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Charge Collection Properties of a Depleted Monolithic Active Pixel Sensor using a HV-SOI process

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We have fabricated and tested a new 0.18 um SOI CMOS monolithic pixel sensor using the XFAB process. In contrast to most SOI technologies, this one provides a double well structure, which shields the thin gate oxide transistors from the Buried Oxide. This in addition with the particular geometry between transistors and BOX makes the technology promising. The process allows the use of high voltages, which are used to partially deplete the substrate. A fully depleted substrate could be achieved after thinning. Thus the fabricated device is especially interesting for applications in extremely high radiation environments, as LHC experiments.

Summary

Silicon-On-Insulator (SOI) technologies have been developed for applications, which require radiation hardness since many years. However, for its use as particle detector the Total Ionizing Dose (TID) response of SOI devices is more complex than bulk silicon devices due to the buried oxide (BOX). On one hand a significant influence of radiation damage in the BOX on the transistor characteristics due to the so-called back gate effect has been observed and published in SOI technologies, and on the other hand the charge collection on such a structure and a possible influence of the BOX needs to be analyzed in unirradiated and irradiated samples.

We have fabricated and tested a new 0.18 um SOI CMOS monolithic pixel sensor using the XFAB process. In contrast to most SOI technologies, this particular technology provides a double well structure, which shields the thin gate oxide transistors from the Buried Oxide (BOX). This in addition with the particular geometry between transistors and BOX makes the technology promising against back gate effects mentioned before. Furthermore, the process allows the use of high voltages (up to 200V), which are used to partially deplete the substrate. The process allows fabricating in higher resistivity, therefore a fully depleted substrate could be achieved after thinning. Thus the newly fabricated device in the XFAB process is especially interesting for applications in extremely high radiation environments, such as LHC experiments.

The TID radiation hardness and the lack of the back gate effect on this prototype have been published previously. Besides, we have carried out a program to analyze the charge collection properties in the silicon bulk below the BOX for this prototype and the possible BOX influence in unirradiated and irradiated samples.

The characterization program was performed on five samples: 1 unirradiated, 3 irradiated with neutrons (1x1013 neq/cm2, 5x1013 neq/cm2 , 5x104 neq/cm2) and 1 irradiated with protons 1x1013 neq/cm2 in a lab environment. A Fe55 source was used for the charge calibration of the samples and an Sr90 source to measure the charge collection properties such as collected charge and charge collection time.

The presentation explains and quantifies the drift and diffusion contribution of the collected charge observed in the unirradiated sample at different voltages. Results from the charge calibration, a bias voltage scan with an Sr90 source and an analysis regarding the depletion depth is presented. The charge collection properties with a Sr90 source at different voltages are discussed with respect to the effects of the different radiation damage processes in the SOI technology and are compared to the first results obtained in test beam, TCT and eTCT measurements.

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