ISSN 2224-5227

2016 • 1

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

БАЯНДАМАЛАРЫ

ДОКЛАДЫ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

REPORTS

OF THE NATIONAL ACADEMY OF SCIENCES
OF THE REPUBLIC OF KAZAKHSTAN

ЖУРНАЛ 1944 ЖЫЛДАН ШЫҒА БАСТАҒАН

ЖУРНАЛ ИЗДАЕТСЯ С 1944 г.

PUBLISHED SINCE 1944

ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫНЫҢ

БАЯНДАМАЛАРЫ 2016 • 1

ДОКЛАДЫ **2016• 1**
НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН

«Доклады Национальной академии наук Республики Казахстан» ISSN 2224-5227
Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы)
Свидетельство о постановке на учет периодического печатного издания в Комитете информации и архивов Министерства культуры и информации Республики Казахстан **№5540-Ж**, выданное 01.06.2006 г.
Периодичность: 6 раз в год. Тираж: 2000 экземпляров
Адрес редакции: 050010, г.Алматы, ул.Шевченко, 28, ком.218-220, тел. 272-13-19, 272-13-18
http://nauka-nanrk.kz. reports-science.kz
Адрес типографии: ИП «Аруна», г.Алматы, ул.Муратбаева, 75

REPORTS **2016 • 1**
OF NATIONAL ACADEMY OF SCIENCES OF THE
REPUBLIC OF KAZAKHSTAN

Reports of the National Academy of Sciences of the Republic of Kazakhstan.
ISSN 2224-5227
Owner: RPA "National Academy of Sciences of the Republic of Kazakhstan" (Almaty)
The certificate of registration of a periodic printed publication in the Committee of Information and Archives of the Ministry of Culture and Information of the Republic of Kazakhstan N 5540-Ж, issued 01.06.2006
Periodicity: 6 times a year
Circulation: 2000 copies
Editorial address: 28, Shevchenko str., of.219-220, Almaty, 050010, tel. 272-13-19, 272-13-18,
http://nauka-nanrk.kz / reports-science.kz
Address of printing house: ST "Aruna", 75, Muratbayev str, Almaty

REPORTS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
ISSN 2224-5227
Volume 1, Number 305(2016), 41 – 44

UDC 539.1.074.55

A. K. Saymbetov, N. M. Zhapashov, N. K. Sissenov, N. B. Kuttybay, B. K. Mukhametkali, Ye. Tulkibayuly, M. K. Nurgaliyev

Al-Farabi Kazakh National University, Almaty, Kazakhstan.
E-mail: asaymbetov@gmail.com

DEVELOPMENT OF HIGH SENSITIVE SILICON STRIP DETECTORS OF LARGE SIZES

Abstract. Currently, in the world, relatively small size detectors are well developed. At the same time there is an urgent need for the development of semiconductor detectors of large dimensions. They are connected with the manifestation of the effects caused by interconnection parameters of the original crystals of large diameter with development of effective nuclear radiation detectors on their basis. In particular, it is related to providing high-quality detector structures such p-n or p-i-n to larger crystals. At the same time there is an urgent need for a large SCD (Ø≥50 ÷ 110 mm, W≥3 ÷ 10 mm). However, they are creating not only physical, technical, technological peculiarities and difficulties, but especially the processes of collecting charges, kinetic processes at large volumes of sensitive area of SCD.

The successful solution of the task of building of high-performance Si (Li) detectors of nuclear radiation of large areas and the extent of sensitive area depends on a proper understanding of the properties of the original crystal of large diameter, and their physical connection to the performance of the detector. This requires a better understanding of the properties of the original crystal and establish their role in the formation of high-performance detector structures such as p-n, p-i-n junctions.

In this paper it was considered the creation and optimization technology of strip detectors with orthogonal field, on the basis of Si (Li) p-i-n structures with, big area of workspace. The results of the energy resolution of these detectors are measured by using a source of ^{226}Ra - α particles and ^{207}Bi- β particles. There are shown the results of measurements of the electrical and spectrometric characteristics of silicon strip detectors. Also, it was illustrated the structure of Si (Li) p-i-n detectors of large.

Key words: silicon detectors, silicon detectors of large size, semiconductor detectors of p-i-n structure, coordinate sensitive detectors, strip detectors of radioactive radiation.

Silicon position-sensitive detectors based on p-i-n structures are now one of the main tools of investigation of various particles and radiation, which are the products of nuclear reactions. Their advantages are small energy, high stopping power, which gives a compact shape to detector, the high rate of collecting statistics and the most mature technology of silicon detectors.

To this purpose it was developed highly sensitive systems where the main part of a semiconductor detector. With the help of these detectors it has already obtained very interesting results in various fields of research [1-3]. Let's bring a few examples.

