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Electrical Characteristic Measurement of AC-coupled Silicon Strip Position Sensor

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1. Introduction

Silicon strip sensor has been used in many areas as medical imaging sensor, tracking device and vertex detector because of its high position resolution. The silicon strip sensor is very promising detector in X-ray medical imaging due to its high resolution and fast signal readout.

Direct coupling silicon detectors were designed, developed, and measurement results of electrical characteristics were presented in the previous Korean Nuclear Society meeting [1]. Since capacitive coupling of electronics to silicon detector (AC-coupled) has the advantage of shielding electronics from dark current, AC-coupled single-sided silicon sensor is developed.

We have designed and fabricated the AC-coupled single-sided silicon strip sensor which provides one-dimensional position sensitivity. A detail of silicon sensor design and measurement results of electrical characteristics are presented.

2. AC-coupled Sensor and Mask Designs

A minimum ionizing particle deposits about 100 keV in a 380 μm thick layer of silicon. With 3.62 eV per electron hole pair, this corresponds to about 28000 electron hole pairs. Electrons and holes have comparable mobilities (1500 and 450 cm^2/Vs at 300 K) which make it possible to use tracking information from negative and positive "ionization charges" independently.

A position of passage of the charged particles is obtained by dividing the large area diode into many small strip regions because the location of the strips showing signals will provide information of position of the passages.

The AC-coupled single-sided silicon strip sensor is fabricated with high resistivity n-type silicon wafer. As the position sensor thinner wafer is prefer to avoid multiple Coulomb scattering due to materials. This thickness is good enough to produce a signal.

A reverse bias voltage is applied to the silicon sensor and then depleted region is formed. The electron-hole pairs that are created in this depletion region along the path of a charged particle are separated and the electrons move to n-side.

Compared with DC-coupled sensors which were reported in the previous Korean Nuclear Society meeting, capacitively coupled readout (which is called as "AC-coupled") has an advantage because of shielding of the electronics from sensor's dark current which can lead to pedestal shifts, a reduction of the dynamic range, etc. Fig. 1. Shows the capacitively coupled silicon strip sensor.

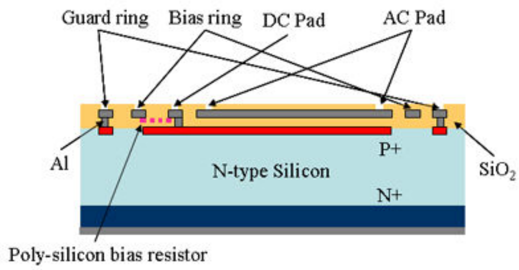

Fig. 1. Conceptual drawing of the AC-coupling single-sided silicon strip detector.

The fabrication processes of the AC-coupled sensors are somewhat more complicated fabrication process and the correspondingly higher precisions of masks are required compared with the DC-coupled sensors.

In the AC-coupled single-sided silicon strip sensor we have to integrate high ohmic resistors and large capacitors into the silicon sensor. We can make the capacitances by separating implantation strips and metallization (readout) strips by a thin oxide layer. The high ohmic biasing resistors can be made in poly-silicon. [2]

We can have the high resistance of the poly-silicon biasing resistor by varying the length and width of the poly-silicon. Our design for this biasing resistor is shown in Fig. 3. The DC-pad in Fig. 3 is made for the leakage current measurements of the AC-coupled silicon sensor. For good electrical contact, both edges of the poly-silicon biasing resistor are doped with highly concentrated n+ ions.

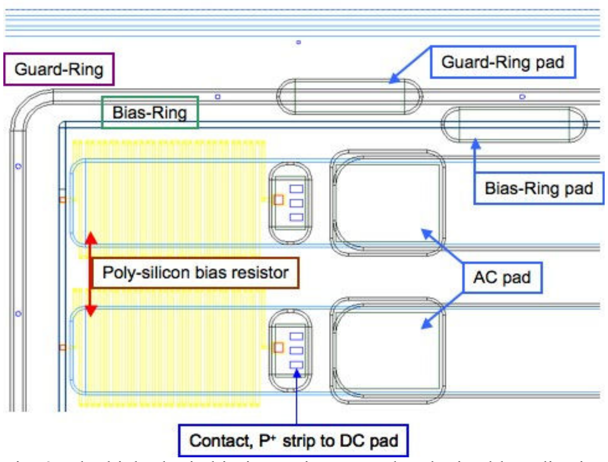

Fig. 2. The high ohmic biasing resistors can be obtained by adjusting the length and width of the poly-silicon and strip mask design.

