Alpha–Particle Induced Soft Error Rate Evaluation Tool and User Interface

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Abstract

A simulation tool for calculating the soft error rate due to α–particle strikes in SRAM's is described. The simulator uses Monte Carlo methods to determine the initial energy and angle of α–particles, then uses layout, process and device information to determine a histogram of charge collection in a memory cell. The soft error rate is determined from a knowledge of the memory cells' critical charge. A graphical user interface for the soft error simulator is also described

1. Introduction.

A simulator was developed to aid in the understanding of soft error susceptibility of SRAMs. *SEEV* (Soft Error EValuator) uses Monte Carlo methods to determine the soft error rate (SER) of a circuit. Random numbers are used to determine initial energy, depth in the source, and incidence angle of an α–particle. An integration over all energies, incidence angles and locations of α–particle strikes in a memory cell is performed. Physical and empirical models describing the α–particle source, charge collection and interactions with materials are incorporated into *SEEV* for estimating energy and angular dependence of α–particle induced charge collection. Thicknesses and areas of overlayers for specific SRAM cells are used, and α–particle energy loss is calculated for each overlayer. Tools for SER estimation have been shown in the past [1,2]. The advantages that *SEEV* has over previous SER estimation tools are ease–of–use and speed ($10^7\alpha$–particle trajectories can be simulated in less than 10 minutes on an Alpha workstation).

2. α–Particle Interactions with Materials.

α–particles are stopped in materials mainly by electronic interactions [3]. *SEEV* evaluates the stopping integral numerically and the resulting data is placed in a lookup table for various materials that are commonly used in the manufacture of semiconductor memories (*i.e.* Si, Al, SiO_2, and polyimide). For silicon, the knowledge of the ionization is required to determine the charge collection. Electron–hole pairs are generated by the electronic interaction between the α–particle and the silicon. For every 3.6eV loss in energy of the α–particle, one electron–hole pair is formed. *SEEV* uses an empirical formula to fit published ionization data [4].

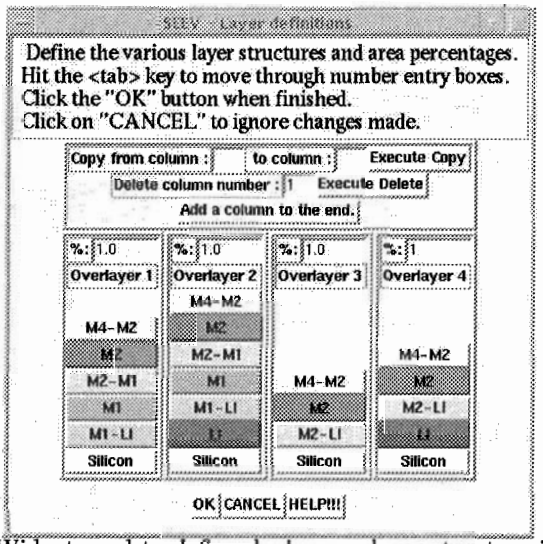

Figure 1: Widget used to define device overlayer structure in *SEEVI*.

3. Charge Collection Models in SEEV.

SEEV assumes an effective funneling length [4], derived from charge collection simulations. This effective funneling length is modified by one over the cosine of the incidence angle, although there are other methods to include angular dependence [1,5]. There is no energy dependence of the funneling length although the total charge collected does depend on the α–particle energy. The total charge collected, Q_{coll}, is calculated by integrating the ionization from the surface of the silicon to a depth along the α–particle track equal to the funneling length (modified by the angular dependence).

4. SEEV User Interface (SEEVI).

A graphical user interface was developed using the Tcl/Tk toolkit [6] to allow a user to define physical and numerical information used in the *SEEV* program. The main menu of *SEEVI* has six menu options that invoke invoke pulldown menus and are used to define:

- File Operations – Load and save an input file, set or clear input parameters or exit *SEEVI*.
- Alpha Source – Define the type of α–particle source and the parameters describing the source.
- Physical Parameters – Define effective funneling length, SRAM cell parameters, define overlayer thicknesses, and interactively add or delete various overlayer materials over the whole cell or portions of a cell. The widget used to interactively define the overlayer structure is shown in Figure 1.
- Output Parameters – Define data to be printed to an output file.
- Simulate – Perform a *SEEV* simulation.
- Title: – Text entry box for a single line title for the simulation.