In medical practice, the position-sensitive detector is used to obtain data on the distribution of radioactive substances i.e. an original photo of the object, which emits X-rays. These devices have become a diagnostic means of identifying malignancy, monitor the general condition of the patient, to monitor the dynamics of the processes occurring in the body [4,5].

In space research semiconductor detectors are very promising for telescopic systems for identification of the isotopic composition of solar and galactic particles. Since the flows of these particles is very weak, it is desirable to broaden the angle of view of the system and its sensitivity, which leads to the dispersion of the length of the trajectories of particles passing through the detector, and the uncertainty in the transmission of these energy detectors. If we know the coordinates of the particles hit, it is possible to accurately determine the path of the particles in each case and to introduce corrective amendments [6,7].

Development of silicon strip detectors with orthogonal field, with high energy and position resolution, linearity of the signal over a wide energy range for various types of particles, is closely linked to the technology of manufacturing the detection modules and properties of the original silicon crystal. The disadvantages of existing silicon strip detectors are not high position resolution, as well as the impossibility of combining the thin entrance window with a sufficient thickness of the sensitive area. Processing methods of creating resistive layers and modes are not enough covered in the technical literature. The identity of the elements of discrete strip detectors with orthogonal field and characteristics of resistive layers of continuous strip detectors caused by the initial parameters of the semiconductor, in particular, distribution of the coordinate of inhomogeneities in the volume and nature. All of these factors significantly alter the processes of diffusion and drift of lithium ions, and the choice of the resistive layer. However, it is necessary to solve a number of issues of technological and physical nature. These issues are related to the process of diffusion and drift of lithium ions in large size silicon and to the optimizing the electrical and radiometric characteristics of each band and structure

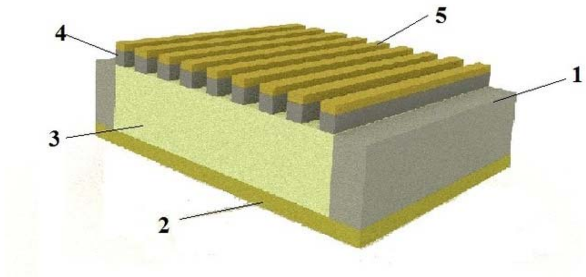

Figure 1 – Strip silicon detectors

Si (Li) p-i-n structure were made on the basis of single-crystal silicon wafer of p-type (1) (Figure 1), as well as initial parameters: the resistivity ρ = 5000Ω.cm, the lifetime of the charge carriers τ = 300 μs. After some chemical-technological operations on plates the diffusion of lithium to one of its sides were carried out in vacuum at a temperature $T = 450^0$C a depth 320-350 μm. After that, to compensate for the entire thickness of the plate it was carried out drift of lithium ions in the entire thickness of the plate. The process of drift conducted at a temperature $T = 80 \div 100^0$C, and the reverse bias voltage of 60-300V compensated for the i-region. The thickness of the i-region is 6 mm (3). After the process of drift the plate was cut in rectangular shape, then diffusion (n +) region (4), in diameter of (100 ÷ 300) microns, were cut by wire saw. As a result of extended operation, it was obtained a groove with depth of 0.4 ÷ 0.6 mm and a width of 200 mm at a distance of 0.4 ÷ 1 mm from each other. Then held a number of chemical-engineering operations. Using a mask on each strip deposited Al (2) and Au (5) contacts.

In the manufacture of silicon strip detectors we measured the electrical spectrometric characteristics of the detectors. Obtained by the proposed method detectors have the following typical parameters: a reverse bias voltage $U_{об}$ ~ 20÷200 V, dark current I ~ 0,1 ÷ 0,5 mA, the capacitance C ~ 2 ÷ 20 pF, the noise of energy E_n ~ 12-35 keV . The energy resolution of the system for α-particles ^{226}Ra (E_α = 7,65 MeV) energy resolution of R_α = 46 кeV and β-particles from the source of ^{207}Bi (E_β ~ 1 MeV) R_β ~ 18 кeV taken at T = 300 ° K.

For most of cases, there are most significant two types of measurements: determination of the energy of the particles and their flow measurement. Sometimes it is necessary to register a group of particles of low intensity in the presence of a large number of other particles with very similar energies.

According to the most intense peak (482 keV and 976 keV) it was defined value of channel AI and in width at half maximum of the most intense peak value it was found energy resolution in the keV by the formula:

$$R_\beta = \sqrt{(\Delta E_0 N_n)^2 - E_{шу}^2} \ ,$$

where ΔE_0 - value of the channel, N_n – number of channels at half-maximum, $E_{шу}$ – noise of installation.

The energy resolution is measured by using a source of α particles ^{226}Ra and β particles ^{207}Bi.

Registration of amplitude spectra was carried out using a conventional spectrometer path.

