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# Estimation of Soft Error Tolerance according to the Thickness of Buried Oxide and Body Bias 28-nm and 65-nm in FD-SOI Processes by a Monte-Carlo Simulation

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## 1. Abstract

We estimate the soft error rates of FD-SOI structures according to the thicknesses of BOX(Buird OXide) layers and body bias on 65-nm and 28-nm processes by reducing the supply voltage. A Monte-Carlo based simulation is used in this work. The parasitic bipolar effect is suppressed by thicker BOX on FD-SOI structure.The simulation results are consistent with the alpha and neutron irradiation measurement results. We will show the SERs of FD-SOI structures according to the body bias in the final paper.

## 2. Introduction

Silicon On Thin BOX (SOTB) [1] and Ultra Thin Body and BOX (UTBB) [2] are two kinds of FD-SOI with a thin BOX layer. It can suppress the charge collected into circuit by a particle hit. Thus, the soft error tolerance is stronger than bulk structure. Variations are suppressed due to the dopantless channel of FD-SOI. The supply voltage of SOTB can be decreased to 0.4 V [3].

In this work, we analyze the alpha particle and neutron induced soft error rates on 65-nm SOTB and 28-nm UTBB latches by a Monte-Carlo based simulation. The simulation tool is called PHITS-TCAD. It is similar to MRED [4], IRT [5] and PHYSERD [6]. PHITS [7] is a kind of physics level simulator as Geant4. The device models are constructed by TCAD simulations. We chang the thickness of BOX layer of the FD-SOI structures, and analyze the SERs of those models.

This paper is organized as follows. Section 3 introduce the PHITS-TCAD simulation tool. The simulation results of the models with different thickness of BOX layer are shown in section 5. Section 6 concludes this paper.

## 3. PHITS-TCAD Simulation Tool

### 3.1 How Does PHITS-TCAD Work

Fig. 1 portrays a flow chart of our simulation system by PHITS and TCAD. PHITS is a Monte-Carlo physics simulator. It is designed to simulate secondary ion generation via nuclear interaction of an incident particle with constituent atoms in a device, and the sequential charge deposition. PHITS can calculate the deposit energy when a secondary particle cross the sensitive volume of a device as shown in Fig. 1. The deposit energy ($E_D$) corresponds to the lost energy of the particle.

In the TCAD simulation part, generated charge ($Q_{\mathrm{gen}}$) is collected into drain by a particle hit as shown in Fig. 1. An SEU (Single Event Upset) occurs in the circuit when $Q_{\mathrm{gen}}$ is large enough. We call it the threshold charge ($Q_{\mathrm{th}}$), which is used to calculate the threshold deposit energy. $E_{\mathrm{Deposit}}$ can be converted to the $Q_{\mathrm{deposit}}$. 1 MeV $E_{\mathrm{deposit}}$ is equivalent to 50 fC $Q_{\mathrm{deposit}}$ [8].

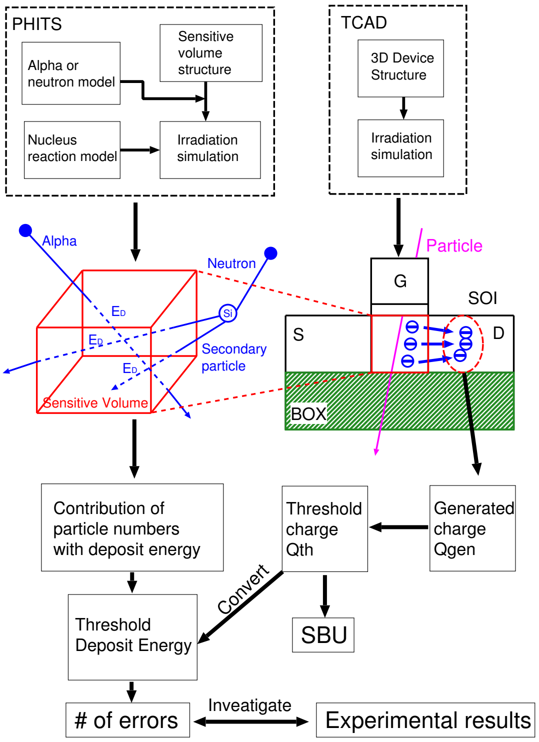


Fig. 1. Flow chart of the PHITS-TCAD simulation system.

