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Impact of interface quality on single-event charge collection in SOI Technologies

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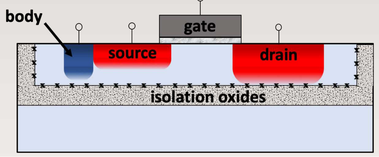
Introduction

Semiconductor | insulator interfaces play a historically important role in the reliability of integrated circuit devices; however, the impact of these interfaces on the underlying physical mechanisms of soft errors, i.e., single-event charge collection, has not been previously reported.

- SOI's electrical isolation acts to restrict the dimensions of sensitive volumes that can collect charge deposited during transient radiation events
- Reducing the size of sensitive volumes improves SEE hardness but the inclusion of insulating interfaces can introduce floating body and ***interface effects***.



Sandia National Labs SOI MOSFET

Modeling

- Synopsis Sentaurus Device Physics package is used for finite-element modeling
- Normal incidence ion strikes are simulated for different LET ions
- Surface recombination velocity along insulating interfaces is parametrically varied

carrier concentrations along interfaces and at defect energies

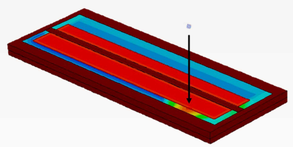
characteristic of interface defects (surface recombination velocity)

driving force toward equilibrium

$$U_s = \sigma_s v_{th} D_{st} \left[\int_{E_v}^{E_c} \frac{dE_{st}}{p_s + n_s + 2n_i \cosh\left(\frac{E_{st} - E_i}{kT}\right)} \right] [p_s n_s - n_i^2]$$

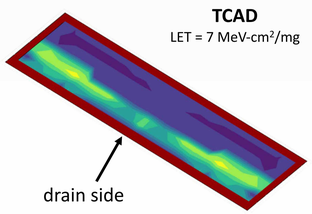
surface recombination [1]

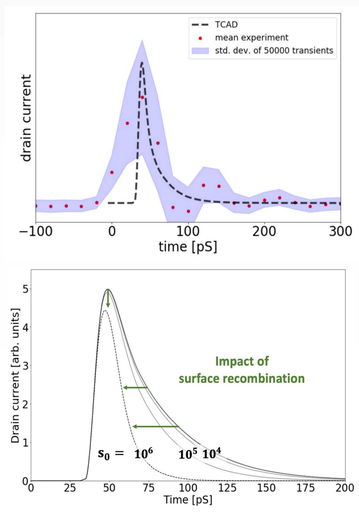
excess carrier distribution 10 pS after strike



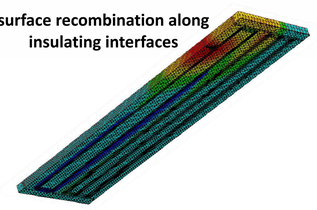
charge collection map for 154 strikes locations

TCAD
LET = 7 MeV-cm²/mg





surface recombination along insulating interfaces



Abstract

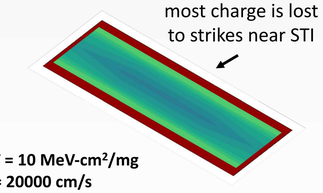
Silicon-on-insulator technologies use electrically insulating oxide layers to minimize the extent of sensitive semiconductor volumes and reduce susceptibility to integrated circuit soft errors that can result from energetic particles. We present experimental data that quantify the impact of the interface quality of isolation oxides on single-event charge collection by manipulating interface quality with total dose irradiation. Our findings indicate that single-event charge collection can be significantly impacted by changes in interface quality produced by a total dose irradiation. Using this experimental evidence to calibrate finite-element simulations, we identify the dominant factors that contribute to the sensitivity of single-event charge collection to interface quality. We find that sensitivity to interface effects is reduced at low LETs and with technology scaling.

The Impact

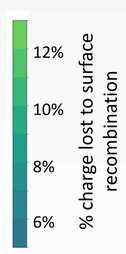
- Experiments and simulations indicate that interface quality can reduce single-event charge collection in SOI depending on strike location and LET
- The interface quality of buried oxides may be considerably worse than gate oxides
- Interface quality has less of an impact on scaled devices with shorter duration transients

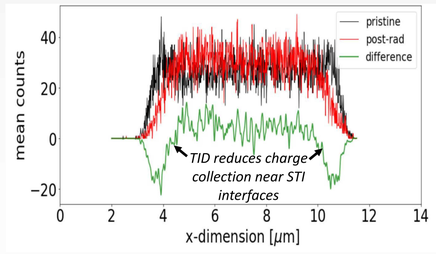
Simulated sensitivity to interface quality

