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APPLICATION OF ADDITIONAL LEVELING DRIFT PROCESS TO IMPROVE THE ELECTROPHYSICAL PARAMETERS OF LARGE SIZED Si (Li) p-i-n STRUCTURES

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ПРИМЕНЕНИЕ ДОПОЛНИТЕЛЬНОГО ВЫРАВНИВАЮЩЕГО ДРЕЙФА ДЛЯ УЛУЧШЕНИЯ ЭЛЕКТРОФИЗИЧЕСКИХ ПАРАМЕТРОВ КРУПНОГАБАРИТНЫХ SI (LI) P-I-N СТРУКТУР

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КАТТА ЎЛЧАМЛИ SI (LI) P-I-N СТРУКТУРАНИНГ ЭЛЕКТРОФИЗИК КАТТАЛИКЛАРИНИ ЯХШИЛАШ УЧУН ҚЎШИМЧА ТЕКШИРИШ ДРЕЙФИНИ ҚЎЛЛАШ

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Abstract. *This paper describes the use of an additional inspection drift to improve the electro physical dimensions of a large-sized Si (Li) p-i-n structure.*

Keywords: Silicon-lithium detector, drift ion lithium, diffusion, monocrystalline silicon

Аннотация. *В данной статье описывается использование дополнительного инспекционного дрейфа для улучшения электрофизических размеров крупноразмерной Si (Li) p-i-n структуры.*

Ключевые слова: Кремний-литиевый детектор, дрейфовый ион лития, диффузия, монокристаллический кремний

Аннотация. *Ушбу мақолада катта ўлчамли Si (Li) p-i-n структуранинг электрофизик катталикларини яхшилаш учун қўшимча текшириш дрейфини қўллаш тасфирланди.*

Таянч сўзлар: Silicon-lithium detector, дрейф ионов лития, диффузия, монокристаллический кремний

Introduction. Silicon-lithium detectors are a key element of semiconductor systems for X-ray, alpha, beta and gamma spectroscopy and are the subject of much research and the main tool of spectrometric apparatus in various fields of science and modern technology. Such detectors have a structure with a p-i-n junction formed by diffusion and drift of lithium in a p-type semiconductor silicon wafer. The scope of Si (Li)-detectors covers the energy range from several hundred eV to 50 keV and more.

The operating conditions of the detection systems mainly depend on the temperature of the silicon detector itself. In practice, the full width at half maximum (FWHM) value of spectrum and the percentage ratio of effectively detected particles are often determined and reported for evaluating the efficiency of the detector. To obtain the most effective radiation detection, the detector should be located at a temperature closer to the temperature of liquid nitrogen. The FWHM value for the detectors with cooling system is up to 10 keV at an α-particle energy of 6 MeV [1].

However, in practice, the use of silicon detectors without cooling system is not excluded. In the work [3], it was compared with the main characteristics (such as sensitivity and energy resolution) of conventional (without cooling system) Si (Li) detectors with thermoelectrically cooled detectors. Here it says that despite of good energy resolution of thermoelectrically cooled detectors, the work is restricted out of the laboratory application, where cooling system is not appropriate. Also, here Xray energy range from 4.5 keV ($Z = 22$) to 17.5 keV ($Z = 42$) is investigated. Comparing the results from various research works, they conclude that cooled detectors have low sensitivity to higher Z elements.

On the basis of silicon detectors, inexpensive, efficient conventional spectrometers (without cooling system) can be constructed for many purposes. In particular, for X-ray telescopes [1], ionizing particle detection systems [2], in medicine [4], and in outdoor operation, for example, to determine the contamination of soil with radionuclides [5].

Materials and methods. Fabrication of the detector structures consists of several stages, these are mechanical and chemical processing of crystals, the process of diffusion of lithium atoms into a silicon crystal, the drift of lithium ions in an electric field, and the final stage is deposition of metal contacts on detector surface [12]. The main aim of “leveling” drift is to carry out the additional drift to prefabricated detector structures to achieve a more uniform distribution of lithium ions in whole volume of monocrystalline silicon. In this work, we considered detector structures without metal contacts obtained by lithium diffusion mode at a temperature $T = 450 \pm 20$ °C, at a time $t = 3$ min, and to a depth $h_{Li} = 300 \pm 10$ μm from both surfaces of the p-type Si crystal. The method of conducting double-sided drift of lithium ions, into a silicon single crystal, for these detectors was carried out by synchronously stepwise increasing the temperature from 55 °C to 100 °C and the reverse bias voltage from 70 V to 200 V. As initial materials we have chosen: a) p-type silicon crystal obtained by the float-zone method (with a diameter of 110 mm, a thickness of 8-10 mm, resistivity $\rho = 1000$-10000 Ohm·cm and with life time $\tau \geq 500$ μs), b) p-type silicon crystal (with a diameter of 110 mm, with a resistivity $\rho = 10$-12 Ohm·cm, lifetime $\tau \geq 50$ μs, grown in an argon atmosphere) obtained by the Czochralski method.

The optimal mode of “leveling” drift was selected at a temperature $T = 65$-70 °C with a reverse bias voltage $U_{rev} = 150$-300 V for 15-40 hours. Temperature and electric field regimes were determined experimentally by comparing best electrophysical parameters of detector with applying temperature and electric field modes. In practice, ordinary drift completion moment is fixed by a sharp increase of reverse current. Sometimes, electrophysical characteristics of detectors, measured just after conventional drift process, show the existence of uncompensated regions. It can be seen from great value of inverse current and from fluctuations in I-V characteristics of detectors. Applying additional “leveling” drift helps to provide uniformly compensated sensitive region.

