Edge Effects and Tilt Dependency of Heavy Ion Irradiation SEE Characterization In PN Junctions

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I. INTRODUCTION

Tilted irradiations are commonly used during Single Event Effect (SEE) characterization, since this method generally gives reliable results. However, recent works have shown an unexpected behavior for some devices: instead of increasing the cross section decreases when the device is tilted for a given ion and energy. This has been observed for digital as well as for analog circuits. This paper tries to understand it and link simulation results with experimental data obtained on PN junctions, initial P type wafer (NA = 10^15 cm^-2) with an implanted N+. Dose = 10^15 cm^-2. Energy 100 keV.

II. SIMULATION RESULTS

Figure 1 presents simulation results for a normal incidence ion strike and zero bias using a Xe beam, energy 459 MeV with two angles a) 0°, perpendicular, and b) at 60°, from the middle of the diode (X = 7 μm) and towards the edges (X=12 and 2).

The first maximum peak current amplitude is in the central part of the diode, then decreases away from center and at the edge a second maximum even higher than the central one, due to the formation of the h-e pairs directly in the depletion zone.

![Fig. 1. SEU simulation at 0° and 60°.](image)

For 60° irradiation, the impacts present very different time characteristics. The cathode current modification extends over a longer period of time when compared to a normal incidence impact. This may be linked to the fact that for normal incidence strikes, the pairs are generated in the same direction as the current flow, and may have a faster contribution on the cathode current; whereas when the incidence is tilted, the pairs are created at remote locations from the device main electrical field and take more time to be collected and, as a consequence the current peak value is lower for the tilted conditions than it is for a perpendicular incidence.

III. IRRADIATION DATA

The experimental data presented here was obtained with a Xe 459 MeV beam. During irradiation, diodes were reverse biased at 3V and connected to a charge pre-amplifier.

Figure 2 represent the collected charge distribution for the same structure but at different angles. Sigma values represent the number of event per bin normalized to the total number of event in all the bins.

At normal incidence most of the events occur for a collected charge of about 1 pC, which is in fair correlation with the charge computed using a 1D model and for an ion strike in the central part of the device. The number of occurrence for charges below half of the peak value accounts for less than 10% of the total number of events, also in qualitative agreement with the area ratio for a 100 μm x 100 μm device, between the central device zone and its peripheral zone starting at about 3 μm of the device edge, as observed in our simulations.

The collected charge amplitude also gets lower with increasing angle, while its distribution widens in agreement with simulations.

![Fig. 2. Amplifier output for a 100 X 100 μm diode with Xe beam at 0° and 60°.](image)

IV. CONCLUSION

From simulations and experiments, we have demonstrated that the charge collection in PN diodes with CMOS-like low junction depth and high substrate doping decreases in amplitude and shows longer time constants when the ion strike is tilted on the periphery of the device. We believe that these observations may intuitively explain the SEE cross-section decrease observed in recent components when tilted.

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