Mask is designed to provide optimized fabrication processes and the good quality silicon strip sensor. We used 5-inch high resistivity slightly N-doped silicon wafers of 380 μm thickness to fabricate the AC-coupled single-sided silicon strip sensor. For this purpose 6-inch mask was needed and Fig 4 shows the various sensor types in the mask design. Several silicon sensors including the DC- and AC-coupled single-sided strips and PIN diode sensors are designed. The sensor designs in the Fig. 3. explain sensor types, pitch sizes and number of the readout channels.

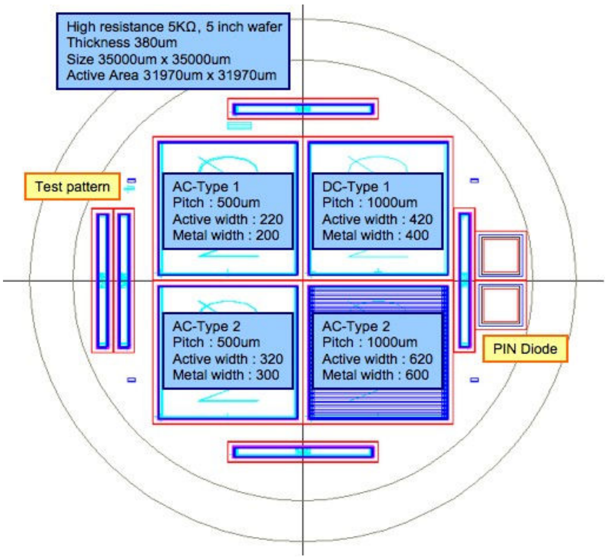

Fig. 3. Various single-sided sensor designs on the 6-inch mask.

4. Measurement of electrical characteristics

The electrical characteristics such as the capacitances and the leakage currents of the DC-typed strip sensors were reported in the previous Korean Nuclear Society meeting [2]. In this paper we present ways of measuring resistance of poly-silicon biasing resistor and capacitance of coupling capacitors and measurement results of the electrical characteristics of the AC-coupled silicon strip sensors.

Fig. 4. shows the measured I/V Leakage current, capacitance, resistance of the biasing resistor and the measured capacitance of the coupling capacitor as a function of the reverse bias voltages, respectively. The results show the values of the leakage current, capacitance, resistance and capacitance are obtained as we target and are stable up to the depletion voltage.

When we operate the reverse bias voltage on the basis of the measured value, if the value of bulk leakage current at 60V is under about 10^{-7}A, we can call it a good quality sensors. In the following figure, the values of the sensors are all within the scope. So they can be called good sensors.

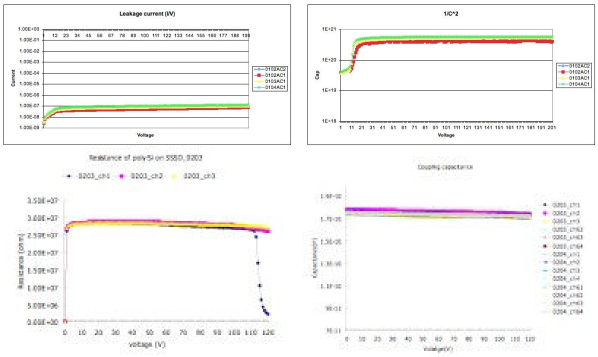

Fig. 4. Bulk leakage current, capacitance, the resistances of the biasing resistor and the capacitances of the AC-coupled single-sided silicon strip sensor as function are measured by varying the reverse bias voltages above the operation voltage.

5. Conclusion

The AC-coupled single-sided silicon strip sensor is designed and fabricated in Korea for the first time. We have reported the concept and details of the sensor design, which is composed of 380μm thick N-doped silicon wafer with 64 P-implant strips. The sensor design is optimized to provide low noise and high intrinsic position resolution. The masks are designed for optimized fabrication processes and good quality sensor. A sensitive area of the sensor is 35000 μm x 35000 μm. The sensor fabrication was done on the 5-inch process line.

Since the sensor is AC-coupled, the fabrication process is complicated to make poly-silicon biasing resistor and coupling capacitor. Our measurement results of resistors of the biasing resistors and capacitances of the coupling capacitors show good agreement with our target values. Electrical characteristics results such as leakage currents and capacitances of the AC-coupled silicon sensor confirmed that the quality of the fabricated silicon sensor are as good as Hamamatsu's [2].

REFERENCES

[1] H. Park. Et al., Development of Double-sided Silicon Strip Sensor, IEEE 2005
[2] H.J. Hyun. Et al., Design and Development of AC-coupled Single-sided Silicon Strip Sensor, Korean Nuclear Society Meeting, May. 25-26, 2006