Evaluation of Radiation Damaged P-in-n and N-in-n Silicon Microstrip detectors

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Abstract

Two p-in-n detectors, being made with a high and a low resistivity material, and one n-in-n detectors were proton-irradiated and beamtested. The radiation-damaged p-in-n detectors required more bias voltage to be as efficient as the n-in-n detectors. The p-in-n detectors did not show a coincidence of a trend in the CV characteristics and in the efficiency characteristics. This indicated that these detector's characteristics were depending more on the other parameters than the resistivity of the material.

I. SUMMARY

Prototype p-in-n and n-in-n detectors with the ATLAS specification were fabricated, which had a strip pitch of 80 µm and the outer size was 64.0 mm (strip direction) x 63.6 mm. Thickness of the detectors was 300 µm. The p-strip readout in the n-bulk silicon detectors were made on a high resistivity (Sintef p-in-n) and a low resistivity material (1 kΩ•cm) (Ham p-in-n). The n-strip readout in the n-bulk silicon detector was made on the high resistivity material (4 kΩ•cm) (Ham n-in-n). The detectors were irradiated and subsequently beam-tested.

The irradiation fluence was 4 x 10^{14} p/cm^2 with the protons from the 12 GeV Proton Synchrotron at KEK. The detectors were cooled at -5 °C during the irradiation and in the beamline till they were extracted, then stored at 0 °C. Before the beamtest, they were warmed up at 28 °C for 7 days effectively in order to anneal the damage and to simulate the warm-up for maintenance in the real experiment.

The body capacitance after the irradiation and warmup was measured at -15 °C and is shown in Figure 1. The p-in-n detectors, although showed smaller capacitance in low validates, seemed not to reach a saturation value until the bias voltage reached above 300 V. It was difficult to extract the depletion voltage out of the measurement.

The detectors were connected to a fast-shaping on-off readout electronics (binary readout) and put in a beamtest with negatively charged pion particles. With one threshold of the electronics, efficiency of detecting signals above the threshold in a single strip was obtained.

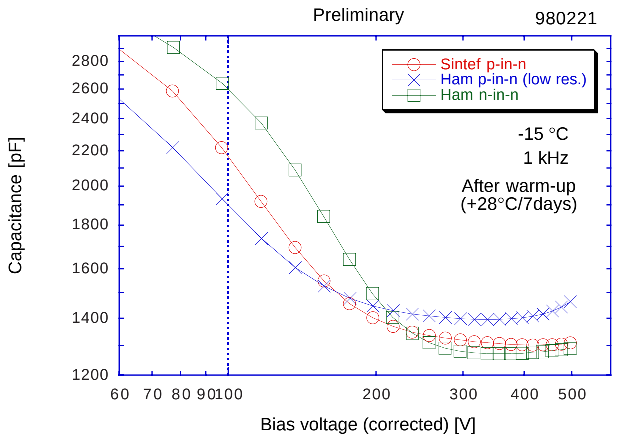

Figure 1: Body capacitance after irradiation and warmup as a function of the bias voltage.

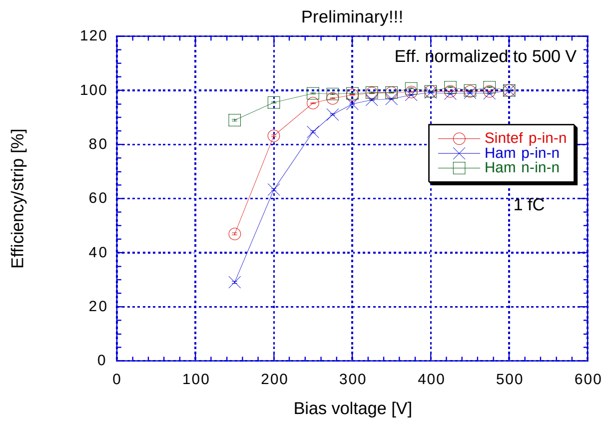

Figure 2: Detection efficiency as a function of bias voltage

The result of the efficiency at a threshold of 1 fC is shown in Figure 2. The n-in-n detector showed high efficiency in low voltage, while the p-in-n detectors required higher voltage to reach the high efficiency, as expected for reading out the p-n junction side and the ohmic side, respectively.

A more interesting observation was the difference of the two p-in-n detectors. The low resistivity detector, Ham p-in-n, required higher voltage than the high resistivity detector, Sintef p-in-n. This was in contradiction with the observation, in the CV measurement, that the low resistivity detector showed the turn-over of the capacitance in a lower voltage than that of the high resistivity detector.

In all, the p-in-n detectors required more bias voltage to be as efficient as the n-in-n detectors when the detectors were radiation-damaged. Two different p-in-n detectors did not show a coincidence of a trend in the CV characteristics and in the efficiency characteristics. This was an evidence that these detector's characteristics were depending more on the other parameters than the resistivity of the material, e.g., the design and the manufacturing process.