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Signal-to-Noise Ratio Measurements of Double-sided Silicon Strip Position Sensor with a Radioactive Source and Proton Beam

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1. Introduction

Since double-sided silicon strip sensor provides two-dimensional position information with high resolution, it has been developed for various areas such as medical imaging sensor, radiation detector, sensing detector in space science. We designed and fabricated the double-sided silicon position sensor in 5-inch fabrication line. We reported the electrical characteristics of the sensors such as capacitances and leakage currents as function of bias voltages in the previous Korean Nuclear Society meeting [1] including results of the radiation damage test and charge collection efficiencies for various sensor designs. In this meeting we will present measurement results of the signal-to-noise ratio of the fabricated double-sided silicon strip position sensor with ^{90}Sr radioactive source. We also measured the signal-to-noise ratio using 35 MeV proton beam of a cyclotron in Korea Institute of Radiological and Medical Science (KIRAMS) [2] in Seoul, Korea. This measurement provides us information of the bulk characteristics and quality of the fabricated sensor.

2. Concepts of double-sided silicon strip position sensor

When charged particles pass through silicon bulk which 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 the electric field.

The sense (implantation) strips on one side of the layer are orthogonal to the ones on the other side. This way one plane measures x and y coordinates of point, where ionizing particle goes through, on its two different sides. The p-side has two metal layers; one layer for the implantation strip and one for the signal readout strip. The double-sided silicon strip sensor therefore is designed to have the double metal structures on the p-side as shown in Fig. 1.

The capacitances and leakage currents were measured with HP 4277A LCZ meter and Keithley 6517 picoameter as a function of reverse bias voltages, respectively. In current prototype the capacitance levels should be flat at about 60~80 volts, which is expected theoretically [3]. We also required the leakage current of the bulk sensor should be less than 5 μA to the full depletion voltage. The prototype sensors which satisfied the above two requirements were used for the signal-to-noise ratio measurements with the radioactive source and the proton beam.

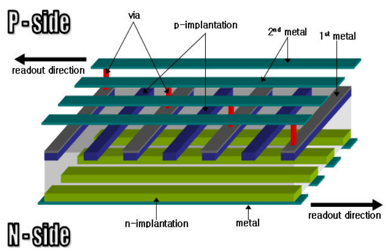

Fig. 1. The mechanical design of the double-sided silicon strip sensor which provides two-dimensional position information and has double metal structures on p-side.

3. Radioactive source test of the sensors

We used ^{90}Sr beta ray for the source test purpose. After the full depletion voltage was applied to the sensor, we measured the signal-to-noise ratio with the beta source. For the trigger purpose, we used the photodiode sensor of Hamamatsu Photonics [4]. We measured noise level of the silicon sensor without the beta source and the beta source is then put on the top of the developed silicon sensor. A lead collimator was inserted between the silicon sensor and the Hamamatsu photodiode sensor (which is called as "reference sensor") to select coincidence signals as shown in Fig. 2.

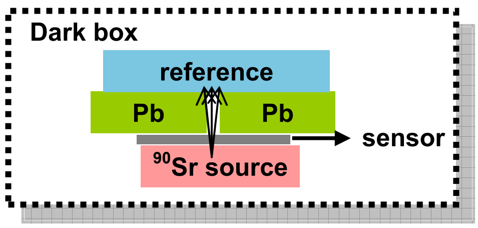

Fig. 2. The schematic drawing of sensor and the radioactive source in the dark box for the signal-to-noise ratio measurement.

We compared the noise level of the developed sensors with that of the reference sensor. It showed that the noise level of our sensor is comparable to that of the reference sensor.

Fig. 3. shows the experimental set up for the signal-to-noise ratio measurement with the radioactive source.