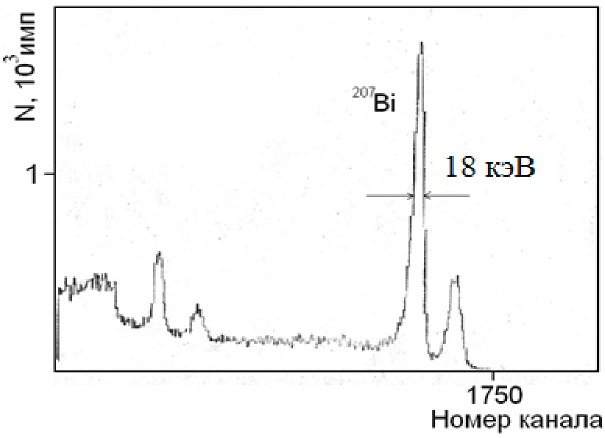

Figure 2 – The energy spectrum of β-particles ^{207}Bi (E_β~1 MeV)

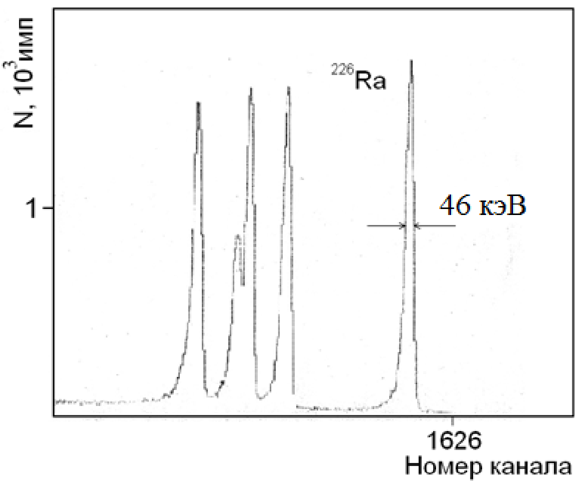

Figure 3 – The energy spectrum of α-particles ^{226}Ra (E_α=7,65 MeV)

As a result, we can obtain a quite convenient detection system capable of generating spectrometric investigation of various ionizing particles from small to sufficiently high energies.

REFERENCES

[8] Muminov R.A., Saymbetov A.K., Toshmurodov Y.K. Special features of formation of high-performance semiconductor detectors based on αSi-Si (Li) heterostructures // Instruments and Experimental Techniques. **2013**. N 1. P. 32-33.

[9] Muminov R.A., Radzhapov S.A., Saimbetov A.K. Silicon-lithium telescopic detector in one crystal // Atomic energy. **2009**. N 2. P. 141-142.

[10] Muminov R.A., Radzhapov S.A., Saimbetov A.K. Developing Si (Li) nuclear radiation detectors by pulsed electric field treatment // Technical Physics Letters. **2009**. N 8. P. 768-769.

[11] Ljudvig J. Detektornye sistemy dlja medicinskoj diagnostiki // Izd. VUZov. **2003.** N 6. P. 75-79.

[12] Toops T., Bilheux H., Voisin S., Gregor J., Walker L., Strzelec A., Finney C., Pihl J., Schillinger B., Schulz M. Neutron tomography of particulate filters: A non-destructive investigation tool for applied and industrial research // Nuclear Instruments and Methods in Physics Research Section A. **2013**. Vol. 729. P. 581-588.

[13] Kurfess J.D., Johnson W.N., Kroeger R.A., Phlips B.F. Considerations for the Next Compton Telescope Mission "AIP Conf. Proc. **2000**. Vol. 510. P. 789-793.

[14] Phlips B.F., Inderhees S.E., Kroeger R.A., Johnson W.N., Kinzer R.L., Kurfess J.D., Graham B.L., Gehrels N. Performance of a compton telescope using position-sensitive germanium detectors // IEEE Trans Nucl Sci. **1996**. Part 2. 43 (3). P. 1472-1475.

**А. К. Саймбетов, Н. М. Джапашов, Н. К. Сисенов, Н. Б. Құттыбай,
Б. Мухаметкали, Е. Түлкібайұлы, М. К. Нұрғалиев**

Әл-Фараби атындағы ҚазҰУ, физика-техникалық факультеті, Алматы, Қазақстан

СЕЗІМТАЛДЫҒЫ ЖОҒАРЫ КРЕМНИЛІ ЖОЛАҚТЫ, ҮЛКЕНҮЛКЕН ӨЛШЕМДІ ДЕТЕКТОРЛАРДЫ ЖАСАУ

Аннотация. Мақалада жұмыс істеу аумағы үлкен Si(Li) негізіндегі p-i-n құрылымды жолақты детекторларды жасау және оңтайландыру технологиялары қарастырылған. Сәулелену көзі ретінде α - ^{226}Ra және β - ^{207}Bi бөлшектері алынып бұл детекторлардың энериялық рұқсат беру аймағы көрсетілген. Кремнийлі жолақты детекторлардың электрофизикалық және спектрометриялық сипаттамаларының нәтижелері келтірілген. Si(Li) негізіндегі p-i-n құрылымды жолақты детекторлардың құрылымы көрсетілген.

