has been developed. Some information on the characteristics of fabricated and studied strip-detectors could be found in the Proceedings of this Conference. High accuracy of the 2-dimensional position determination is realizable by means of double-sided strip-detectors. The position accuracy for both "X" and "Y" coordinates could be essentially improved by a fabrication of the strip-detector with special strips configuration and exploring the method of submicron position sensitivity (2).

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REFERENCES

1. V.M.Pugatch, Yu.N.Pavlenko, Yu.O.Vasiliev et al., IEEE Trans. on Nucl. Sci., 39, 1369-1371 (1992).
2. V.M.Pugatch, A.B.Rosenfeld, P.G.Litovchenko et al., Ukr. Fiz. Zh., 35, 12-19 (1990).