The compensation accuracy of the initial semiconductor is the most important quality criterion for Si (Li) p-i-n structures intended for the manufacture of spectrometric detectors [13]. The deviation of the local lithium concentration during its drift, at any separate (local) points from the concentration of their acceptors, leads to fluctuations in the electric potential, and, as a consequence, to deterioration of the radiometric characteristics of the detector [14]. For this reason, temperature and field drift conditions are subject to particularly stringent requirements. At the same time, the increased thermal generation of carriers at the drift temperature and the presence of local inhomogeneities in the distribution of the acceptor impurity do not allow uniform compensation in the entire volume of the sensitive region of the detector [15].

Results and discussion. The capacitance of Si (Li) p-i-n structured detectors is mainly connected with size (thickness) of the depletion layer and with a specific resistance of initial material. Correspondingly, by measuring Voltage-Farad characteristics, it is possible to determine the specific resistance of compensated region of silicon in the prepared structure and estimate the values of maximum energy of charged particle under the conditions of its total absorption in the depletion layer [6].

Fig. 1 and Fig. 2 show that the “leveling” drift leads to a significant improvement in the degree of compensation of the detector obtained by Czochralski method compared with detector obtained by float-zone method. This is explained by the fact that in the initial highresistance Si crystal obtained by float-zone method there are more effective sizes of local inhomogeneities in comparison with the low-resistance Si crystal obtained by Czochralski method, which determine the appearance of large dipole formations at the drift stage.

Fig. 1 and Fig. 2 show that the “leveling” drift leads to a significant improvement in the degree of compensation of the detector obtained by Czochralski method compared with detector obtained by float-zone method. This is explained by the fact that in the initial highresistance Si crystal obtained by float-zone method there

a) b)

Fig. 1 – Change of the Voltage-Farad and Voltage-Noise characteristics of the detector obtained by Czochralski method with the diameter D = 110 cm^2 and thickness Wi = 4 mm. Before and after “leveling” drift under temperature T = 65-70 °C with a reverse bias voltage U_{rev} = 150-300 V for 15-40 hours

a) b)

Fig. 2 – Change of the Voltage-Farad and Voltage-Noise characteristics of the detector obtained by float-zone method with the diameter D = 110 cm2 and thickness Wi = 4 mm. Before and after “leveling” drift under temperature T = 65-70 °C with a reverse bias voltage U_{rev} = 150-300 V for 15-40 hours

Conclusions. Therefore, conduction of “leveling” drift, providing a sufficient degree of compensation, is a mandatory technological operation. Here, the choice of the temperature-time regime of the “leveling” drift depends on the specific resistance of the initial materials. It follows that, for low-resistance material, “leveling” drift is more effective. For our chosen samples, the optimal mode of “leveling” drift was selected at a temperature T = 65-70 °C with a reverse bias voltage U_{rev} = 150-300 V for 15-40 hours.

The results of this work can help to improve a technology of manufacturing large sized p-i-n structured Si (Li) detectors.

References:

[1]. H. Tajima, T. Kamae, S. Uno, T. Nakamoto, Y. Fukazawa, T. Mitani, M. Nomachi, In X-Ray and Gamma-Ray Telescopes and Instruments for Astronomy 4851, 875 (2003).
[2]. N. Cartiglia, R. Arcidiacono, M. Baselgaet, Nucl. Instrum Method Phys. Res. A 796, 141 (2015).
[3]. R.A. Muminov, S.A. Radzhapov, A.K. Saimbetov, Tech. Phys. Lett. 35 No 8, 768 (2009).
[4]. K. Taguchi, J.S. Iwanczyk Medical Phys. 40, 10 (2013).
[5]. V. Desnica, S. Manfred, X-Ray Spectrometry: Int. J. 35, 280 (2006).
[6]. J. Eberth, J. Simpson, Prog. Part. Nucl. Phys. 60, 2 (2008).
[7]. I.E. Alexeev, S.V. Bakhlanov, N.V. Bazlov, Nucl. Instrum. Methods Phys. Res. A 890, 64 (2018).
[8]. P. Dryák, P. Kovář, Appl. Radiat. Isotop. 87, 325 (2014).
[9]. J. Lee, N. Lakshminarayan, S.K. Dhungel, K. Kim, J. Yi, Sol. Energ. Mater. Sol. Cells 93, 240 (2009).
[10]. F. Osmic, P. Wobrauschek, C. Streli, S. Pahlke, L. Fabry, Spectrochim. Acta Part B: Atomic Spectroscopy. 58, 2123 (2003).
[11]. R. A. Muminov, A.K. Saymbetov, N.M. Japashov, Yo.K. Toshmurodov, S.A. Radzhapov, N.B. Kuttybay, M.K. Nurgaliyev, J. Nano Electron. Phys. 11 No 2, 02031 (2019).
[12]. R.A. Muminov, A.K. Saumbetov, N.M. Japashov, J. Semiconduc. Technol. Sci. 17 No 5, 591 (2017).
[13]. F.H. Ruddy, J.G. Seidel, Haoqian Chen, A.R. Dulloo, SeiHyung Ryu, IEEE Transact. Nucl. Sci. 53, 1713 (2006).
[14]. B. Beckhoff, R. Klein, M. Krumrey, F. Scholze, R. Thornagel, G. Ulm, Nucl. Instrum. Methods Phys. Res. A 444, 480 (2000).
[15]. D. Protic, E.L. Hull, T. Krings, K. Vetter, IEEE Transact. Nucl. Sci. 52, 3181 (2005).