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DEVELOPMENT OF TECHNOLOGY AND MAKING OF SILICON DETECTOR STRUCTURES OF LARGE SIZE

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

Abstract. In this paper we consider the creation technology and the formation of silicon-lithium detectors p-i-n structure of large size. The technology of manufacturing of detectors of large size is shown. For the manufacture of lithium-silicon p-i-n structures it was chosen the industrial p-type silicon as a bulk material, with a resistivity $\rho=1 \div 5$ кOh, the lifetime of carriers $\tau \geq 300$ microseconds. Also it was considered the technological problems of manufacturing of detectors large size, in particular, difficulties arising in the process of mechanical and chemical treatment. It is shown detailed descriptions of the manufacturing process of p-i-n structure. Additionally, there are gradually illustration of the structure of the samples and the processes of diffusion and drift. Noted materials and chemical composition of mixtures used in the manufacturing technology of large size detectors.

Nuclear spectroscopy technique has now reached a very high level. This progress is largely due to the creation of semiconductor detectors (SCD) of nuclear radiation. SCD is widely used in the experiments, where the low rate accounts or short lifetime preclude the application of magnetic spectrometers in applied and basic researches. The development of semiconductor detectors with a high energy and positional resolution, with the linearity of the signal over a wide energy range for various types of particles, is closely linked to the presence of impurity inhomogeneities in the crystal volume and semiconductor properties of the initial crystals. Especially important parameters are the value of the sensing surface and radiometric characteristics of the SCD [1-4].

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 [5-7].

In this paper we consider the creation technology and the formation of silicon-lithium detectors p-i-n structure of large size, for the manufacture of lithium-silicon p-i-n structures from industrial p-type silicon, with a resistivity ρ=1 ÷ 5 кOh, the lifetime of carriers τ≥300 microseconds.

Also, it is known the technology of production [1], which includes cleaning, deposition and diffusion of lithium. This technique is most effective when compared to other technology to create high-quality p-n junctions of large and small areas. Lithium is applied to the surface of the silicon, sputtered in vacuum from metal lithium. In this method it is possible to strictly control the location of the p-n junction in size and depth, concentration and impurity concentration gradient that allows you to create semiconductor detectors with highly reproducible characteristics.

The process of making p-i-n structure is composed of the following steps:

1) To remove the layer, which was disturbed during cutting, is used double-sided grinding on grinder with micropowder M-14, M-5 with consequent reduction of the diameter of the abrasive. After grinding the process of washing the plates with deionized water and alkali-free soap, in each side is removed layer with thickness less than 50 microns.

2) Preparation of the initial structure is due to the diffusion of lithium. Lithium diffusion was carried out in a vacuum p ~ 10^{-5} torr at a depth of 300 micrometers on the entire surface of the wafer for t = 3 minutes at a temperature equal to 450 ° C.

3) The pickling polishing etchant - acid mixture $HF:HNO_3:CH_2COOH_2$ with a ratio of 1: 3: 1 and aniline etchant.

4) The drift of lithium ions in an electric field of the p-n junction should be carried out at a temperature of 70-80^{0}C and reverse bias voltage 100 ÷ 400 V for 20 ÷ 30 days. It depends on the thickness of the sensitive region.

5) After the end of the drift to identify i-region one side of the crystal n + -region n + -i-p structures are grind on a glass disk with micropowder of silicon carbide.

This thickness of the sacrificial layer illustrates with taking into account blurring diffusion profile. The thickness of the polished layer is typically 50 ÷ 400 microns. Derivation of the i-region is carried out with the help of decorating etchant HNO3: HF = 1: 1000. The i-region is considered to be fully withdrawn when its contours are close to a circle with a diameter equal to the diameter of the diffusion region (Figure 1).

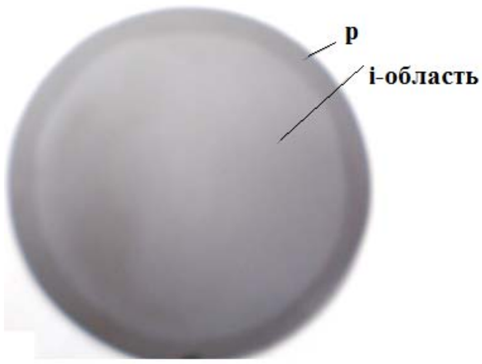

Figure 1 – Si(Li) p-i-n structure

For technical problems it is should be included mechanical and chemical processing of silicon wafers of large diameters. To generate the required p-n or p-i-n structures on wafers with larger diameters ensure a high flatness of their surfaces need solutions for a number of technical problems to mechanical and chemical treatments.

To maintain optimum flatness of wafers in chemical processing, it is required to obtain a uniform velocity of these processes simultaneously etching the entire surface of a large area. To ensure these conditions, we have developed the optimum formulations of chemicals, as well as developed a dynamic process of chemical etching. The essence of this process lies in the fact that the plates are of silicon crystals at a certain angle ($60 \div 65^0$) and rotated as a particularly selected rate. These modes of chemical treatment processes were selected in accordance with, mainly with respect to the initial diameter of the silicon crystal plates.

Diffusion of lithium was carried out in vacuo from two sides to a depth of ~ 400mkm at t = 450^0C. The depth of diffusion is controlled by ball-polished section. After the diffusion the plate was etched for obtaining the T-shape on both sides. After etching, polishing etchant mixed at acid HF: HNO3:CH3COOH and aniline etchant, initial samples had reverse currents I≤10 microamps, and then were put on a drift of lithium ions. The drift of lithium ions was carried out at a temperature (70 80^0C) and voltage U=(100 ÷ 400)V, followed by low temperature in (T = 60^0C U = 200V) leveling drift. After the end of the drift to identify the i-region the crystals are ground on a glass disk micropowder silicon carbide M-14. The thickness of the polished layer is generally ~ 100um. Withdrawal full i-region is carried out with the help of decorating etchant HNO_3: HF with an optimal ratio.

