Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Design and Development of AC-coupled Single-sided Silicon Strip Sensor

H.J.Hyun[a*], J.B. Bae[a], D.H. Kah[a], H.D. Kang[b], H.J. Kim[a] and H. Park[a]
[a]*Basic Atomic Energy Research Institute, Kyungpook National Univ., Daegu 702-701, Korea*
[b]*Radiation Science Research Institute, Kyungpook National Univ., Daegu 702-701, Korea*
email: hjhyun@gmail.com

1. Introduction

Semiconductor detectors, and in particular silicon detectors, have unique properties that make them very suitable for the detection of ionizing radiation. The uniqueness of the silicon compared with other semiconductor are: •the band gap energy (1.12 eV at room temperature) is small and it leads to a large number of charge carriers per unit energy loss of the ionizing particles to be detected. •The density (2.33 g/cm^3) of the silicon is high and it leads to a large energy loss per traversed length of the ionizing particle and •high mobility (1450 cm^2/Vs) of electrons provides fast charge collection time.

Thus the silicon sensors are the most widely used for various sensing purposes such as imaging sensors in medical science, silicon tracking detectors in experimental particle physics, and etc.

We reported the design and development processes of the DC-type double-sided silicon strip sensor in the previous Korean Nuclear Society meeting [1]. We will present in this meeting for the designed and developed the single-sided silicon strip sensors which have coupling capacitors and bias resistors. The concept and details of the sensor design will be presented and the measurement results of the electrical characteristics of the fabricated sensors will be also reported.

2. AC-coupled sensor design

When charged particle penetrates silicon bulk, it loses its energy by generating the electron-hole pairs. A minimum ionizing particle (MIP) deposits about 3.8 MeV/cm [2]. To produce the electron-hole pair 3.6 eV energy is needed and this corresponds to about 42000 pairs in a 400 μm thick layer of the silicon. It is enough to produce a large 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. 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.

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.

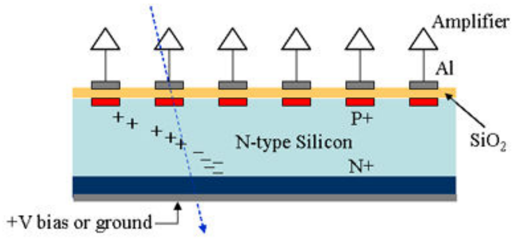

Fig. 1. Illustration of the basic operation principle of the AC-coupled single-sided silicon strip sensor.

The fabrication processes of the AC-coupled sensors are somewhat more complicated fabrication process and the correspondingly higher required precision of masks 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 polysilicon. The drawing of AC-coupling sensor design is shown in Fig. 2.

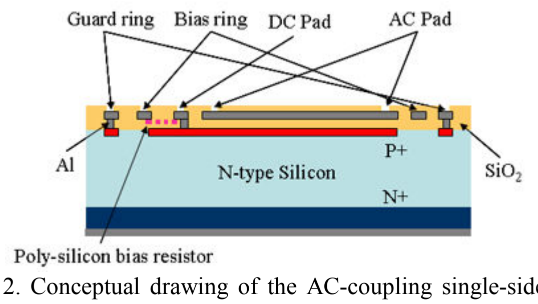

Fig. 2. Conceptual drawing of the AC-coupling single-sided silicon strip detector.

We can have the high resistance of the polysilicon biasing resistor by varying the length and width of the polysilicon. Our design for the 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 polysilicon biasing resistor will be doped with highly concentrated n+ ions.

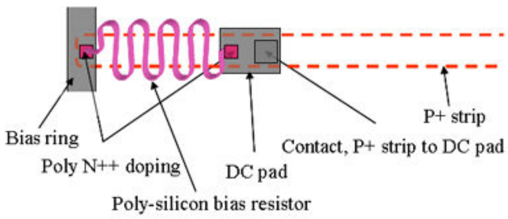

Fig. 3. The high ohmic biasing resistors can be obtained by adjusting the length and width of the polysilicon.

