Performance Characteristics of an SSB Radiation Detector with a Guard Electrode for Radon Detection

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1. Introduction

^{222}Rn, which emits alpha particles, is a cancer-causing natural radioactive gas. And it is recommended that radon level in public space may be fixed below 4 pCi/L. The 88% of ^{218}Po, which is one of the progeny nuclei of ^{222}Rn, tend to become positively charged.

Two different types of Silicon Surface Barrier (SSB) radiation detector, which is generally used to detect charged particles such as alpha particles and fission fragments, were fabricated for ^{222}Rn detection [1]. One is a plain planar-type and the other is a guard electrode-configured SSB radiation detector. A detection principle of radon detection is the electrostatic collection of the progeny nuclei of ^{222}Rn, and the energy measurement of the alpha decay with an SSB detector [2, 3].

The leakage currents of the two-type SSB radiation detectors were measured with a semiconductor characterization system. And the energy spectra for an alpha particle form ^{238}Pu were also measured in vacuum to compare the performance of the two-type SSB radiation detector.

2. Experiment

In this section, we present the fabrication of two-type SSB radiation detectors.

2.1 Fabrication of two-type SSB radiation detector

All the experimental processes were performed in a 1000-class clean room environment. An n-type silicon wafer, which was doped with phosphorous and had a (111) crystal plane orientation, was used to make the SSB radiation detectors. The 4" silicon wafer shows a 2 kΩ·cm resistivity. The thickness of wafer was 500 µm. This wafer was cut into 10 × 10 mm by using as Disco Dad/2H6T dicing saw. All the cleaning and etching processes were conducted in a wet station. All the cut wafers were cleaned with a mixture of concentrated sulfuric acid and hydrogen peroxide at 100 ℃ to remove any organic impurities on the cut wafers. The proportion of the mixture was 4:1 volume, respectively. Another cleaning process, which used a mixture of concentrated HF and DI water (1:10 vol. proportion), was also incorporated at room temperature to remove the silicon dioxide layer and the remaining inorganic impurities. 18 MΩs DI water was used to wash the cut wafers in the respective steps.

HF concentration in the etching solution determines the etching degree of the silicon wafer in the same etching. The etchant was based on a mixture of concentrated fluoric acid, nitric acid, and glacial acetic acid. This solution that had and electronic degree was volumetrically proportioned at 1:4:2. Etching was processed at 0±1 ℃ to make etching reacting slow.

About 99.99% Au and Al were evaporated by using a Thermal Evaporator to create a Schottky and an Ohmic contact, respectively [1, 4]. The cut wafers were loaded at the same time into an evaporator sample loader, which has a plain planar-type mask and a guard electrode mask, to make the conditions of the metal contacts identical. The deposition rate was 35 Å/s. The thickness the two evaporated metals were 300 Å. The active areas of a plain planar-type SSB and a guard electrode-configured SSB were 8 mm and 5 mm respectively. The evaporated wafers were mounted onto FR4 substrates and soldered by using a conductive epoxy.

Fig. 1 Fabricated SSB radiation detectors. The right SSB has guard electrode.

3. Results and discussion

The leakage currents of the constructed SSB radiation detectors were measured by using a semiconductor characterization system (Keithley model 4200-SCS) within a shielding box to prevent external electro-magnetic waves. The leakage current was measured with an increasing voltage at 0.1 V. The measured leakage currents of the two-type SSB radiation detectors are shown in Fig. 2. The guard-electrode configured SSB radiation detector shows low leakage currents.

The energy spectra for an alpha particle from ^{238}Pu were measured with the SSB radiation detectors by using ORTEC Soloist. The measurement of the alpha spectrum was performed under a state of a vacuum to prevent an interaction with air.

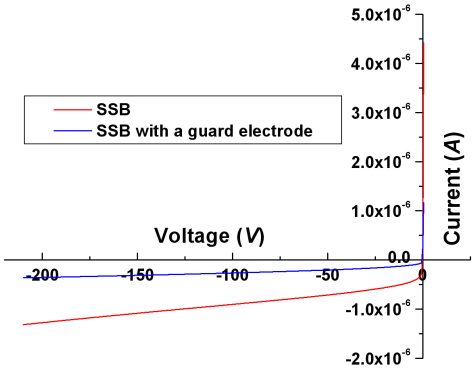

Fig. 2 The measured leakage currents of two-type SSB radiation detector.

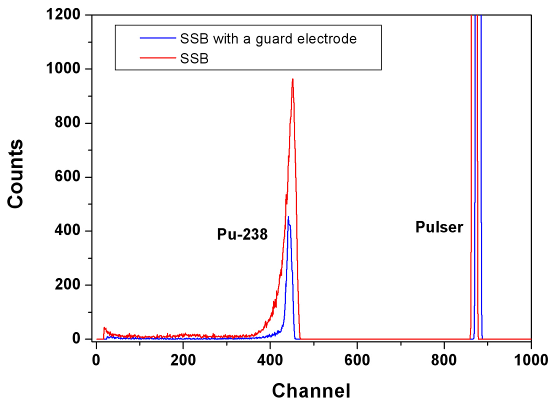

Fig. 3 The measured energy spectra for an alpha particle from ^{238}Pu.

The applied voltage was -30 V and the live time of a MCA was fixed at 600 seconds. The plain planar-type SSB radiation detector shows 5.54% energy resolution. And the SSB radiation detector with a guard electrode shows 2.94% energy resolution.

As the results, the SSB radiation detector with a guard electrode shows low leakage current and good energy resolution.

In future work, we construct an electrostatic chamber to detect radon by means of an alpha particle from ^{218}Po.

*Acknowledgments

This work has been carried out under the nuclear R&D program of the Ministry of Science and Technology (MOST) of Korea. And we are also supported by the iTRS Science Research Center / Engineering Research Center program of MOST / Korea Science and Engineering Foundation (grant # R11-2000-067-02001-0) and partially supported by the BK21 program of Korea Research Foundation(KRF).

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