Comparison of Spectral responsibility on Silicon PIN Photodiode Radiation Detectors due to Surface Encapsulation

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1. Introduction

Although room temperature semiconductor radiation detectors, such as CdZnTe, CdTe and TlBr, are currently commercially available nowadays, a silicon PIN photodiode is still widely used in radiation detection fields owing to its cost-effectiveness rather than compound semiconductors. In particular, a Si PIN photodiode shows good performance to detect low energy X-ray and charged particles. Relatively high energy gamma-ray detection can be available when matched with an appropriate scintillator such as CsI(Tl). In this study, various encapsulations were applied on a fabricated Si PIN photodiode, and spectral responsibilities were compared to achieve a better quantum efficiency.

2. Methods and Results

2.1 Fabrication of Si PIN photodiodes

To fabricate Si PIN photodiode radiation detectors, the starting material is an N-type silicon wafer, with a resistivity above 11 kΩ·cm, 6-inch diameter, 670 µm, and <1,1,1> crystal orientation. Active areas were in 5 × 5 mm^2, and 10 × 10 mm^2. Anti-reflective coating with silicon nitride was applied to increase the spectral responsibility. A photo of the fabricated PIN photodiode radiation detectors is shown in figure 1 and the detailed fabrication processes can be found in an early study [1]. The fabricated PIN photodiodes were mounted on an HTCC (High-temperature co-fired ceramic) die.

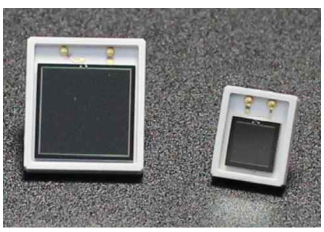

Fig. 1. Fabricated PIN photodiode radiation detectors: 10 × 10 mm^2 active area (left), 5 × 5 mm^2 (right) active area.

2.2 Electrical characteristics

Before measurement of the spectral responsibility, leakage current and capacitance were measured. Leakage currents and capacitances were measured with a Keithley SCS-4200 semiconductor characterization system up to 100 V and 40 V, respectively. The fabricated PIN photodiodes show leakage currents in the range of several nano-amperes at room temperature. The capacitances were measured to be about 50 and 10 pF, respectively, at a reverse bias voltage of 40 V with active areas of 10 × 10 mm^2, and 5 × 5 mm^2.

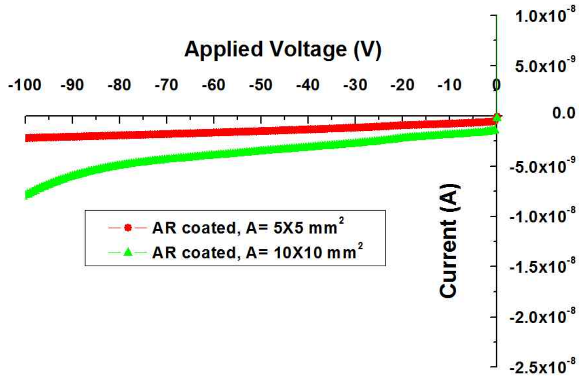

Fig. 2. Current-voltage (I-V) characteristics of the fabricated PIN photodiode radiation detectors for two different active areas.

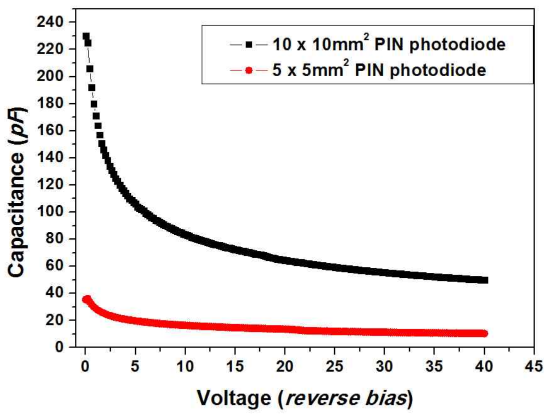

Fig. 3. Capacitance-voltage characteristics of the fabricated PIN photodiodes for two different active areas.