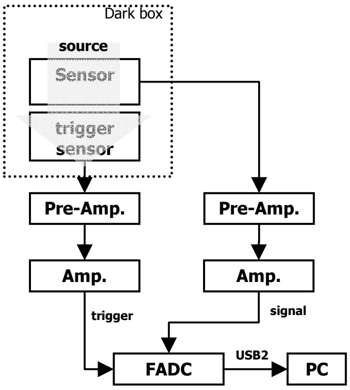

Fig. 3. Experiment setup for the signal-to-noise ratio measurement.

A 25MHz USB2 based home-made Flash Analog to Digital Converter (FADC) board has one analog input, one trigger input and one output. An analog signal from the double-sided silicon sensor was connected into the analog input of the FADC board via a preamplifier and an amplifier. A signal from the reference sensor was connected into the trigger input of the FADC board via a preamplifier, an amplifier and a discriminator. The FADC outputs were recorded into the personal computer and data was analyzed with C++ based data analysis program.

Fig. 4 shows the measurement result and the signal-to- noise ratio was measured to be 25.0 which shows the very good quality of the sensors.

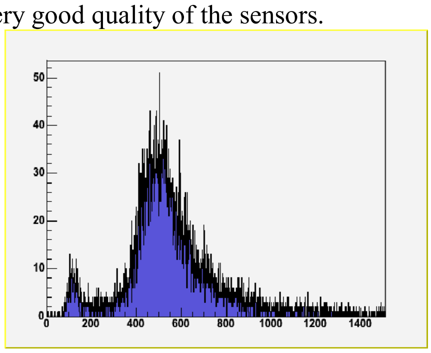

Fig. 4. The measurement result of the signal-to-noise ratio with the ^{90}Sr beta source.

4. Proton beam test of the Sensors

This experiment was performed using a 35MeV proton beam at the KIRAMS in the Seoul. The irradiation was performed at the room temperature, and bias was applied to the sensor during the irradiation.

Fig. 5 shows the schematics diagram of the set up for the signal-to-noise ratio measurement with the proton beam.

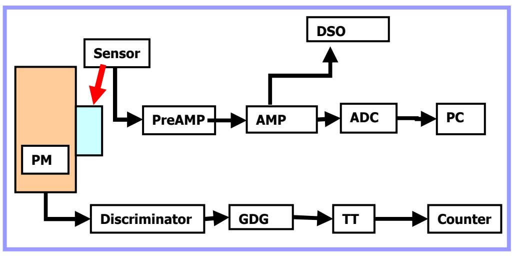

Fig. 5. Schematics diagram of the electronics in the dark box for the signal-to-noise ratio measurement with the proton beam.

A liquid scintillator detector was used for the trigger purpose. The Photo-Multiplier Tube (PMT) signals attached to the detector were connected into the FADC trigger input through the discriminator and the gate generator. The developed sensor signals were connected into the FADC analog input via a preamplifier and an amplifier. The FADC outputs were analyzed as the same way which was described in the previous section.

The result of the signal-to-noise ratio measurement is shown in Fig. 6 to be about 5.1. This measurement was done with our developed pin diode sensor.

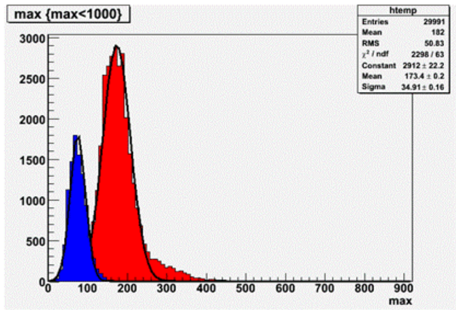

Fig. 6. A measurement result of the signal-to-noise ratio with 35MeV proton beam at KIRAMS.

We are planning to do the same measurements with different beam sources and sensor types in coming summer.

6. 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 comparable to Hamamatsu's.

We presented the signal-to-noise ratio measurements with ^{90}Sr radioactive source. The result showed that the signal-to-noise ratio of the strip sensor is as good as 25.0. We also performed beam test and the fabricated sensors were irradiated in 35 MeV proton beam. We measured the signal-to-noise ratio of the sensor and detail analysis for various sensor types is still in progress.

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