Radiation TID and Traps Effects in Al_2O_3/Ga_2O_3 MIS Capacitors

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Motivation

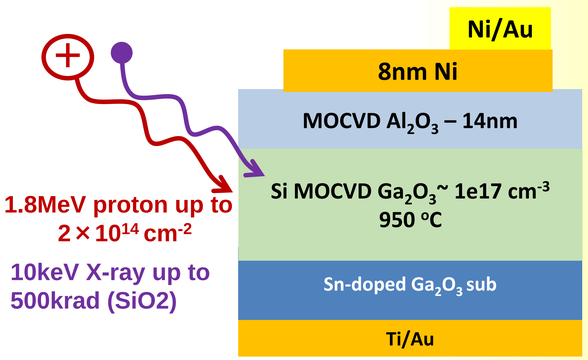
β-Ga_2O_3 is a 4.8 eV ultra wide bandgap (UWBG) semiconductor known for its **large breakdown field**[1] and **radiation resistance**[2]**.** To date, little work has been done on the impact of total ionizing radiation (TID) in β-Ga_2O_3 devices. Understanding TID effects along with prior work on displacement damage (DD) is needed to advance tech development that exploits the radiation hardness of β-Ga_2O_3 for applications in radiation-rich environments and as remote radiation detectors.

Objective: This work investigates DD and TID effects in Al_2O_3/Ga_2O_3 MIS capacitors by **comparing proton and x-ray irradiation** effects on electrical properties using capacitance-voltage (C-V) analyses.

Key Experimental Method

Approach:

- Apply 1.8 MeV proton up to 2 x10^{14} cm^{-2} fluence and 10keV X-ray up to 500krad (SiO_2) with in-situ voltage biasing during each radiation dose step.
- Radiation effects on devices are characterized through **C-V** characteristics.
- The effects of TID, DD and interface trapping can be quantified by comparing C-V threshold voltage shifts, **ΔV_{FB}**.

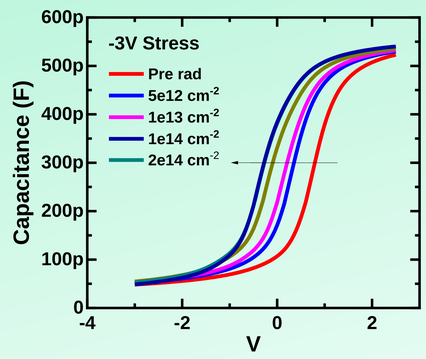


MIS device structure used to for radiation response testing

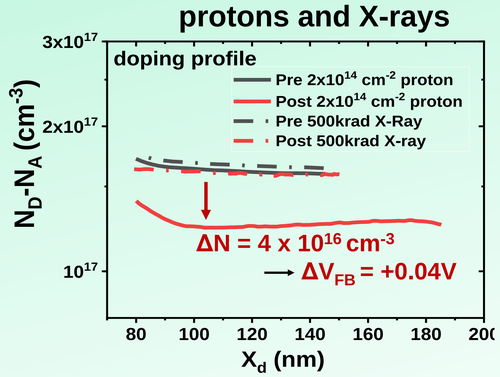
[1] Higashiwaki *et al.*, Appl. Phys. Lett. 100, 013504 (2012)
[2] E. Wendler *et* al., 11th Intl. Conf. Interact. of Rad. with Sol., 93, (2015)