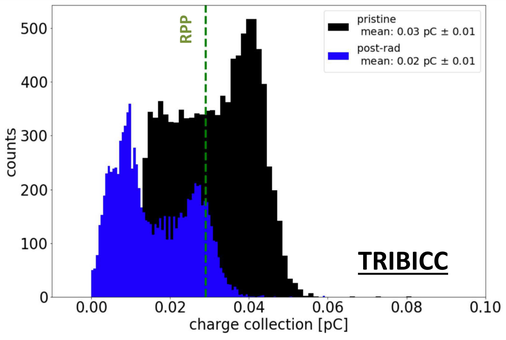
most charge is lost to strikes near STI

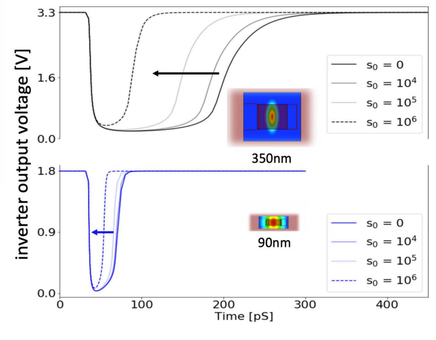


LET = 10 MeV-cm²/mg
s_o = 20000 cm/s
* highest in literature [2]





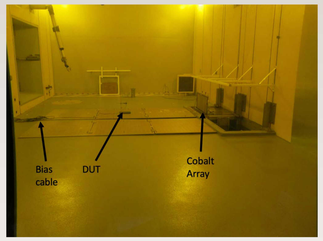


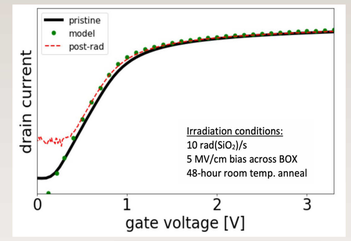


Experiment

Gamma Irradiation Facility

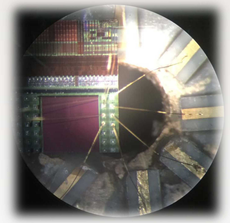
- Cobalt-60 irradiation
  - 5 MV/cm applied across buried oxide
  - 10 rad(SiO_2)/s till observable damage

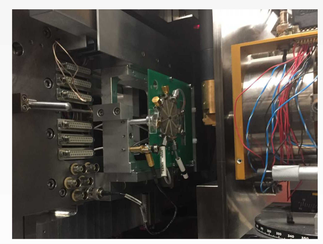


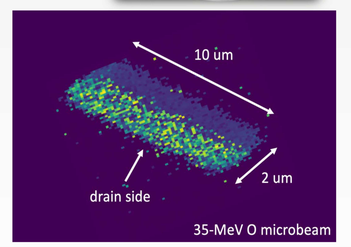


Microbeam Probing

- Ion-beam induced charge collection, *IBICC*
  - Magnetically raster ion beam device
  - Map collected charge [3]
- Time-resolved *IBICC*
  - Capture transients at each terminal using 20 GHz scope (20 pS/point)







Conclusions

Interface quality is experimentally demonstrated to impact charge collection during single-events in SOI. Single-events occurring at locations near insulating interfaces are the most sensitive to surface recombination and the impact increases with increasing LET. If devices are operated in a circuit with limited restoring current, SETs are more likely to be impacted by surface recombination than in unloaded devices. Despite a general trend of increasing insulating surface area to active silicon volume with SOI technology scaling, interface effects on ion-induced charge collection *decrease* with feature scaling.

Comparison of experimental data with simulation models provides the first reported evidence that the interface quality of the isolation oxides in SOI can be much lower than that of gate oxides.

References

[1] D. J. Fitzgerald and A. S. Grove, "Surface recombination in semiconductors," *Surf. Sci.*, vol. 9, no. July, pp. 347–369, 1968.
[2] L. L. Rosier, "Surface State and Surface Recombination Velocity Characteristics of Si-SiO2 Interfaces," *IEEE Trans. Electron Devices*, vol. 13, p. 260, 1966.
[3] G. Vizkelethy, D. K. Brice, and B. L. Doyle, "The theory of ion beam induced charge in metal-oxide-semiconductor structures," *J. Appl. Phys.*, vol. 101, no. 7, pp. 1–6, 2007.

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