Evaluation of the p-stop structures in the n-side of the n-on-n silicon strip detector

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I. INTRODUCTION

A large area (64 mm x 63.6 mm) prototype silicon strip detector was fabricated out of 4-inch silicon wafer. It had n-implant strips in the n-bulk silicon and a large p-pad in the backside. This was designed to work under heavy radiation environment such as LHC well after the type inversion of the silicon bulk and decrease of bulk resistivity.

Initially and even after the type inversion, the surface of the n-side is known to have the n-type characteristics due to the accumulation layer of electrons attracted to the accumulated positive charges in the interface of the oxide and the bulk. This conductive layer shorts the n-implant strips unless the strips are isolated with extra p-implant between the n-strips. A conventional method is to cover the rest of area other than the n-implant strips with the p-implant layers (full-frame p-stop structure).

A new type of p-stop structures were being proposed in order to reduce the inter-strip capacitance and to help to increase the onset voltage of micro-discharge. The full-frame p-stop has a resistivity but still is conductive and couples the neighbor n-strips. The individual/atoll p-stop structure is to separate the p-implant only to surround the n-implant but not continuous. The combined p-strop structure is to overcome the continuous conductive accumulation layer outside the individual p-stop structures such that the individual p-stop structures are confined in cells with an external rail of p-stop structure.

The detector fabricated had six regions where those p-stop structures are implemented. The strip widths of the detector are summarized in Table I and the p-stop structures are shown in Fig. 1 schematically.

II. INTERSTRIP CAPACITANCE

Inter-strip capacitance has been measured for the six regions. Inter-strip capacitance is the major contributor to the intrinsic noise of the detector-readout electronics. The results for the regions of individual, combined, and full-frame common are shown in Fig. 2. A sharp variaton of the capacitance was observed below the bias voltage of 60 volts which is the indication that the depletion has reached to the n-side. Over the depletion voltage, the inter-strip capacitance decreased slowly to saturation values at over 150 volts. This slow decrease is the indication of the accumulation layer between the strips. The combined and the full-common have shown the faster decrease than that of the individual structure.

III. BEAMTEST

Electronics noises and the charge collections were measured in the detector-readout electronics chain. Two modules (i.e.., detector-readout electronics unit) were fabricated. One module has a 12 cm strip length by daisy-chaining the two detectors and two readout planes. Thus, effectively, the p-strop structures were tested in four detectors in the two modules.

In the noise measurement, the combined structure has shown the least noise among the three p-stop structures. A beamtest was carried out using the 4 GeV/c pions from the 12 GeV proton synchrotron at KEK. The amount of charges collected was analyzed between the strips. The charge collections were split into the regions around the strips and the central region between the strips from the positions of the incident particles. The ratios of the median charges at a bias voltage of 200 volts were plotted in Fig. 3. In general, about 90% of the charges were collected in the central regions. In comparison of the p-stop structures, the combined structure has shown slightly better charge collection by 2-3 % over the individual structure.

The charge collection was also measured using the 1060 nm laser light.

V. SUMMARY

A large area (64 mm x 63.6 mm) n-on-n prototype silicon strip detector was fabricated. It had strips of 80 micron pitch and different p-stop structures in six regions on the n-side, among them being conventional full-frame common, individual, and combined p-stop structures. An evaluation was made for the p-strop structures in the inter-strip capacitance, the electronic noise, and the beamtest. The combined p-stop structure showed an indication of less accumulation layer between the strips, less noise, and slightly larger charge collection between the strips.