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Review
of local scientific consultant for a doctoral thesis of Japashov Nursutan on the topic "Development of high-sensitive detection system based on large-sized silicon lithium structures", submitted for the degree of Doctor of Philosophy (PhD) in the specialty "D071900 - Radio engineering electronics and telecommunications"

In the dissertation of Japashov Nursultan, a study of highly sensitive detection systems based on silicon-lithium structures with an sensitive area diameter more than 110 mm is considered. A silicon lithium detector with p–i–n structure and readout electronics for these detectors were chosen as the objects of study. The paper proposes a new double-sided method of diffusion and drift of lithium particles into monocrystalline silicon to create highly sensitive Si (Li) p-i-n structured detectors. As initial materials for these detectors were chosen silicon crystal - p-type, obtained by the float-zone method, with diameter 110 mm, thickness 8-10 mm, resistivity $\rho = 1000 \div 10000$ Ohm * cm and with life time $\tau \geq 500$ μs was used and silicon of p-type grown in an argon atmosphere by the Czochralski process, with diameter 110 mm, a high resistivity of $\rho = 10 \div 12$ Ohm.cm and with a lifetime of $\tau \geq 50$ μs.

Furthermore, it was created readout electronics for these detectors. More precisely, a special charge-sensitive preamplifier with low noise and low delay times was developed. After that, the rest of the reading electronics was developed, which includes a counter and an AVR microcontroller with access to a personal computer for monitoring radiation.

Silicon detector systems are well developed at the present time, but an increase their efficiency and accuracy in detecting ionized radiation is still an urgent research issue. There are several problems that prevent to obtain a high-precision of radiation detection instrument. They are mainly related to the size of the sensitive area of the detectors.

- One of the long and energy-intensive processes in the technology of manufacturing Si (Li) p-i-n nuclear radiation detectors is the formation of the i-region by diffusion and drift of lithium ions. So, to create a sensitive area of the detector with a thickness of more than 4 mm, months of painstaking work are required. In addition, providing a large sensitive surface of semiconductor detectors in combination with high energy resolution is still a rather difficult task. This is primarily due to a special requirement for the technology of growing semiconductor materials for semiconductor detectors. The most developed industrial detector materials of silicon of large diameters contain significant inhomogeneities in the distribution of electro-physical parameters over the volume of the crystal. The local and impurity bands present in the sensitive volume of semiconductor detectors significantly impair its radiometric characteristics. Consequently, the requirements of a large sensitive surface and high energy expansion are mutually exclusive.

To shorten manufacturing time and avoid inhomogeneities in the fabrication of Si (Li) p-i-n nuclear radiation detectors, we propose a double sided diffusion method for lithium ions, which precedes a further double sided drift, which is the next stage after double sided diffusion in the development of the detector. The fabrication of the Si (Li) p-i-n structure by means of double sided technology helps to shorten the manufacturing time of the detector and optimizes the physical parameters of the detector. The double sided technology of manufacturing p-i-n structure has a number of advantages, this - with the double sided formation of the p-i-n structure, the manufacturing time is reduced by several times, the structure becomes more homogeneous and etc. Because while penetration of lithium ions in silicon, lithium ions are distributed from the surface side of the crystal into the depth, while the deeper the distribution, the greater the non-uniformity appear in the crystal. Accordingly, with the double sided technology, the ion penetration length is halved and this noticeably reduces the manifestations of the non-uniform distribution of lithium ions in mono-crystalline silicon.

Also, for the successful operation of detection systems, it is very important to construct suitable electronics, since detection of signals using silicon band detectors is complex. This is due to the following characteristics of the detectors: small multichannel signals, pending intelligent electronics for signal detection (high gain and noise suppression), leakage current (DC).

To perform the dissertation, the following tasks were set for the doctoral student:

-To chose suitable initial materials for detectors.

-To study experimentally electro-physical characteristics of initial material for detectors.

-To develop the technological modes of double-sided diffusion of lithium atoms in silicon wafers of large sizes;

- To develop the technological modes of double-sided drift of lithium ions in silicon wafers of large sizes;

- To develop suitable and high efficient readout electronics for large size Si(Li) p-i-n detectors;

- Hardware implementation for highly efficient spectrometric system based on large size Si(Li) p-i-n detectors;

В результате проведенных исследований докторантом Джапашов Н были получены следующие результаты:

As a result of the research, Japashov N obtained the following results:

- It was found that the optimal regime for lithium diffusion into large-diameter silicon (≥110 mm) with a thickness of the sensitive region $W \geq 4mm$ is at a temperature $T = (450 \pm 20)\ ^0C$, t = 3 min, h_{Li} = (300 ± 10) mm.

- The method of conducting a double sided drift of lithium ions into a silicon monocrystal is performed by a synchronous stepwise increase in temperature from 55 ° C to 100 ° C and a reverse bias voltage from 70V to 200V.

- The technology of double-sided drift of lithium ions into a silicon monocrystal improves spectrometric characteristics, increases the efficiency of the detection system and reduces the time to manufacture the detector.

- The developed charge-sensitive preamps for silicon detectors have high speed (delay time no more than 5 ns), low sensitivity to the input capacitance, which ensures, as a result, a low-noise amplifier with a level of 0.43 $nV/Hz^{1/2}$ and its stability, and the possibility of matching the impedance of the connected line and the input of the amplifier.

During the research and in the process of working on his thesis, N. Japashov demonstrated a high level of theoretical and practical readiness. The results of his scientific work are important and have good practical application.

In think, the dissertational work of Japashov Nursultan satisfies all the requirements for works submitted for the degree of Doctor of Philosophy (PhD). The author has proved himself to be a qualified specialist in the field of Radio engineering electronics and telecommunications. I recommend the Academic Council to accept the dissertation work of Japashov N for public defense for a PhD degree in Radio engineering electronics and telecommunications, and I wish him further success.

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