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Design of array type Si PIN photodetector for neutron imaging of cargo inspection system

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1. Introduction

While radiation equipment industry such as medical imaging, security inspection, military and space are received huge attention as a new growth industry, the core parts of security inspection system and radiation imaging equipment are mostly imported due to lack of source technology in Korea. Thus related source technology should be developed. And also global market are growing faster due to expanded needs. Because of these reasons, national research project is ongoing at the National Radiation Equipment Fab. center for developing mixed (neutron, X-ray) radiation imaging system and two core technologies are developing i.e. radiation generator and imaging system including radiation sensor and signal processing module.

In this paper, optimized combination of scintillator and Si-PIN photodetectors is suggested based on the neutron dose calculation. And also, low noise 4 channel array type Si-PIN photodetector were designed for matching with plastic scintillator.

2. Methods and Results

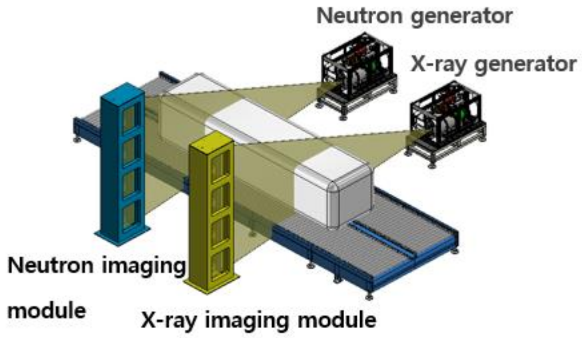

Fig. 1. The schematic of cargo inspection system using mixed (neutron, X-ray) radiation.

After the September 11 attacks, the paradigms of cargo inspection system had been changed from revenuer to anti-terrorism, so importance of acquiring technique of material information continues to grow. Because the radiation image using only X-ray cannot provide material information, neutron and X-ray mixed radiation cargo inspection system is needed for acquiring material information in order to detect explosives or nuclear materials. Fig. 1 is the schematic of mixed radiation cargo inspection system which have two radiation generator and imaging module. The generated radiation pass through the cargo, and informative radiation incident to the imaging module. The imaging module is the stack of radiation detector which are composed of scintillator on the Si-PIN. So, scintillation efficiency and light detection efficiency of Si-PIN photodetector is key parameter of system performance. In the point of signal processing, minimization of reverse leakage current and capacitance of Si-PIN is also important for maximum signal to noise ratio at high biased operation state.

The image resolution of inspection system can be determined by the pitch of each scintillator. Adding to high resolution X-ray image, material discrimination is possible from neutron imaging module. So optimized determination of plastic scintillator size is essential with considering neutron counts.

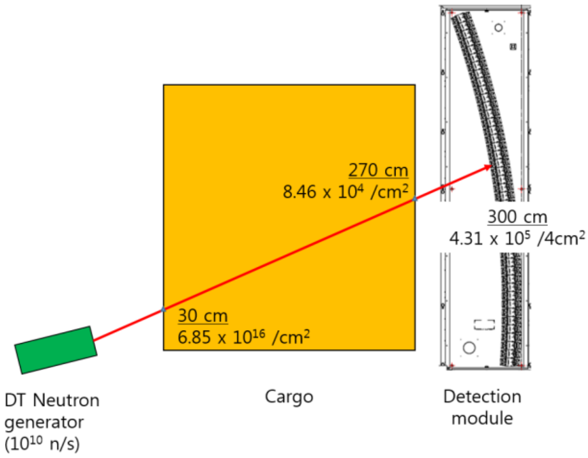

Fig. 2. The calculated neutron dose according to the distance from the DT generator.

According to our calculation, 4.31 x 10^5/s of neutron is incident to the 4 cm^2 cross section of plastic scintillator which is located 3 meter distance from DT generator (Fig. 2). It is enough to react the informative neutron with the scintillator, but large area of Si-PIN is needed for detecting the light. The larger the active area, the bigger the reverse leakage current and the capacitance of Si-PIN, which result in lower the signal to noise ratio. So 4 channel array type Si-PIN is designed and each Si-PIN is tiled on the PCB for minimizing the reverse leakage current and capacitance (Fig. 3). With this concept, signal to noise ratio would be maximized and material discrimination ability could be enhanced.

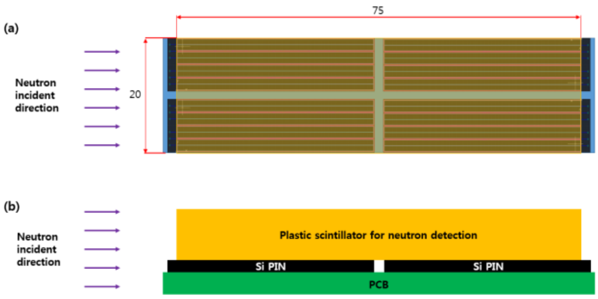

Fig. 3. (a) Top view (unit:mm) and (b) side view of designed neutron detector in the imaging module.

Fig. 4. Design of 4 channel array type Si-PIN for coupled with plastic scintillator (1 chip).

Fig. 4 is the design of 4 channel array type Si-PIN for coupled with plastic scintillator. Fabrication steps were designed as 6 photomask process including N-channel stop, guard ring/active area implantation, contact/metallization and anti-reflection area. The brief fabrication process flow of 4 channel Si-PIN photodetector (37.3mm x 9.6mm) is as follow. Starting with the double side polished n-type high resistivity [1] (>10 KOhm) Si substrate of (100) orientation, SiO_2 layer is formed by wet oxidation. After removing the backside oxide, N-type layer with POCl3 diffusion process is carried out on the bottom side and slightly oxidation for protecting N-layer. The guard ring [2] and active layer is formed by ^{11}B and BF_2 implantation followed by oxide deposition and contact hole formation. After metallization lithography, Al/Au was deposited by e-beam evaporation equipment and lift off was performed. After that, antireflection layer process was carried out and back side global metallization was performed. Wafer level device array was cut into single device by dicing machine and each device packaged to PCB substrate with wire bonding equipment. Whole the fabrication process will be carried out at semiconductor process clean room inside Korea National Radiation Equipment Fab (Fig. 5) which are able to process semiconductor based CMOS fabrication step.

Fig. 5. Semiconductor process clean room for radiation sensor fabrication at Korea National Radiation Equipment Fab.

3. Conclusions

Expected neutron dose of cargo inspection system is calculated and optimized combination of plastic scintillator and Si-PIN photodetectors is suggested. To maximize the signal to noise ratio, 4 channel array type Si-PIN photodetector were designed and fabrication process optimization would be carried out at the Korea National Radiation Equipment Fab.

ACKNOWLEDGEMENTS

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