Radiation Hardness of Double-Gate Ultra-Thin SOI MOSFETs

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We compare the radiation hardness of ultra-thin Silicon-On-Insulator (SOI) MOSFETs operated in single-gate (SG) and double-gate (DG) mode as a function of silicon island thickness. DG-MOSFETs are found to be systematically less sensitive to radiation effects. Density gradient simulations show that quantum effects, inducing volume inversion in double-gate mode operation, reduce the detrimental effects of oxide trapped charge on threshold voltage shifts and mobility degradation.

SOI technology presents numerous advantages when compared to traditional bulk Si MOSFETs and, in particular, double-gate (DG) transistors exhibit exceptional electrical performance. When SOI devices are subjected to ionizing radiation, significant amount of charges can be trapped in the buried oxide layer (BOX). These charges may invert the back channel and create a leakage path that severely degrades performance. However, the combination of reduced silicon film thickness and double-gate operation can improve significantly the radiation hardness of SOI devices. The volume inversion that characterizes the operating condition of ultra-thin DG-MOSFETs reduces more efficiently the detrimental impact of radiation induced oxide charge on threshold voltage. The inversion carrier centroid in DG-MOSFETs is pushed further from the interfaces than it is in SG-MOSFETs, resulting in an effective smaller first moment of oxide trapped charge. On the other hand, for single-gate operation, the reduction of the Si-film thickness increases the coupling between front and back-gate [1] which in turns enhanced the impact of BOX charge on front-gate current.

Our simulations focus on the case of extremely thin films, including the sub-10 nm range where quantum effects become noticeable. Figure 1 illustrates the effect of Si-film thickness on threshold voltage for devices operated in single and double-gate mode. As observed experimentally [2] for comparable SG-mode devices, threshold voltage increases with decreasing film thickness as a consequence of sub-band splitting, which is accentuated in SG transistors. This figure also shows the very interesting effect of radiation on these devices. We observe that radiation-induced oxide charge has a remarkably small and steady effect on double-gate mode devices, whereas the effect of the same radiation dose on single-gate devices increases as the Si-film gets thinner.

These results demonstrate that the advantage of DG transistors increases in ultra-thin films. Additional radiation-induced effects are investigated and discussed including changes in transconductance, subthreshold slope and leakage current, and the influence of interface trap generation.

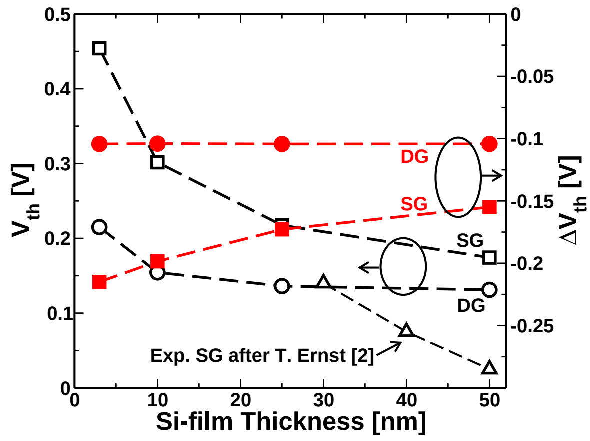

Figure 1: V_{th} and ΔV_{th} vs. Si-film thickness.

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