Probing Radiation Effects in Gate-All-Around MOSFETs using Focused Particle Beams

M. Titze, A. Belianinov, A. Tonigan, S. Su, G. Vizkelethy, W. Wampler, B. Hehr, E. Bielejec, R. Arghavani
Sandia National Laboratories, Albuquerque, NM, 87123, USA
mictitz@sandia.gov
M. Wang, H. Zhou, V. Narayanan
IBM Research Albany, Albany, NY, 12203, USA

Gate-All-Around field effect transistor (GAAFET) architecture fundamentally alters the gate and isolation dielectric structures compared to previous generations of planar and Fin-based transistors. Furthermore, the GAAFET architecture isolates the active device regions from the underlying silicon substrate in a way that makes these devices behave similar to radiation hard silicon-on-insulator technology, by significantly reducing the radiation-induced charge collection volume. These properties may improve the dose-rate upset response of GAAFET based integrated circuits. As the GAAFET technology gets adopted by industry, it is paramount to understand their failure mechanisms in relevant radiation environments, such as space or reactors.
Here, we use focused ion and electron beams from a Raith VELION dual-beam FIB-SEM to probe the response of individual GAAFETs. Specifically, we use a 35 keV Li beam to create displacement damage (DD), shown in Figure 1(a). However, since ions also generate ionization damage along their path, this is truly a DD + total ionizing dose (TID) damage test. Hence, we use a 20 keV electron beam to compare to the effect of a beam creating only total ionizing dose. Our results show increasing leakage current under DD, while under TID the overall transfer behavior of the transistor is unaffected over a large range of TID, shown in Figure 1(b).
The presented FIB-SEM technique can be readily integrated into existing FIB-based transistor testing processes to easily and quickly test transistor radiation hardness to two relevant radiation environments without the need for large-scale testing facilities.

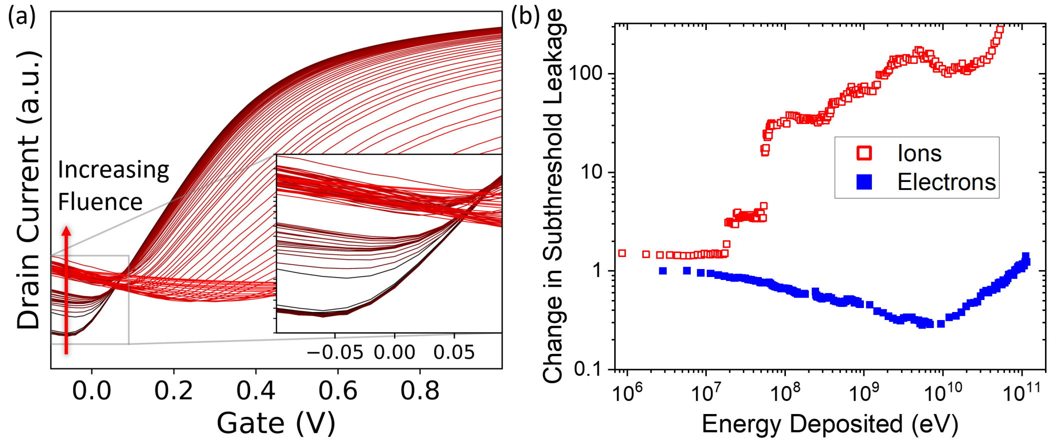

Figure 1: Radiation response of GAAFET (a) Transfer curve of GAAFET under ion irradiation showing stepwise increase in the subthreshold leakage current. The Inset shows a zoomed-in view of the subthreshold region. (b) Change In subthreshold leakage in a DD + TID (ions) and a TID-only (electrons) radiation environment. The amount of TID deposited is used to compare the two beams.