Radiation and Trap Effects in Ni/Al_2O_3/ Ga_2O_3 MIS Capacitors

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Abstract:

Developing electronics grade gate dielectric with low defect density, high breakdown strength, and low leakage current is essential for next-generation β-Ga_2O_3 transistors. Developing a high-quality dielectric coupled with the maturation of β-Ga_2O_3 materials will enable circuits, power conditioning, and detectors on the same wafer. For this study, we developed a series of Ni/Al_2O_3/Ga_2O_3 metal insulating semiconductor (MIS) diodes to characterize the insulator, insulator-semiconductor interface, and bulk material. The impact of X-rays, which poses total ionizing dose effect (TID), and proton irradiation, which consists both displacement damage (DD) and TID, are separately investigated to understand the individual radiation effects.

In this work, a ~15 nm Al_2O_3 insulator layer was grown in-situ atop of Si-doped β-Ga_2O_3 by MOCVD growth method. Ni gate contacts were deposited on the insulator and Ti/Al/Ni/Au contacts on the β-Ga_2O_3 formed the Ohmic contacts. Defects were characterized before and after irradiation using current-voltage sweeps, constant capacitance deep level transient and optical spectroscopies (DLTS/DLOS). The devices were irradiated with 1.8 MeV proton radiation with fluence stepped from 5×10^{12} cm^{-2} to 3×10^{14} cm^{-2}. During proton irradiation, a gate bias of -3 V, 0 V, and 2.5 V were applied to separate diodes to vary the strength and direction of the electric field in the insulator. Similar biasing conditions were employed during 10 keV x-ray over a range of doses to demonstrate TID effects without DD. Post-irradiation characterization indicates protons cause displacement damage in the bulk Ga_2O_3 regardless of biasing condition (revealed by carrier removal and trap introduction) while the TID effect is more prominent in the Al_2O_3 layer and is largely affected by field strength. In addition, the pre- and post-irradiation of interface trap density distribution [$D_{it}(E)$] will be compared for both X-ray and proton. Results suggest that TID effect is minimized when devices are put into forward bias condition. Understanding this effect can be crucial in realizing rad-hard β-Ga_2O_3 transistors.