Effects of DD & TID on Al_2O_3/Ga_2O_3 MIS capacitors

C-V: proton irradiated



Carrier removal comparison: protons and X-rays



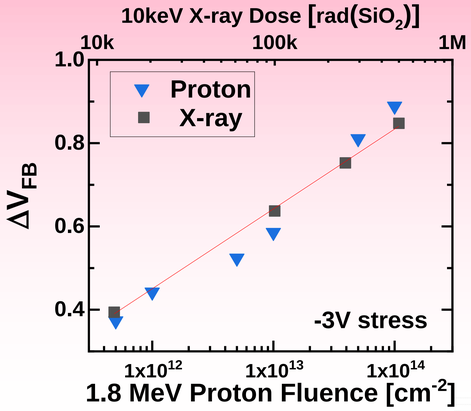
Protons can cause both TID & DD effects

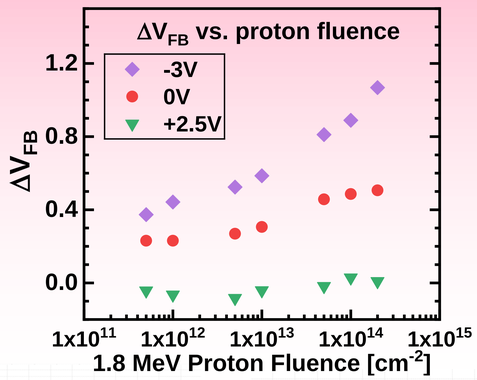
- large **ΔV_{FB}** seen in C-V
- **Monotonic negative shift** implies increased positive charge inside dielectric.
- Carrier removal from bulk material due to DD-induced traps as expected, but only accounts for **+0.04** of total **ΔV_{FB}.**

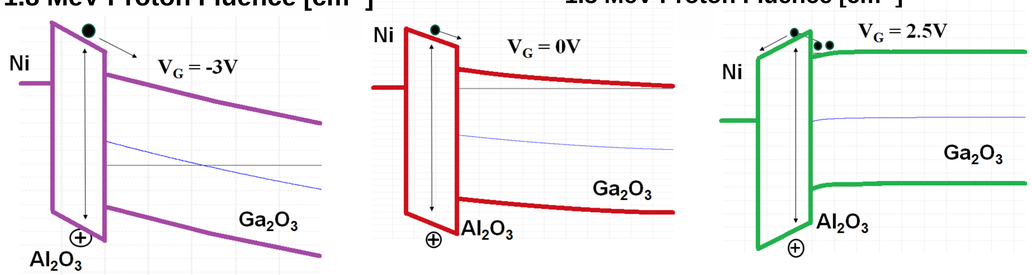
X-ray is shown to cause mostly TID, as:

- **Minimal carrier removal** (DD effects) observed, as expected.

Comparison of proton and x-ray irradiation on ΔV_{FB} with in-situ bias



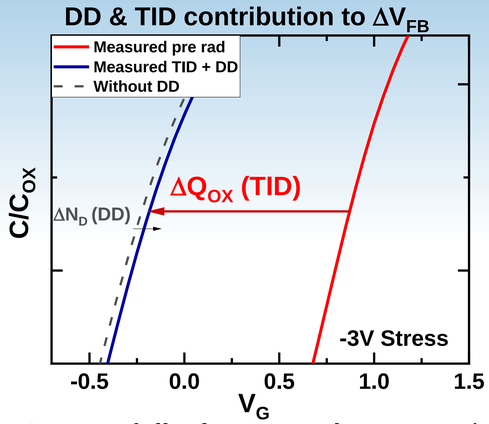




- TID effect **increases** with field strength. As higher field strength prevents recombination of ionized EHPs.
- Negligible **ΔV_{FB}** at forward bias indicates putting devices into accumulation helps mitigate TID damage.
- Equivalent amount of **ΔV_{FB}** caused by proton can be obtained entirely from X-ray within chosen dose range.
- TID caused **ΔV_{FB}** were an order of magnitude **higher** than DD.

Conclusions & future work

DD & TID contribution to ΔV_{FB}



- Impact of **displacement damage** and **TID** on Ga_2O_3 MIS devices were investigated using **proton** and **X-ray** irradiation.
- TID effects from proton irradiation were isolated and identified by comparing with X-ray irradiation results.
- TID effects from protons and x-rays **almost identical**.
- DD due to proton irradiation accounts for **< 10%** of measured **ΔV_{FB}**

In collaboration with the Sandia National Lab IBL team.

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