CHEMICAL TECHNOLOGICAL PROCESSES IN LARGE-SCALE SEMICONDUCTOR NUCLEAR RADIATION DETECTORS

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ABSTRACT

This article reviews the development technology of semiconductor nuclear radiation detectors, in which a unique scientific approach to each technological step is implemented. Important aspects of chemical processing on a silicon wafer are shown. It is shown that the chemical- technological process of production of semiconductor detectors recording nuclear radiation can be described by mathematical modeling..

Keywords: *silicon, detector, nuclear radiation, plate, mechanical, chemical processes, grinding, mathematical modeling.*

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1. INTRODUCTION

Currently, in world practice, great attention is paid to the creation of new types of semiconductor devices, as well as their improvement. Controlling technological processes in the development of semiconductor devices, bringing the practice of scientific work closer to theoretical calculations, controlling practical technological processes based on precise mathematical models is one of the important tasks in this direction [1].

When creating semiconductor devices with complex technological processes, it is especially important to plan and define each step in advance. In the preparation of semiconductor detectors, the

etching process of a monocrystalline silicon wafer is first performed, and mechanical and chemical processes are carried out to eliminate the defects formed during the etching process [2].

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2. RESEARCH METHODS.

At the initial stage of the development technology of semiconductor nuclear radiation detectors, mechanical processing is carried out to improve the flatness and plane parallelism of semiconductor silicon plates, as well as to adapt the plates to the required size and obtain the required surface cleanliness.

The following substances are used for the mechanical processing of semiconductor plates: B4C boron carbide; SiC silicon carbide. Also, the microhardness of powders is 10-9 on the appropriate scale, the range of powders from M-5 to M-14 is used in mechanical processing. The process of mechanical processing is carried out by successively changing the granularity of powders from large grains to small grains.

Grinding of large-diameter semiconductor plates is carried out using an abrasive suspension, in which a stream of water is used as a fluid. The polishing process itself is carried out on the surface of the glass circle, in order to evenly distribute the grains along the surface, reduce friction and control the temperature, as well as soften shock-vibration movements.

It is known that the use of different sizes of abrasive material and thorough washing of the wafers are used to eliminate micro-cracks and other structural defects in silicon wafers. Microcracks and other structural defects can serve as favorable places for the accumulation of foreign ions. This affects the lifetime of charge carriers and leads to the formation of recombination centers that significantly reduce the efficiency of recording radioactive radiation. Therefore, the plates should be polished on both sides with a thickness of 50 μm with M14÷M5 micro powders successively, and the plates should be washed in distilled water with ultrasonic mixing for 10 minutes and dried using infrared light.

3. RESULTS AND DISCUSSION.

In the preparation of silicon-based nuclear radiation detectors with a large diameter, the process of chemical erosion serves to eliminate surface defects on the crystal surface [3]. Chemical technological processes serve to eliminate surface and line defects on the silicon wafer. It is known that a certain sequence of reactions is observed when acidic compounds interact with the surface of a semiconductor silicon wafer during chemical erosion. When eliminating defects on the silicon surface, it is necessary to achieve control of the chemical erosion process by controlling the overall speed and temperature of the mixture prepared from acids.

The selection of large-scale silicon material and the implementation of technological processes in it are associated with some difficulties [4], which are related to the increased surface area, the careful control of the uniform thickness of the plate, the selection of the composition of the surface, ensuring the smooth parallelism of the sides of the silicon plate, etc.

In this case, during the process of chemical dissolution, silicon wafers are placed in a fluoroplast glass, a chemical mixture of HF:HNO3 (1:1000 ratio) is prepared and poured into the fluoroplast glass. The chemical decomposition process lasts 12÷15 minutes, and as the temperature of the chemical mixture rises, it becomes light brown.

Before the chemical etching process, it is necessary to perform the surface cleaning process of the silicon wafer samples. Removal of dust and particles is usually done by placing the sample in distilled water and stirring vigorously. In addition, the removal of organic iodine-containing substances, which are present in large quantities, is also carried out by boiling the samples in solvents with simultaneous ultrasound examination.

Large area silicon wafers are surface cleaned for a chemical etching process and degreased in a hot soapy water solution in an ultrasonic tank. Then it is washed in distilled water and boiled in light grade toluene for 3-4 minutes. After treatment with deionized water for 30-40 minutes, the samples should be dried with a filter.

Plates are pre-diffused in a rotating fluoroplastic beaker for 8÷10 minutes using a chemical mixture of HP:HNO3:CH3COOH (1:3:1), 30÷50 ml per sample. amount, polished by chemical treatment. After boiling in nitric acid, an amorphous oxide film (dioxide, silicon hydroxide) is formed on the silicon surface. Therefore, prior to diffusion, the crystals are regenerated by treatment in a low- concentration solution of hydrofluoric acid in water, HF:H2O.

Chemical-technological processes usually take place in moving streams, and the hydrodynamic forms of their movement have a significant impact on the efficiency of chemical processing. Therefore, the description of the movement of material flows is important when creating mathematical models [5,6]. Making a silicon wafer with a specified thickness and high quality in chemical etching is a complex process in itself. A mixture is prepared using nitric, acetic and hydrofluoric acids and the mixture is cooled at low temperature.