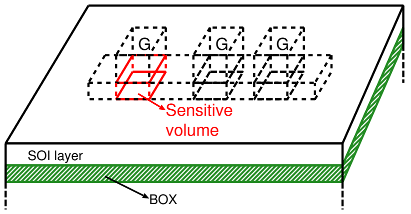


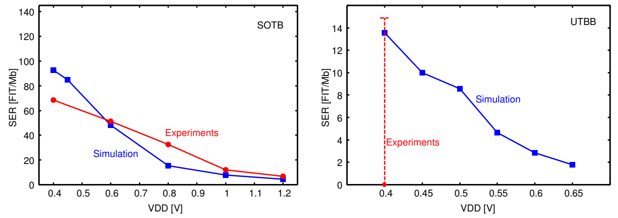
Fig. 2. Device structure used in PHITS simulations. This structure shows the sensitive volume of a latch. The SOI layers under G is regarded as the sensitive volume according to the TCAD simulation.

### 3.2 Simulation Setup

Fig. 2 shows the bird view of the device structure in PHITS simulations. It shows a latch structure. The red box indicates a sensitive volume. It is built based on the layout structures of the latch in test chips. The SOI body under the gate of an inverter is considered as a sensitive volume. The thicknesses of the thin BOX and the SOI body of SOTB are 10-nm and 12-nm while those are 25-nm and 7-nm in UTBB respectively. The same structures are constructed in TCAD simulations by 3D device-models.

## 4. Neutron Irradiation Induced SERs by Simulations and Experiments

Fig. 3(a) and 3(b) show the neutron induced SER by neutron irradiation experiments and PHITS-TCAD simulations. The neutron irradiation experiments are conducted at RCNP



(a) The SERs of SOTB structure according to the neutron irradiation experiments and simulations.

(b) The SERs of UTBB structure according to the neutron irradiation experiments and simulations.

Fig. 3. Results of neutron irradiation experiments and PHITS-TCAD simulations.

in Osaka Univ. Eq. (1) is used to calculate the SERs of PHITS-TCAD simulations.

$$SER_{\mathrm{SBU}}[\mathrm{FIT/Mb}] = \frac{3.6\times10^{18}\times A_{\mathrm{neutron}}\times N_{\mathrm{SBU}}\times F}{N_{\mathrm{Neutron}}} \qquad (1)$$

where $A_{\mathrm{neutron}}$ is the area of neutron beam in PHITS simulations. $N_{\mathrm{SBU}}$ is the number of SEUs and $N_{\mathrm{Neutron}}$ is number of all neutron particles. F is the Flux as the same as RCNP.

Accroding to the neutron irradition experimental results, there is no error in the 28-nm UTBB structure. Thus, the SERs are shown by 90% error-bar in Fig. 3(b). The SER is no larger than 15 FIT/Mb when VDD is 0.4 V. The 28-nm UTBB is 10x stronger than the 65-nm SOTB when VDD is 0.4 V according to the neutron irradiation simulations.

## 5. Neutron induced SERs on 65 and 28-nm processes influenced by BOX layer Thicknesses

As the results of simulations are consistent to the experimental results, The SERs of several device models can be forecast. In this section, we change the thickness of BOX layer in the 65-nm SOTB and 28-nm UTBB by TCAD simulations. The SERs of these new models are analyzed by the PHITS-TCAD simulation tool influenced by reducing the supply voltage.

