Development of Double-sided Silicon Strip Position Sensor

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1. Introduction

Since double-sided silicon strip sensor provides two-dimensional position information with high resolution, it has been developed in various areas for medical imaging sensor, radiation detector, sensing detector in space science and silicon vertexing/tracking detector in experimental particle physics. We designed and fabricated the double-sided silicon position sensor in 5-inch fabrication line. We present measurement results of electrical characteristics of sensor such as leakage currents and capacitances as function of bias voltages. We also performed source test with ^{90}Sr beta source and tested radiation damage of fabricated sensors with 35 MeV proton beam. The charge collection efficiencies for different sensor designs were measured with laser scanning method.

2. Concepts of Double-sided Silicon Strip Sensor

The silicon strip position sensor is designed as being double-sided readout to provide two-dimensional position information. When charged particles pass through silicon bulk that is fully depleted by applied reverse bias voltage, electron-hole pairs are produced and electrons are collected in N-side and holes are collected in P-side by electric field.

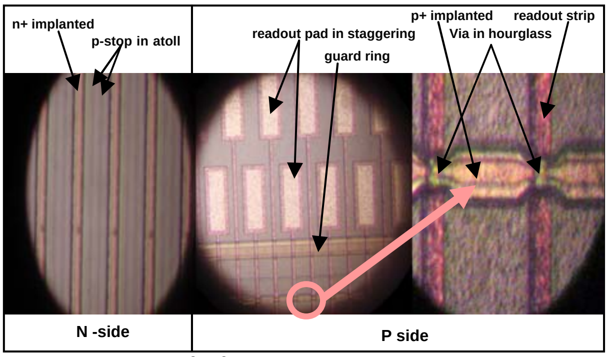

Figure 1. Photos of a fabricated double-sided silicon strip position sensor in 5-inch fabrication line.

Figure 1 shows pictures of N and P-side of the fabricated double-sided silicon strip sensor which is fabricated in 5-inch fabrication line. P-stop in atoll is shown on N-side to prevent electrical short between N-implants due to electron accumulation layer. To reduce capacitance in the double metal structures on P-side hourglass pattern is employed in via process as seen in the figure. The sensor strip pitch for N and P-implants are 50 μm and 100 μm, respectively. On the other hand readout pitches are 50 μm for both sides. The details of sensor design can be found in elsewhere [1].

3. Electrical Characteristics Test of Sensors

Full depletion can be determined experimentally by measuring the capacitance between N and P-side of the detector as a function of reverse bias voltage. The capacitances were measured with HP 4277A LCZ meter.

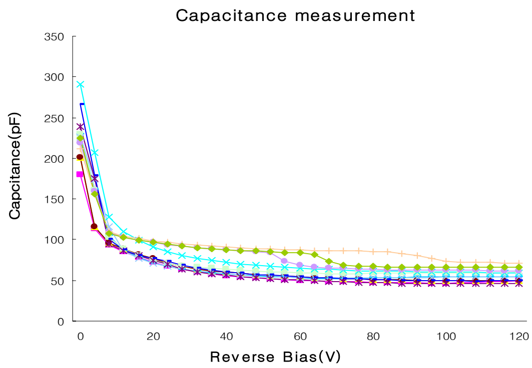

Figure 2. Capacitance measurement results between N and P-side of the silicon sensor as a function of reverse bias voltages.

In current prototype the capacitance levels out at about 60 volts, which is expected theoretically [2].

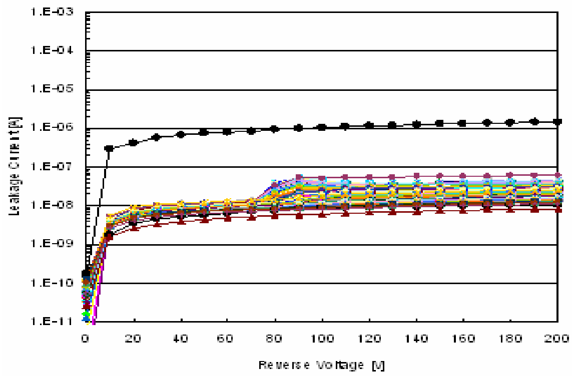

Figure 3. Leakage currents (black dot) between N and P-side of the silicon sensor and leakage currents (colored dot) of single strip on P-side as a function of reverse bias voltages.

The leakage current measurements with Keithley 6517 picoameter as a function of reverse bias voltages for silicon bulk between N and P-side and each strip on P-side is shown in Figure 3. It shows that the leakage current level of the single strip sense is less than 10 nA up to the full depletion voltage and a level of bulk leakage current level is about 1 μA. This measurement provides us information of the bulk characteristics and quality of the fabricated sensor.