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Silicon wafers are chemically treated to a certain thickness to remove complex configuration parts and surface irregularities (precision machining, chemical and chemical-mechanical grinding). Chemical processing is carried out in cold acid solutions (nitrogen, vinegar, hydrofluoric acid, etc.) in equipment that accurately controls the process. Defects in the crystal structure of semiconductor materials are identified. The depth and width of the profile are measured using electron microscopes. Complex solutions are prepared for polishing and chemical processing, electrolytes. Optimal modes of chemical processing are selected. When testing the new technology, a mixture is prepared using solutions used in chemical and chemical-mechanical grinding and chemical processing. Semiconductor plates are processed and chemically cleaned until they reach the specified thickness according to technological documents.

Chemically treated silicon wafers are polished with the following chemical acids: hydrofluoric acid HF, nitric acid HNO3, acetic acid CH3COOH, 1:3:1 ratio in organic solvents and fluoroplastic baths are prepared for processing in acids (Fig. 1).
The temperature of baths and solvents is corrected. If the temperature of the solvents and the bath is low, the chemical treatment is slow, then the degree of chemical treatment can be controlled. Chemical processing is carried out for 15÷20 minutes in specially prepared chemical processing equipment in the laboratory.

It is of great importance to maintain the reaction speed and temperature during the chemical etching process on the silicon wafer with the help of chemical acids. Therefore, chemical processing processes are regulated according to the established regimes. In general, the description of mathematical modeling of the chemical-technological process of production of semiconductor detectors recording nuclear radiation is a system of differential equations. Often such a system of differential equations cannot be solved analytically, and therefore numerical methods are used to solve them.

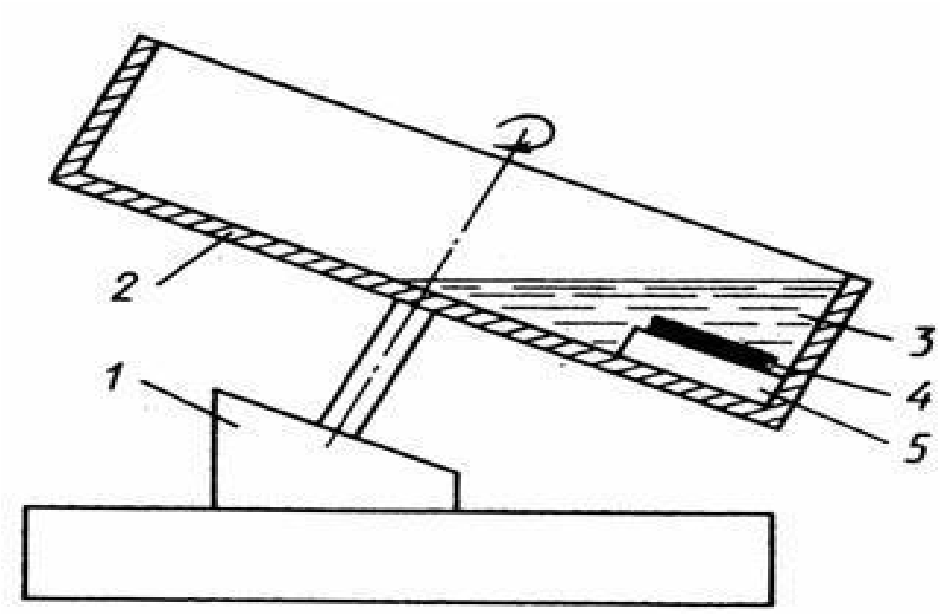

Fig. 1. Schematic of a silicon wafer chemical treatment device. 1- holder; 2- fluoroplastic bath; 3- solvent; 4- silicon plate; 5- fluoroplastic disk to protect the back side of the silicon wafer.

At present, the use of silicon-based detectors in the recording of nuclear radiation is the most promising for the detection of charged particles. Semiconductor detectors are widely used in nuclear physics experiments, as well as in fields such as medicine, geology, environmental protection, etc. At the same time, their creation is associated with a number of physical, structural, technical and technological features. In this case, the perfection of the initial crystal with a large diameter, the clear manifestation of the effects in it, and the production of effective nuclear radiation recording detectors based on them are important. In particular, it has a special place in the production of high-quality

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detector structures with large-sized sensitive surfaces and areas based on p-n or p-i-n structures based on large diameter (d>100 mm) silicon single crystal.

8. CONCLUSION

Therefore, in the development of nuclear radiation detectors based on large-sized primary silicon, a deeper study and analysis of the physical processes associated with its efficiency is required. Therefore, taking into account the degree of influence of the initial silicon properties on the electrophysical and radiometric properties of the detector, it is desirable to implement each stage of the technological process on the basis of mathematical modeling. In the preparation of semiconductor detectors, high-quality implementation of chemical technological processing of raw material is an important factor that ensures their effective operation.

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