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FEATURES OF SILICON p-n STRUCTURES WITH A LARGE SENSITIVE SURFACE AND A VOLUME CHARGE AREA

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Annotation. The report considers the features of semiconductor instrumentation of a large sensitive surface and space charge region based on silicon single crystals. Studied and shown the functional features and purpose of the developed devices "Radonometer", "Radiometer", coordinate-sensitive structures, etc. Their functional purposes in science and technology are shown. The features of p-n and p-i-n structures based on single crystals of wafers with a diameter of d>60 mm and a thickness of W>1.5 mm are shown.

Keywords: coordinate-sensitive structures, p-n and p-i-n junction, radonometer, radio spectrometer, mathematical modeling.

The beginning of semiconductor instrumentation in modern semiconductor physics was associated with the discovery of the p-n junction structures by the Shockley Nobel Prize Laureate in 1947. At present, semiconductor devices, microelectronics and, in recent years, devices with the development of nanophysics and nanotechnology are quite well developed for various types and purposes.

At the same time, there is a rapid development of semiconductor devices of large sizes (volumes) of the sensitive area, surface and thickness, in particular, semiconductor detectors of nuclear radiation.

The development of nuclear physics, as well as in all areas of science and technology, has led to the use of semiconductor instrumentation in this area, in particular: semiconductor detectors of nuclear radiation, replacing ionization, calorimetric, induction, scintillation, gas-discharge chambers, etc. The possibility of developing semiconductor detectors based on pn structures was proposed in the late 1950s and early 1960s professor Ryvkin S.M. [1-2].

The use of monocrystalline silicon-based nuclear radiation detectors has significantly influenced the development of experimental nuclear physics. High energy resolution, linearity of the signal in a wide range of energies for charged particles of various types, speed of response, insensitivity to magnetic fields, stability, and, finally, small dimensions allow such detectors to be considered indispensable in solving a number of problems in nuclear spectroscopy, activation analysis, dosimetry, as well as in experimental nuclear accelerators.

Semiconductor detectors are used in nuclear power engineering, in the production of high-purity substances, for applied and basic scientific research, medicine and agricultural technology,
environmental protection and in other equally important fields of science and technology. All this determines the further development and improvement of the development of semiconductor nuclear radiation detectors with a wide range of operating characteristics and operating conditions. At present, for their manufacture, elementary semiconductors (silicon, germanium), as well as complex semiconductor compounds (gallium arsenide, cadmium telluride, etc.) are used as a starting material. On all of the above materials, detectors are created on p-n, p-i-n and surface-barrier structures.

The wide variety and complexity of the requirements of modern science and technology, the tendency to expand the range of spectrometric energies stimulate the development of high energy resolution silicon detectors (~ 120 eV for soft γ- and X-ray radiation), as well as detectors with a large sensitive area (≥10 cm³).

The successful solution of these problems depends on the correct understanding of the relationship between the electrophysical and spectrometric characteristics of such detectors with the parameters of the initial material and technological modes of manufacturing detectors.

The classification of semiconductor detectors currently has a huge variety in terms of purpose, size and requirements of modern science and technology of nuclear physics. To date, we have been developing and researching a variety of detectors based on silicon crystals. There are developments starting with the minimum dimensions: diameter d ~ 6-7 mm and thickness W = 8-10 microns, as well as various other sizes, different types and purposes: with a diameter of 100 to 110 mm and a space charge area up to 6 cm thick. Below are some of our developed silicon detectors of various types and purposes.

In Fig. 1, 2, 3, 4, we have developed and manufactured silicon detectors of various types and purposes.

![Fig.1. Varieties of some developed detectors of various types and purposes](image)

Figure 2 shows a setup designed to measure low-intensity alpha, beta and radon VA in air, water and soil, this setup uses silicon detectors based on silicon crystals with a diameter of more than 50 mm. This installation is intended for use in nuclear spectroscopy, dosimetry, mining and metallurgical industry, in environmental problems, as well as geophysical research and earthquake prediction.
One of the important developments is a radonometer with a semiconductor detector in the form of a mobile device, which makes automated, continuous and express measurements of the volumetric activity (VA) of radon-222 in groundwater at a depth of 150-200 m in order to predict earthquakes [3].

For these semiconductor position-sensitive detectors, a computer simulation of all steps of the technological process of manufacturing detectors was carried out, taking into account at each step the degree of influence of the properties of the initial silicon on the electrophysical and radiometric characteristics of the detector. Which made it possible to see the true tomographic results.
The performed mathematical modeling can be used not only to study semiconductor detectors, but also to study other semiconductor devices, in particular diodes, transistors, thyristors, etc.

Thus, a computer mathematical modeling of the obtained characteristics of semiconductor coordinate-sensitive detectors (SCSD) is created. The developed computer mathematical model makes it possible to generalize and ensure high quality of the information received in the detectors of SCSD [4].

References