Design and Fabrication of Double-sided Silicon Strip Sensor

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1. Introduction

We have designed and fabricated the double-sided silicon strip sensor which provides two-dimensional position sensitivity. The concept and details of the sensor design are presented and the fabrication processes are also reported.

2. Sensor and Mask Design Concept

2.1 Sensor Design

A minimum ionizing particle deposits about 75 keV in a 300μm thick layer of silicon. With 3.62 eV per electron hole pair, this corresponds to about 21000 electron hole pairs. Electrons and holes have comparable mobility (1500 and 450 cm^2/Vs at 300K) [1] which make it possible to use tracking information from negative and positive "ionization charges" independently. In a double-sided silicon strip sensor this is used to obtain two coordinates in one 380μm thick layer of silicon. For this purpose a 380μm thick layer of slightly N-doped silicon (resistivity > 5 kΩcm) has P-and N-doped implants on its two sides. The respective sides are therefore called P- and N-side.

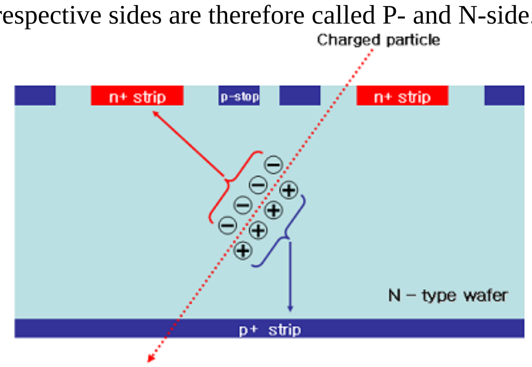


Figure 1. Schematic that illustrates the general principal of a silicon position sensor.

A reverse bias voltage is applied such that an electric field is created all through the bulk. This electric field prevents electron hole pairs that are created along the path of a charged particle from recombination by separating them. Two signals of the same size can then be detected, one on each side of the layer. On the P-side positive charges (holes) are collected, whereas the N-side collects negative charges (electrons). A schematic that illustrates this general principal is shown in Figure 1.

The sense 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 double-sided silicon strip sensor therefore is designed to have the double metal structures on the P-side as shown in Figure 2.

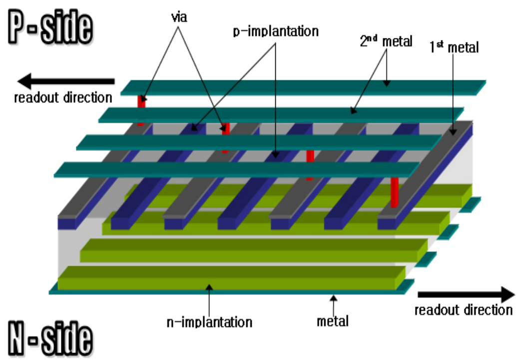


Figure 2. Mechanical design of the double-sided silicon strip sensor which has double metal structures on P-side.

Both sides of a silicon plane are sealed by thermally grown SiO_2. This leads to positive interface charges at the interface between amorphous SiO_2 and crystalline silicon. These positive oxide charges attract a negative accumulation layer in the silicon near the interface. Such a layer of high electron density at the interface would therefore act like a short between N-implants on the N-side. A signal arriving at the N-side would immediately spread out over all channels uniformly and could not be detected. The accumulation layer is of no harm on the P-side. Neighboring sense strips are here isolated from each other by a depletion zone that forms between regions that have different kinds of majority carriers. This is the case between P-implants, where the majority carriers are holes, and the accumulation layers, where the majority carriers are electrons.

An additional P-implant (so called p-stop) between two N-implants provides P-N junctions at the interface that block conductive crosstalk to levels of the order of the intrinsic conductivity. We designed p-stop in atoll form to prevent an electric short due to electron accumulation layer between N-implants on the N-side as shown in Figure 3.