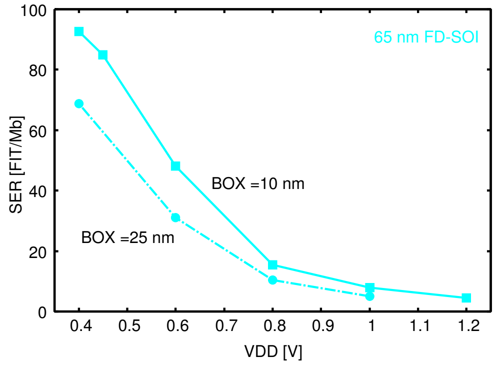
Fig. 4 shows the neutron irradiation simulation results by PHITS-TCAD. In the 65-nm FD-SOI structure, the collected charge reduces by a particle hit. The main mechanism of charge collection in FD-SOI is the parasitic bipolar effect. The substrate voltage is increased when the bipolar is turned on by a particle hit. However, it affect the SOI layer weakly by increasing the thickness of BOX. The SERs of 65-nm decrease almost 20% as shown in Fig. 4(a). Compared to the 65-nm process, the soft error tolerance become stonger in 28-nm structure. The SERs of 28-nm only increase 10% by thinner BOX layer as shown in Fig. 4(b).

Fig. 5 shows the threshold LET influenced by the thickness of BOX in the 65-nm FD-SOI structure by TCAD simulations. The threshold LET decreases by thinning BOX layer. The parasitic bipolar effect of substrate is suppressed by the thicker BOX.

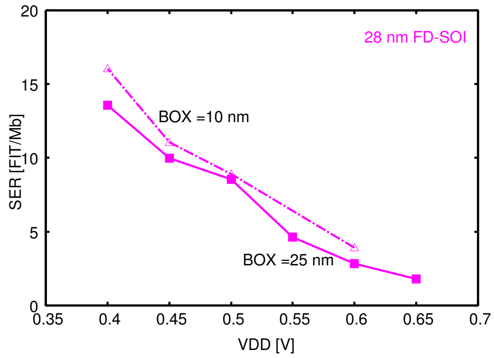
The parasitic bipolar effect is influenced by changing the body bias, the soft error tolerance is also changed by different body bias. We will show the results in the final paper.

## 6. Conclusion

We analyze the soft error rates on 65-nm SOTB and 28-nm UTBB by a monte-carlo based simulation tool PHITS-TCAD. According to the PHITS-TCAD simulation results, the SERs of 65-nm FD-SOI structure are 20% decreased when the BOX layer are increased from 10nm to 25nm. The parasitic bipoar effect is suppressed by thicker BOX layer. However, the SERs of 28-nm FD-SOI only increase 10% when the BOX layer are decreased to 10 nm. The soft error tolerance of 28-nm structure is stronger than 65-nm. The SERs do not change a lot by the thickness of BOX layer in 28-nm process. We will show the SERs influenced by changing the body bias in the final paper.



(a) Simulation results of 65-nm FD-SOI. The SERs decrease by thicker BOX layer.



(b) Simulation results of 28-nm FD-SOI. The SERs increase by thinner BOX layer.

Fig. 4. Results of neutron irradiation simulations by PHITS-TCAD simulations. The thicknesses of BOX layer are changed.

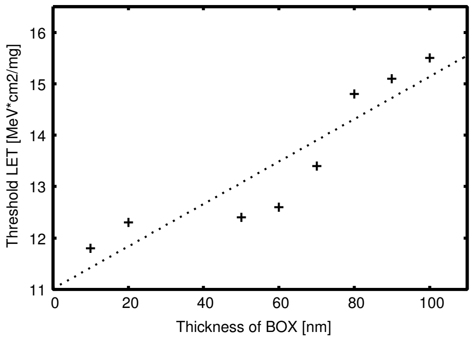


Fig. 5. The threshold LET influenced by the thickness of BOX in 65-nm FD-SOI. The supply voltage is 1.0 V.

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