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Fabrication and Characterization of Si PIN Diode with Al_2O_3 Anti-Reflection Layer for Radiation Detectors

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1. Introduction

In this paper, double deep diffused structured Si PIN diode having ALD Al_2O_3 anti-reflection and passivation layer were fabricated and characterized. Detailed device fabrication process will be described at the experimental section. Electrical, optical and radiation response characteristics were characterized. After ALD Al_2O_3 anti-reflection layer deposition, ~37% of reverse leakage current was reduced. Most of ^{133}Ba energy peak was observed but resolution should be enhanced for using low energy direct type detector.

2. Methods and Results

2.1 Device Fabrication

Starting with the double side polished n-type high resistivity (>10 KOhm) Si substrate of (100) orientation, 500nm SiO_2 layer was formed by wet oxidation. Back side SiO_2 layer was removed and POCl diffusion process was carried out for N+ layer formation followed by protecting oxidation. After guard ring and edge area open by photolithography, B11 implantation and thermal activation were performed. Second photolithography was carried out for active area open, BF_2 was implanted followed by thermal activation. After metallization lithography, Al/Au was deposited and lift off was performed followed by Al_2O_3 antireflection layer was deposited by ALD with N_2 bubbled trimethylaluminum source. Back side global metallization was also carried out. Up to now, front-end process was completed and package process was started. Wafer level device array was cut into single device by dicing machine and each device were packaged to ceramic substrate with wire bonding equipment.

Figure 1 shows the I-V characteristics of fabricated Si PIN diode before and after Al_2O_3 layer formation. After Al_2O_3 passivation and anti-reflection layer formation, reverse leakage current was reduced from 45 nA/cm2 to 23 nA/cm2 at -70V biased state, respectively. This results are mainly caused by the suppression of the surface leakage current of Si PIN diode by passivation effect adding to self- cleaning effect of ALD process which can scavenging the dangling bond of Si surface [1]. According to the quarter wavelength principle ($d_{arc}=\lambda_{inc.\ Photon}/4n_{arc}$, where d_{arc} is optimum ARC thickness, $\lambda_{inc.\ Photon}$ is wavelength of incident photon and narc is refractive index), 75 nm of Al_2O_3 was deposited for using ~ 500nm wavelength light emissive scintillator.

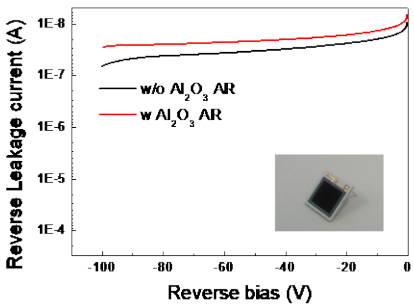

Fig. 1. I-V characteristics of Si PIN diode at the reverse biased region with and without Al_2O_3 layer. Inset is the picture of ceramic packaged Si PIN photodetector.

2.2 Energy spectra of ^{133}Ba

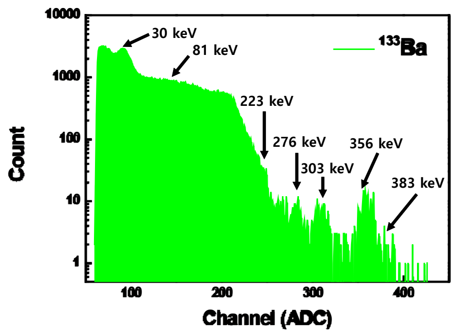

Fig. 2. Energy spectra of Si PIN radiation detector with Al_2O_3 ARC layer for ^{133}Ba gamma-ray source (V=-50V).

Figure 2 is energy spectra of fabricated Si PIN detector with Al_2O_3 ARC obtained using ^{133}Ba low energy gamma-ray source. Most of ^{133}Ba peak was observed but resolution should be enhanced for using low energy direct type detector.

3. Conclusions

Si PIN diode with ALD Al_2O_3 ARC was fabricated at Korea National Radiation Equipment Fab.

Center which was fully operated from Sep. of 2016. One of focused research topic is Si PIN diode for RTSDs and fabrication process optimization still progresses.

After Al_2O_3 ARC formation, 37% of reverse leakage current was reduced due to surface cleaning and passivation effect of ALD process. Most of low energy gamma-ray was detected using ^{133}Ba source but further resolution enhancement should be needed.

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REFERENCES

[1] G. Dingermans, W. M. M. Kessels, "Status and prospects of Al_2O_3-based surface passivation schemes for silicon solar cells", Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films 30 (2012) 040802