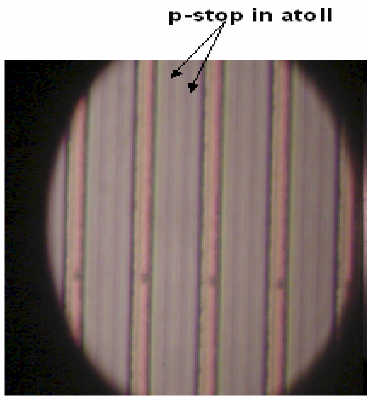


Figure 3. This is a photo of the prototype of the fabricated silicon strip sensor which has p-stop in atoll.

2.2 Mask Design for Fabrication

Mask is designed to provide optimized fabrication processes and the good quality silicon strip sensor. The contact of the double metal structures on P-side has hourglass form to reduce the capacitance [2] and it is shown in Figure 4.

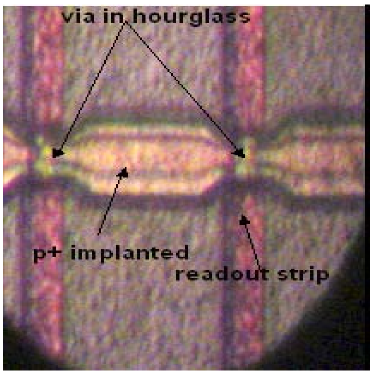
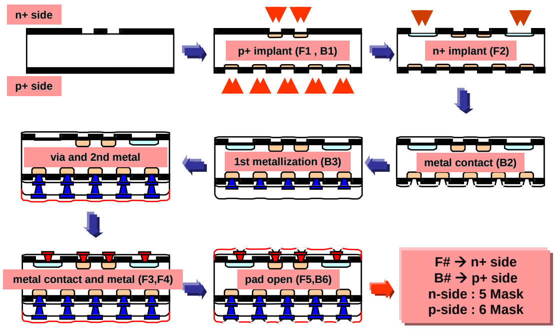
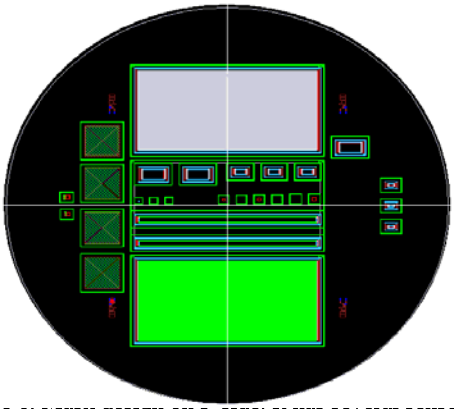


Figure 4. This is a prototype sensor photo showing the hourglass form in the double metal structures on P-side for reduce noise.

Figure 5 shows the optimized fabrication processes for double-sided silicon strip sensor with double metal structures. Since our sensors are double-sided, we started with P-implants on the both sides, and then N-implants are followed. After that, metal contact, metallization, and via (contacts between metal and metal) processes are followed. A total of 11 masks were needed for the sensor fabrication: 5 and 6 masks for N- and P-side, respectively.



Several silicon sensors including the double- and single-sided strip and PIN diode sensors are designed on the 6-inch masks as shown in Figure 6. The designed double-sides strip sensor has 512 readout channels on N- and P-sides with strip pitch 50µm and 100 µm for N- and P-side, respectively. But readout pitch is 50 µm for both sides.



Figur[illegible]r design patterns such as double- and single-sided strip sensors and PIN diode sensors

3. Conclusion

Double-sided silicon strip sensor provides a very promising technology due to its high position resolution, moderate radiation hardness, and stable performance. We have reported the concept and details of the sensor design, which is composed of 380 µm thick N-doped silicon wafer with 512 orthogonal P and N strips on opposite sides. 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 51072µm x 25600µm. The sensor fabrication was done on the 5-inch process line.

REFERENCES

[1] G. Lutz, Semiconductor Radiation Detector, Springer, New York, 1999. p.80.
[2] J. Fast et al., Nucl. Instr. and Math. A 435 (1999) 9.