Fully Depleted SOI Pixel Photo Detectors with Surface Potential Pinning

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Abstract In the SOI pixel technology, an important mission of the research project is to develop a technique for extremely low noise and wide dynamic range photon energy measurements in the small area. We propose charge collection and surface potential pinning structure for a SOI detector for low noise and wide dynamic range.

This technique greatly increases charge-to-voltage conversion gain while stabilizing the operation of SOI circuits. A double doping technique for increasing potential barrier to holes at the surface region is effective for a stable operation to the variation of back bias voltage.

Keyword SOI, SOI Pixel, Surface potential pinning, Potential barrier

1. Introduction

Recently, an importance of imaging is increasing to examine objects in more details in diverse fields. To the invisible particle beams, such as X-ray, infrared ray, charged particle radiation, the visualization is becoming positively necessary as well [1][2]. 4-D image of the particle beams which obtained by fast and large date processing from 2-D or 3-D or time axis may accelerate to lead new discovery and knowledge in material science, biomedical, and astronomy.

For the particle beams imaging device, radiation imaging detector including high-sensitive sensor and LSI processing circuits in the pixel has been reported. SOI pixel technology has begun to use for the radiation imaging detector while high-sensitivity and high energy resolution are challenged.

In this paper, we describe a novel SOI pixel photo detector with more sensitive and high dynamic range for the radiation imaging.

2. SOI pixel

Fig. 1 shows conventional structure of the SOI detector. In this structure, thin SOI-layer formed on top of the BOX (Buried-Oxide)-layer is used for the LSI circuits as general SOICMOS technology. Sensor-layer under the BOX-layer is used as sensor-layer. The SOI-layer and sensor-layer are connected only through a Via in BOX-layer[2]. SOI-layer and sensor-layer are electrically separated by BOX-layer. Entire sensor-layer detecting the particle beams is fully depleted to collect the charge generated by the energy of particle beams using drift field.

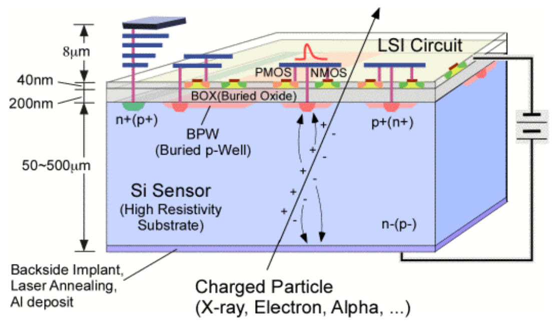

Figure 1. Conventional SOI detector [3].

In the conventional SOI detector, surface potential variation affects behavior of the circuits on the SOI-layer so-called Back-gate effect[1]. In order to reduce the back-gate effect, BPW is deposited vicinity of the surface in the sensor-layer. Also, the BPW increases charge collection efficiency. However, the capacitance of detector is increased due to the deposition of BPW which reduces the charge-to-voltage conversion gain.

3. Charge collection and surface potential pinning structure

In order to increase the conversion gain and to reduce the back-gate effect, a new detector with charge collection and surface potential pinning structure is proposed. Fig. 2 shows the proposed detector. Two different n-wells in depth, BNW and BN4, are formed in the detector.

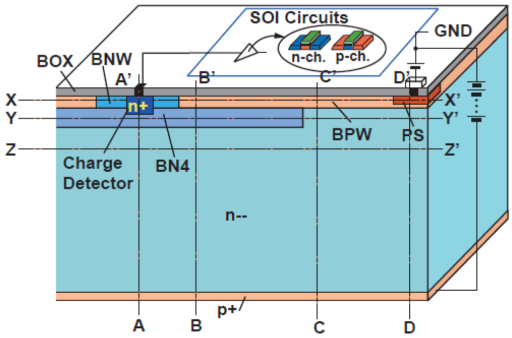

Figure 2. Proposed detector.

The BNW and n+ are used for detecting the charge which generated by the energy of radiations. Deposited BPW at the surface of the sensor-layer pins the surface potential. Due to the pinned surface potential, MOS transistor circuits have been stabilized on the behaviors and it reduces the dark current of the surface as well. Moreover, it leads the charge to charge detector with lossless by the potential barrier. In case the charge is remained in the neutral region under BPW, the potential barrier is not formed.

To prevent this issue, the potential of charge detector region is defined as higher than that of neutral region and the detector is fully depleted in the neutral region indeed. High concentrated p+ is doped at the back side of the device and a high negative voltage is applied to the p+ layer for the full depletion of the sensor-layer. BN4 which buried n-well deposited under the BPW is double doped to rise the potential barrier to hole and to maximize the charge collection efficiency. Moreover, the proposed structure realizes minimum size of the charge detection region and it leads high charge-to-voltage conversion gain by minimizing capacitance of the charge detection region.

Simulation results for potential distributions along with different axis of the proposed detector are shown in Fig. 3-5. In the simulation, detector size is 40µm×40µm, and thickness of sensor-layer is 200µm. -2V, 3V, and -115V are induced to the BPW, the charge detection region, and to the back-side p+, respectively.

Fig. 3 shows potential distribution of vertical cross-section A-A', B-B', C-C', and D-D'. It confirms that the entire sensor-layer is fully depleted from the back-side to the surface and the charge transfers to vicinity of the surface once. Fig. 4 is enlarged at vicinity the surface in Fig. 3. It confirms the presence of the potential barrier to charge under the BPW along with the cross-section B-B', C-C', and D-D'. The transferred charge by the fully depleted sensor-layer is collected to the detection region eventually because the potential along with cross-section A-A' is the highest in the detector. Fig. 5 shows potential distribution of horizontal cross-section X-X', Y-Y' and Z-Z' in Fig. 2. Fig. 5 confirms the pinned surface potential distribution as shown X-X'. The charge is collected to the detection region effectively.

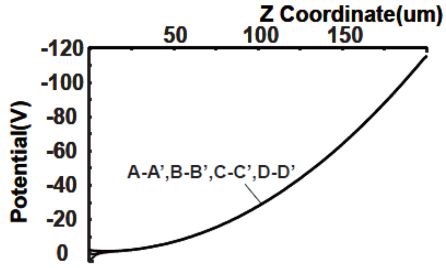

Figure 3. Potential distribution of vertical cross-section 0-200µm.

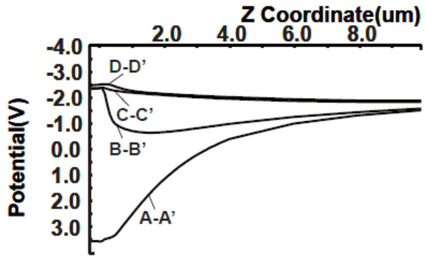

Figure 4. Enlarged view at the vicinity of the surface 0-10µm.

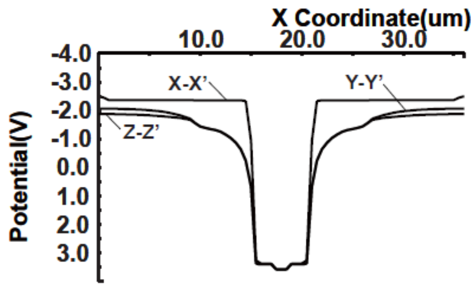

Figure 5. Potential distribution of horizontal cross-section

4. Conclusion

In this paper, we proposed detector with charge collection and surface potential pinning structure. This detector can realize high charge-to-voltage conversion gain and high quantum efficiency.

Reference

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