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Characteristics and Fabrication of Silicon PIN Photodiode for Radiation Detectors

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1. Introduction

Solid state semiconductor based radiation detectors have been investigated for many applications such as dosimetry, medical imaging and digital radiology etc. Among the solid state semiconductor, silicon-based semiconductor radiation detectors [1, 2] were developed and commercialized in low-energy x- and gamma ray detection fields. Silicon-based detector has an advantage of fast response, small active volume and high detection efficiency.

In this work, the aim was to test the technology presently available at the Korea Atomic Energy Research Institute for the fabrication of silicon PIN photodiode as radiation detectors. A silicon PIN photodiode was fabricated by in-house process optimization and we measured performance of silicon PIN photodiode for electrical and radiation detection characteristics.

2. Methods and Results

3.1 Fabrication process of Silicon PIN photodiode

The silicon PIN photodiode was fabricated by in-house process in the clean room facility. A double-side polished n-type silicon wafer of high resistivity (>10 kΩ) with (100) orientation and 675 μm-thick was selected as a starting material.

Firstly, the 500 nm-thick silicon oxide layer was formed using oxide furnace equipment. N-side silicon oxide layer was removed by buffered oxide etchant and Phosphorous Oxychloride ($POCl_3$) diffusion process was carried out for the formation of n+ doping layer. Then, ^{11}B implantation was performed after guard ring and edge protection area open by photolithography process. After the photolithography was carried out for active area open, the active area silicon oxide layer was removed by inductively coupled plasma. The BF_2 was second implanted followed by thermal activation. Al and Au were used to make the electrode on the front side after metallization lithography by using electron beam evaporator and lift off was performed. Also, back side metallization was performed and anti-reflection layer was deposited. An anti-reflection layer is used to reduce surface reflection of the incident light. The device array in 6 inch wafer was cut into single device by dicing machine and the each device packaged to ceramic substrate with wire bonding equipment. The fabricated silicon PIN photodiode are shown in Fig. 1.

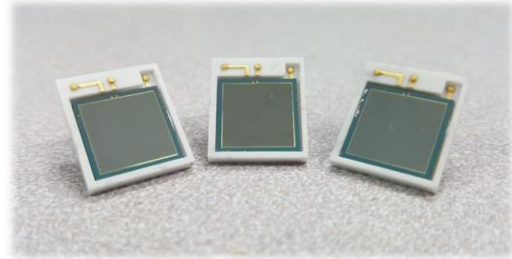

Fig. 1. The fabricated silicon PIN photodiode by in-house process.

3.2 Electrical characteristics

The manufactured silicon PIN photodiode was characterized by measurement of the leakage as a function of reverse bias voltage at room temperature. The leakage currents for the silicon PIN photodiode by in-house process are shown in Fig. 2. The leakage current distributions were observed to be ~ 40 nA at reverse voltage -50V. Because the low leakage current of diode is extremely important to make the radiation detector having a very low noise level, the reverse leakage current can be further reduced by optimization of the fabrication condition for silicon PIN photodiode in the respective fabrication process.

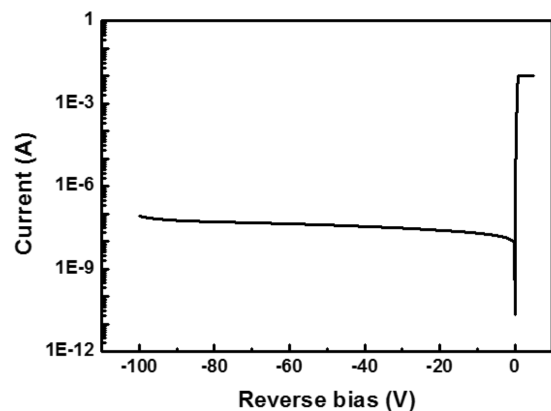

Fig. 2. Leakage current distribution as a function of the reverse bias voltage for in-house fabricated silicon PIN photodiode.

3.3 Radiation detector characteristics

We was performed the radiation characteristics of silicon PIN photodiode by radiation response measuring system. The pulse height spectrum in case of the 10 x 10 mm^2 active area of the silicon PIN photodiode using ^{133}Ba source are shown in Fig. 3. The energy resolution of the fabricated PIN photodiode for 30 keV and 81 keV were about 14.9% and 12.6%, respectively.

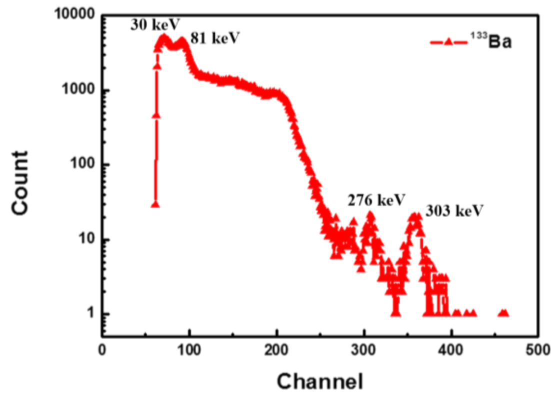

Fig. 3. The pulse height spectrum of the silicon PIN photodiode radiation detector measured using ^{133}Ba source.

3. Conclusions

In order to test the technology presently available by in-house process as radiation detection characteristics, we have studied the fabrication and radiation detection characteristics of silicon PIN photodiode.

From the current-voltage and radiation response characteristics, we confirmed the leakage current of ~ 40 nA at reverse voltage -50V and good radiation responsivity for a 10 x 10 mm^2 active area detector. However, the performance of silicon PIN photodiode for radiation detector can be further improved by optimization of the fabrication process conditions.

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