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Analysis of Edge and Surface TCTs for Irradiated 3D Silicon Strip Detectors

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We performed edge and surface TCT measurements of a double sided 3D silicon strip detector at the Jozef Stefan Institute. Double sided 3D devices are a useful counterpart to traditional planar devices for use in the very highest radiation environments. The TCT techniques allow the electric fields in 3D devices to be probed in a way not possible before.

Short 3D strip detectors, produced at CNM Barcelona, have been used for this study. The strip detectors had a substrate thickness of 280 micrometers and a strip pitch of 80 micrometers. The columns, that formed the electrodes, had a diameter of 10 micrometers, and were 250 micrometers deep. The junction electrodes were connected together to form the strips with 20 micrometer wide Aluminium metallisation. The Ohmic electrodes were all connected together on the backside of the device with a uniform contact. This is a similar technology as to that used for the ATLAS IBL 3D pixel sensor candidates. The detectors were tested both prior to irradiation and after irradiating to 5 x 10ˆ15 N/cmˆ2. Studies were performed into the effect of varying bias voltage and also the effect of annealing on the irradiated sample. An IR laser (1064 nm) was used to scan the devices with a FWHM of 7 micrometers. Scans with a step of 2.5 micrometers were performed over the surface of the device in both x and y directions, illuminating either the front surface or the cut edge. The irradiation and edge polishing were completed at the Jozef Stefan Institute in Ljubljana.

The TCT experiment was undertaken in an atmosphere of dry air, with the irradiated samples held at a temperature of -20℃. Annealing was achieved insitue by warming to 60℃ for intervals of 20, 40, 100, 300 and 600 minutes corresponding to room temperature annealing times of between 8 days and 200 days. 300 minutes is equivalent to the amount of annealing expected for 7 years of operation in an LHC experiment.

The current waveforms, as a function of illumination position and applied bias, were obtained for both pre and post irradiated devices and after annealing. This gives information on the origin of the induced signal, that is the portion from electron or hole motion. From the rise times of the signals, the velocity profile of the carriers in the devices and therefore electric fields can be determined. The collected charge was calculated from the integral of the waveforms. The results are compared to previous simulations.

The current waveforms are analysed to give results such as the collected charge as a function of illumination position for the front surface, the cut edge and the velocity profile.

There is a clear non-uniformity of the sensors prior to irradiation. While the lateral depletion between the columns is low, at approximately 4V, a uniform carrier velocity between the columns is not achieved until 5 times this value at 20V. Before irradiation, both the drift of electrons and holes provide equal contributions to the measured signals. After irradiation there is clear charge multiplication enhancement along the line between columns with a very non-uniform velocity profile in the unit cell of the device. The annealing of the detector further enhances this non-uniformity and charge multiplication effects.

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