Monte-Carlo Simulation for the Effects of Composite Materials on Single Event Effects of Sub-100 nm Semi-conductor Devices

Eishi Ibe, Yasuo Yahagi, Hironaru Yamaguchi

Production Engineering Research Laboratory,

Hitachi, Ltd.

ibe@perl.hitachi.co.jp

Single event upset (SEU; soft error) induced by terrestrial neutrons is being recognized as a common error mode. of semiconductor devices at the ground. Monte-Carlo simulation technique with nuclear spallation (Intra-Nuclear Cascade and statistical evaporation models) and charge collection models in 3D device structure including source, drain, isolation oxide, single/triple wells of infinite-matrix memory cells is applied for analyses of single event effects (SEEs) of semi-conductor devices. Experimental approaches by medium-energy (1-800 MeV) neutron irradiation experiments are also applied for commercial devices. The simulation technique is particularly important under design phase to predict and minimize the susceptibility of semiconductor devices before mass production to the market.

Although there are some reports which indicates composite material effects on SEU susceptibility, the simulation model in the current program package CORIMS is very limited in this viewpoint: It simulates only nuclear spallation reaction of Si nucleus and analyze secondary ion tracks and energy deposition in Si substrate.

We have made a new Monte-Carlo simulation code SEALER by which such composite material effects are fully simulated on Windows^{TM} PCs. SEALER includes:

(1) CAD algorithms to construct 3D device structure;

(2) Eight composite material data for Si, SiO_2(isolation oxide), Si_3N_4(side wall, etc), Ta_2O_5(capacitor material), WSi_2(contact), Cu (metal line), Al (metal line), TiN (buffer, etc);

(3) Data base for nuclides from nucleon to tungsten (about 2000 nuclides) , approximation functions of total reaction cross section neutron with Si, N, O, Ta, Ti, Al, Cu, W, neutron spectrum in the field and some selected facilities (TSL, LANSCE, CYRIC, FNL, RCNP);

(4) Data base for parameters in approximation function of LET (electrical and nucleus) in SRIM tables polynomial approximations for the ion-medium combinations of 78 elements in 8 composite materials;

(5) Algorithm to calculate inverse reaction cross section based upon generalized evaporation model (GEM) . SEALER demonstrates that the contribution of secondary ions from lighter elements (O, N) from SiO_2 and Si_3N_4 play important role and heavier ions like Ta from WSi_2 may play only limited role.