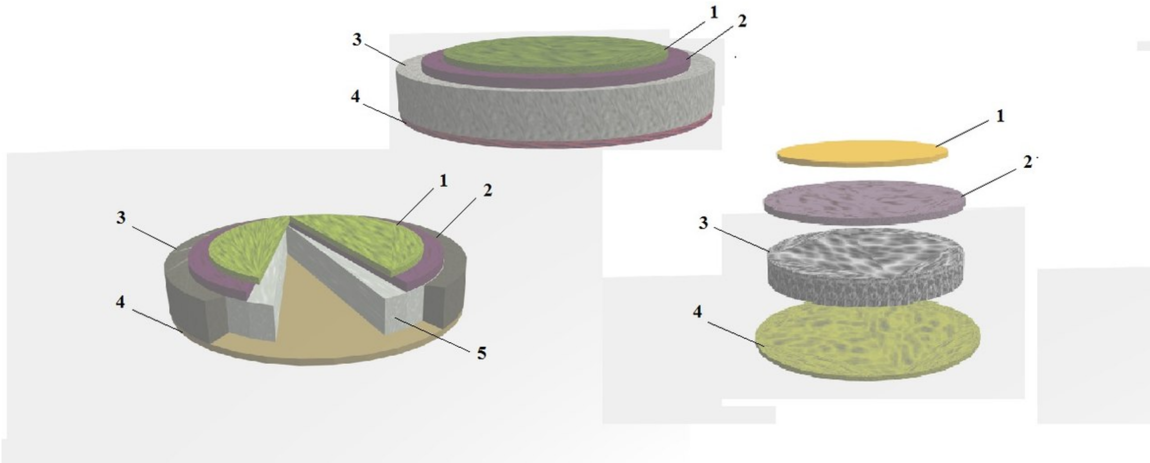

Figure 2 – The silicon-lithium detector of p-i-n structure:
1 – Contact of Au, 2 – n region, 3 – p region, 4 – contact of Al, 5 – i area

After the full compensation one of the n + - diffusion regions ground off to a depth of ~ 400 mkm. Then, the entire crystal undergoes chemical-processed. To the finished structure metal contacts are deposited, Al (~ 1000^0A) and Au (~ 300^0A) in the n + -region and i-area, respectively (Fig. 2).

Obtained by the above method Si (Li) detectors have improved characteristics, namely under reverse bias U_{obr} = 200V. Detectors with sensitive area thickness W_i = 4 mm have a dark current value I ~ 0.7 mA, the capacitance of C = 3 ~ 4 pF , the energy equivalent noise E_n ~ 14-17 keV.

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ҮЛКЕН ӨЛШЕМДІ КРЕМНИЛІ ДЕТЕКТОРЛЫҚ ҚҰРЫЛЫМДАРДЫ АЛУ ЖӘНЕ ОНЫҢ ТЕХНОЛОГИЯСЫН ЖАСАУ

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

Аннотация. Жұмыста p-i-n структуралы кремний литийлі детекторлардың жасалу және қалыптасу технологиялары қарастырылған. Үлкен өлшемді детекторлардың жасалу технологиялары сипатталған. Кремний литийлі, p-i-n құрылымды детекторлады жасау үшін шикізат ретінде меншікті кедергісі $\rho=1\div5$ кОм және токты тасымалдаушыларының уақыты $\tau\geq300$ мкс болатын өндірістік кремний таңдап алынды. Сонымен қоса бұл жұмыста үлкен өлшемдегі детекторларды жасаудағы кездесетін негізгі технологиялық мәселелер қарастырылған, атап айтқанда, детекторларды механикалық жәнеде химиялық өңдегенде кездесетін қиын-шылықтар туралы жазылған. p-i-n құрылымын жасаудың түбегейлі сипаттамасы берілген. Үлкен өлшемді детекторлады алудағы қолданылатын қосылыстар мен материалдар тұрғысында толық мағлұмат берілген.

РАЗРАБОТКА ТЕХНОЛОГИИ И ПОЛУЧЕНИЯ КРЕМНИЕВЫХ ДЕТЕКТОРНЫХ СТРУКТУР БОЛЬШИХ РАЗМЕРОВ

А. К. Саймбетов, Н. М. Джапашов, Н. К. Сисенов,
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Ключевые слова: кремниевые детекторы, кремниевые детекторы больших размеров, кремниевые детекторы p-i-n структуры, координатно-чувствительные детекторы, стриповые детекторы радиационного излучения.

Аннотация. В работе нами рассматривается создания и технологии формирования детекторных кремний-литиевых p-i-n структур больших размеров. Изложена технология изготовления детектора больших размеров. Для изготовления кремний-литиевых p-i-n структур нами выбран материал из промышленного кремния p-типа с удельным сопротивлением $\rho=1\div5$ кОм, временем жизни носителей тока $\tau\geq300$ мкс. Также рассматривается технологические проблемы изготовления детекторов больших размеров, в частности, трудности, возникающие при процессе механической и химической обработки. Даны подробные описания всего процесса изготовления p-i-n структуры. Поэтапно проиллюстрирована структура образца и процесс диффузий и дрейфа. Отмечены материалы и химический состав смесей, применяемые в технологии получения детекторов больших размеров.

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