Түйін сөздер: кремнилі детекторлар, үлкен өлшемді кремнилі детекторлар, p-i-n құрылымды кремнийлі детекторлар, координатты сезгіз детекторлар, радиациялық сулеленулің жолақ детекторлары.

**А. К. Саймбетов, Н. М. Джапашов, Н. К. Сисенов, Н. Б. Куттыбай,
Б. Мухаметкали, Е. Тулкибайулы, М. К. Нұрғалиев**

КазНУ им. аль-Фараби, физико-технический факультет, Алматы, Казахстан

РАЗРАБОТКА ВЫСОКОЧУВСТВИТЕЛЬНЫХ КРЕМНИЕВЫХ СТРИПОВЫХ ДЕТЕКТОРОВ БОЛЬШИХ РАЗМЕРОВ

Аннотация. В работе рассматривается создание и оптимизации технологии стриповых детекторов с ортогональным, полем на основе Si(Li) p-i-n структур с большим объемом рабочей области. Показаны результаты энергетического разрешения этих детекторов измеренных с помощью источника α частиц ^{226}Ra и β частиц ^{207}Bi. Приведены результаты измерения электрофизических и спектрометрических характеристик кремниевых стриповых детекторов. Показана структура Si(Li) p-i-n детектора больших размеров.

Ключевые слова: кремниевые детекторы, кремниевые детекторы больших размеров, кремниевые детекторы p-i-n структуры, координатно-чувствительные детекторы, стриповые детекторы радиационного излучения.

Information about authors:

Saymbetov A.K. – PhD, senior lecturer of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

Japashov N.M. – First course PhD student, lecturer of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

Mukhametkali B.K. – lecturer of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

Sissenov N.K. – First course master degree students of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

Kuttybay N.B. – First course master degree students of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

Tulkibayuly Ye. – Forth course student of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

Nurgaliyev M.K. – Forth course student of al- Farabi Kazakh national university at faculty of Physics and Technology, Almaty, Kazakhstan.

CONTENTS

PUBLICATION ETHICS AND PUBLICATION MALPRACTICE IN THE JOURNALS OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN

For information on Ethics in publishing and Ethical guidelines for journal publication see http://www.elsevier.com/publishingethics and http://www.elsevier.com/journal-authors/ethics.

Submission of an article to the National Academy of Sciences of the Republic of Kazakhstan implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see http://www.elsevier.com/postingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. In particular, translations into English of papers already published in another language are not accepted.

No other forms of scientific misconduct are allowed, such as plagiarism, falsification, fraudulent data, incorrect interpretation of other works, incorrect citations, etc. The National Academy of Sciences of the Republic of Kazakhstan follows the Code of Conduct of the Committee on Publication Ethics (COPE), and follows the COPE Flowcharts for Resolving Cases of Suspected Misconduct (http://publicationethics.org/files/u2/New_Code.pdf). To verify originality, your article may be checked by the originality detection service Cross Check http://www.elsevier.com/editors/plagdetect.

The authors are obliged to participate in peer review process and be ready to provide corrections, clarifications, retractions and apologies when needed. All authors of a paper should have significantly contributed to the research.

The reviewers should provide objective judgments and should point out relevant published works which are not yet cited. Reviewed articles should be treated confidentially. The reviewers will be chosen in such a way that there is no conflict of interests with respect to the research, the authors and/or the research funders.

The editors have complete responsibility and authority to reject or accept a paper, and they will only accept a paper when reasonably certain. They will preserve anonymity of reviewers and promote publication of corrections, clarifications, retractions and apologies when needed. The acceptance of a paper automatically implies the copyright transfer to the National Academy of sciences of the Republic of Kazakhstan.

The Editorial Board of the National Academy of sciences of the Republic of Kazakhstan will monitor and safeguard publishing ethics.

Правила оформления статьи для публикации в журнале смотреть на сайте:

www:nauka-nanrk.kz

http://www.reports-science.kz/index.php/ru/

Редакторы *М. С. Ахметова, Д. С. Аленов, Т.А. Апендиев*
Верстка на компьютере *С.К. Досаевой*

Подписано в печать 05.02.2016.
Формат 60х881/8. Бумага офсетная. Печать – ризограф.
3,1 п.л. Тираж 2000. Заказ 1.

Национальная академия наук РК
050010, Алматы, ул. Шевченко, 28, т. 272-13-18, 272-13-19