4. Beta Source Test of Sensors

We used ^{90}Sr beta source for source test purpose. After the full depletion voltage was applied sensor, we measured the beta source signal on the oscilloscope. We measured noise level of the silicon sensor without beta source and the beta source is then put on the top of the silicon sensor in a dark box. We clearly saw the beta source signal on the oscilloscope as shown in Figure 4.

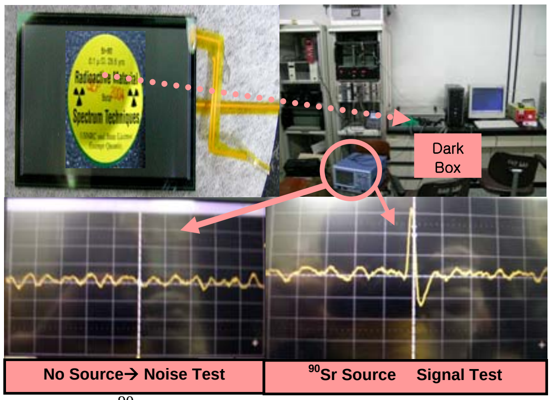

Figure 4. The ^{90}Sr beta source is put on the top of silicon sensor in a dark box. The bottom left is a sensor noise and the bottom right is a beta source signal.

We compared our measurement results with those of a single-sided silicon sensor by Hamamatsu company. It showed that noise level of our sensor is worse but signal level is better than those of Hamamatsu's.

5. Radiation Damage Test of Sensors

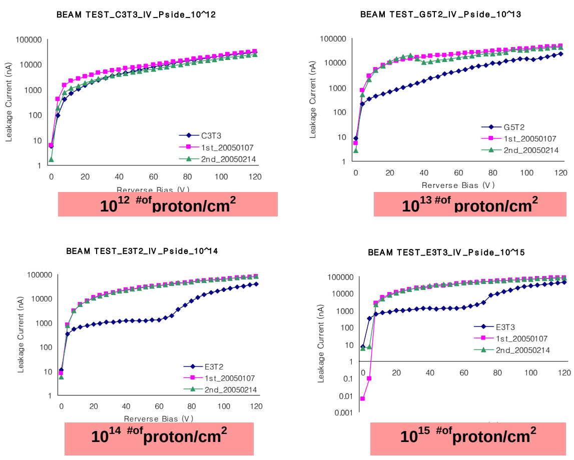

Figure 5. The leakage current as a function of reverse bias voltages after sensors were irradiated with 35 MeV proton beam.

We used 35 MeV proton beam of a cyclotron in Korea Cancer Center Hospital in Seoul. The fluxes of the proton beams are 10^{12}~10^{15} number of proton/cm^2. Our results showed that leakage currents do not have radiation effect up to 10^{12} number of proton/cm^2. But radiation damages are clearly shown above 10^{13} of proton fluxes.

6. Charge Collection Measurements with a Laser

The charge collection efficiencies for different silicon sensor designs were measured with a HPK(PLP-01) 945 nm laser.

Charge collection efficiency(%)= minimum/maximum*100

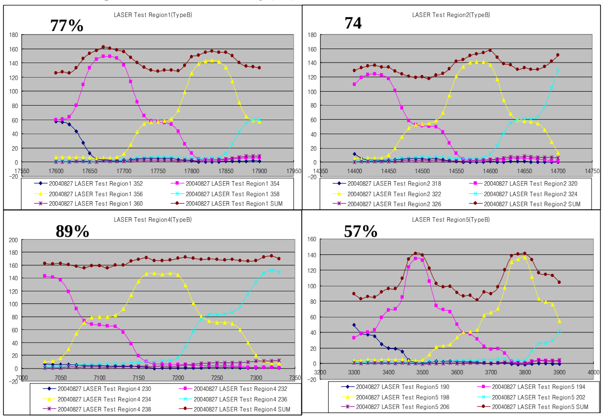

Figure 6. Charge collection efficiencies were measured with a PLP-01 945 nm laser for different sensor types to find optimized sensor designs.

We expected that charge collection efficiency of the strip floating method will give same level as the proto-type design. But measurement results showed lower efficiency for the floating method.

7. Conclusion

We fabricated the double-sided silicon strip sensor on the 5-inch fabrication line for first time in Korea. With various measurements and tests showed that qualities of the fabricated sensor are as good as Hamamatsu's. We tested electrical properties of sensors. The measurement showed that the leakage current of the sensor is less than 5μA (corresponding to 1nA/channel). We also measured source signal with ^{90}Sr. As radiation damage test, sensors were irradiated in 35 MeV proton beam with high fluxes and the sensors did not show any radiation effect up to 10^{12} number of proton/cm^2. A laser scanning was done to measure charge collection efficiencies for different sensor types and detail analysis is still on progress.

REFERENCES

[1] D.H. Shim et al., Korean Nuclear Society Meeting, May. 26-27, 2005.
[2] G. Lutz, Semiconductor Radiation Detector, Springer, New York, pp 101-102, 1999.