3. Mask design

Mask is designed to provide optimized fabrication processes and the good quality silicon strip sensor. We used 6-inch high resistivity slightly N-doped silicon wafers of 400 μm thickness to fabricate the AC-coupled single-sided silicon strip sensor. For this purpose 7-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. 4 explain sensor types, pitch sizes and number of the readout channels.

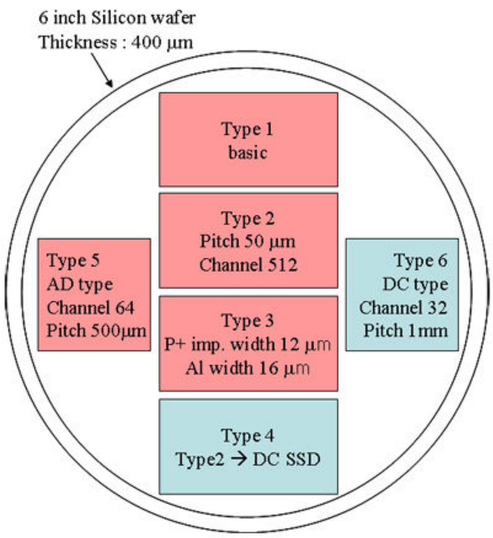

Fig. 4. Various single-sided sensor designs on the 7-inch mask.

We considered various possible fabrication steps to optimize the fabrication processes. We started with p-implants with an ion implanter and then oxidation process will follow to provide capacitances. After that, polysilicon is implanted for the biasing resistor and metal contact, metallization, and passivation processes are followed. A total of 6 masks were needed for the AC-coupled single-sided strip sensor fabrication.

Fig. 5 is a part of the design of the single-sided strip sensor on the mask. It shows the guide ring pad, the DC pads (smaller pad in the figure) for the leakage current measurement, the AC pads and polysilicon resistors after pad open mask.

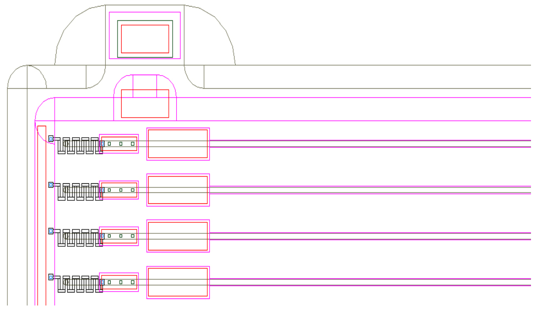

Fig. 5. A mask design for the single sided strip sensor.

4. Measurement of electrical characteristics

The electrical characteristics such as the capacitances and the leakage currents of the single-sided strip sensor will be measured as soon as the prototype sensors are fab-out that is scheduled on the middle of April. Detail measurements will be presented at the meeting.

Fig. 6 shows the way of measurement of the coupling capacitance of the fabricated single-sided strip sensor.

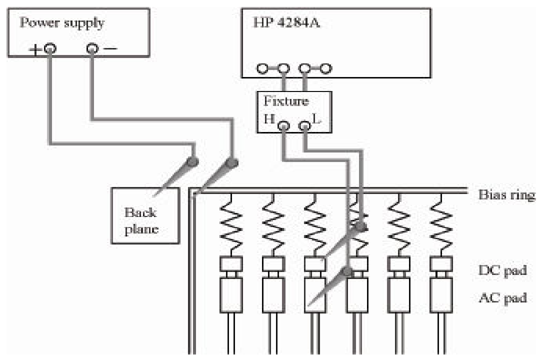

Fig. 6. A diagram of the coupling capacitance measurement of the fabricated silicon sensor.

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 400 μm thick N-doped silicon wafer with various different pitch sizes and number of readout channels. 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. The electrical tests of the prototype sensors will be reported as soon as the sensors are fab-out and the measurements are done which are scheduled on the middle of this month.

REFERENCES

[1] D.H. Shim et al., Design and Development of Double-sided Silicon Strip Sensor, Korean Nuclear Society Meeting, 2004.
[2] G. Lutz, Semiconductor Radiation Detector, p79, Springer, New York, 1999.