5. Simulation Results.

One example of a calculation that can be performed by SEEV is the simulation of SER due to α–particles coming from ceramic package lids and from metal lines. Figure 2 shows *SEEV* calculations of the energy spectra at the silicon

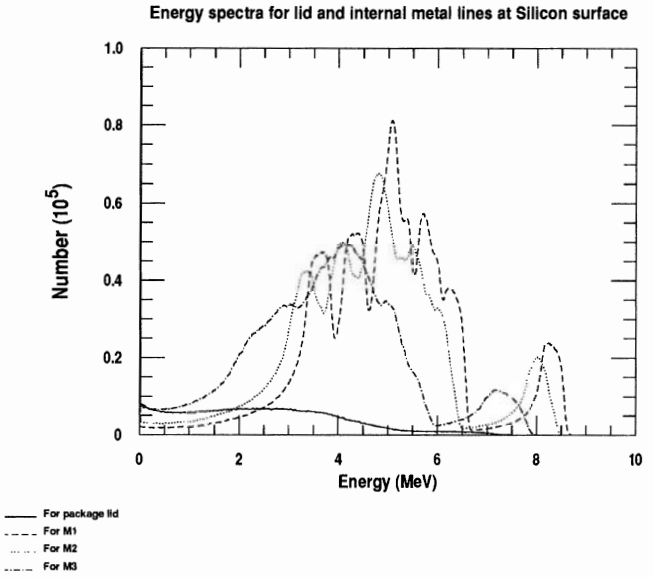

Figure 2: Energy spectra of various α–particle sources at the Silicon surface.

surface of α–particles that were generated in a package lid and in three different metal levels. Since M1 is the thinnest metal level and is closest to the silicon surface, the energy spectrum shows more discrete energy peaks. As distance away from the silicon surface increases, α–particles with varying incidence angles tend to lose more energy and the energy peaks get shifted down and more smeared out. Due to the shift in the energy and effects due to differences in incidence angle, the SER due to α–particles coming from metal lines and package lids will be different. Figure 3 shows *SEEV* calculations of relative SER for the various sources of α–particles.

Another example of a *SEEV* calculation is shown in Figure 4. The voltage dependence of SER for two different SRAM cell designs is shown. To obtain these graphs, circuit simulations of the critical charge needed to upset an SRAM cell is determined. The relative SER is then read from a graph similar to that shown in Figure 3. Measurements of a similar technology and cell to that simulated showed a SER dependence of 1.3 decades/V, in excellent agreement with simulation results of 1.29 decades/V.

References

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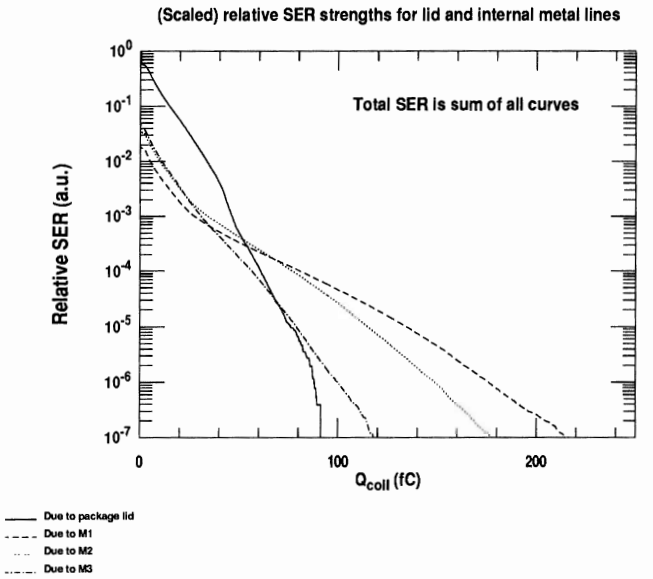

Figure 3: SER for various sources of α–particles.

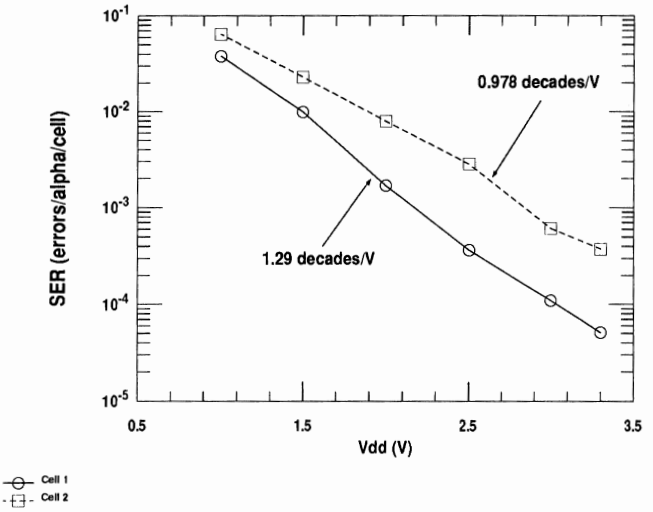

Figure 4: Calculation of SER dependence on applied external bias.