2.3 Surface Encapsulation

Four different encapsulations were applied on the surface of the PIN photodiode radiation detectors. A STYCAST® 1266 epoxy encapsulant from Emerson & Cuming Company, ASP-1110 epoxy encapsulant from Silion TS Company, a quartz glass with 500 μm thickness, and ITO glass with 500 μm thickness were applied on the surface of the PIN photodiodes, respectively.

2.4 Spectral responsibility

The spectral response of the PIN photodiode radiation detectors was measured with the calibrated spectrophotometer at the Korea Research Institute of Standards and Science (KRISS). The range of wavelength for the spectral response measurement was from 300 nm to 1,000 nm. Fig. 4 shows the measured spectral responsibility of the bare PIN photodiode radiation detectors as a reference value. Spectral responsibilities for four different encapsulated PIN photodiodes are being measured, and thus, the results will be presented at the conference.

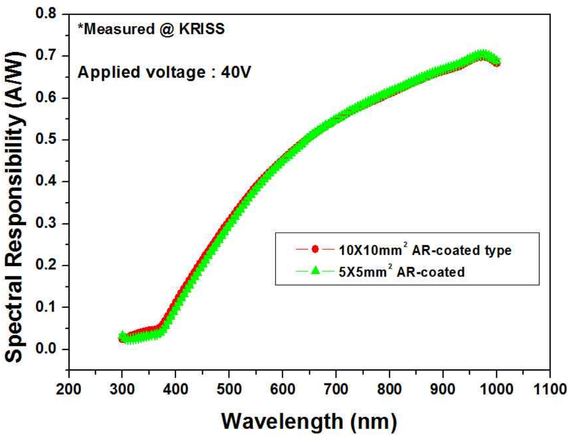

Fig. 4. Spectral response of the bare PIN photodiode with respect to active areas.

2.5 Pulse Height Spectra

The bare PIN photodiode was matched with a CsI(Tl) scintillator to detect a relatively high energy gamma-ray. Fig. 5 shows the pulse height spectra for the Na-22, Cs-137, and Co-60 gamma-ray source in case of 10 × 10 mm^2 active area PIN photodiode. Cremat® CR-110, ORTEC 572 shaping amplifier, and ORTEC spectrum master MCA were used. Energy resolutions for 512 keV, 662 keV, 1.17 MeV, and 1.33 MeV photopeak were 15%, 11%, 9%, and 7.3 %, respectively. Pulse height spectra in the case of the encapsulated PIN photodiodes were under taken, and thus, the results will be shown at the conference.

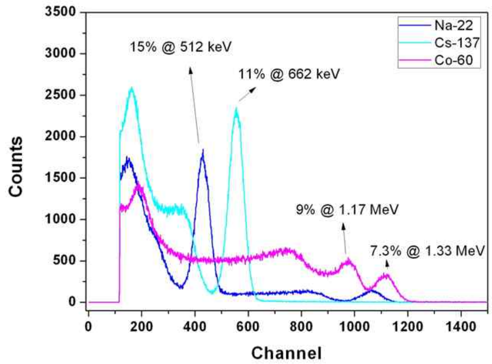

Fig. 5. Pulse height spectra of the CsI(Tl)/PIN photodiode radiation detector. The used PIN photodiode was bare-type (non-encapsulation type) and 10 × 10 mm^2 active area PIN photodiode.

3. Conclusions

Spectral responsibilities in the range of 300 nm to 550 nm are important to the PIN photodiode when it is applied to match with scintillators since the emission wavelength of most scintillators fall into this range. Application of appropriate encapsulation on the photodiode surface is necessary with the view of its rigidity and performance deterioration.

A specific comparison with respect to the encapsulation methods will be presented at the conference since these results are currently being measured.

ACKNOWLEDGMENTS

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[1] H.S. Kim, S. H. Park, J. H. Ha, S. Y. Cho, K. S. Park, Design and Fabrication of a Si PIN-type Radiation detector for Alpha spectroscopy, J. Korean Phys. Soc. Vol.55, p. 454, 2009.