Gamma-Ray Irradiation Effects on Ga_2O_3 MOSFETs

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The high-voltage and high-temperature capabilities of Ga_2O_3 metal-oxide-semiconductor field-effect transistors (MOSFETs) are expected to find applications in extreme radiation environments. This paper reports the first investigation into the effects of ionizing radiation on Ga_2O_3 MOSFETs. The devices remained fully functional after exposure to a cumulative gamma-ray (γ-ray) dose of 1 MGy(SiO_2). High γ-ray tolerance was demonstrated for the bulk Ga_2O_3 channel by virtue of the MOSFETs' stable DC output characteristics against irradiation. Radiation-induced degradations in the gate insulation and surface passivation were found to limit the overall radiation resistance of these devices.

Field-plated lateral depletion-mode β-Ga_2O_3 (010) MOSFETs that showed non-dispersive output characteristics were used in this work [1]. The devices adopted a gate length, a gate width, and a gate-source spacing of 4, 200, and 5 µm, respectively, with variable gate-drain spacings (L_{GD}) of 10–25 µm and field plate lengths (L_{FP}) of 0–3 µm. ^{60}Co γ-ray irradiations with an average photon energy of 1.25 MeV were carried out in dry N_2 atmosphere at room temperature with a dose rate of 10 kGy(SiO_2)/h for cumulative absorbed doses of 10, 30, 70, 230, 500, and 1,000 kGy(SiO_2). No electrical bias was applied during γ-ray exposure.

The Ga_2O_3 MOSFETs showed no discernible degradation in the maximum drain current density (I_{DS}) or on-resistance (R_{ON}) for γ-ray irradiation up to 500 kGy(SiO_2), reflecting the absence of radiation-induced bulk traps or scattering centers in the Ga_2O_3 channel. The small hysteresis in the post-irradiation transfer characteristics was comparable to that of a pristine device. A stable threshold voltage (V_T) against irradiation indicated insignificant generation of trapped charges in the Al_2O_3 gate dielectric and/or deep levels at the Al_2O_3/Ga_2O_3 interface that would act as fixed charges. However, cumulative doses of 230 kGy(SiO_2) and above resulted in higher off-state I_{DS} by 1–2 orders of magnitude due to dielectric damage, as well as increased dynamic R_{ON} due to charging of radiation-induced interface traps in the drain access region. At the highest cumulative dose of 1 MGy(SiO_2), the devices showed a 2–4% reduction in the maximum I_{DS} with an accompanying positive V_T shift of 0.5–1 V, indicating the formation of negative charges and/or acceptor traps under the gate. Representative device characteristics before and after γ-ray irradiation are shown in Figs. 1–3.

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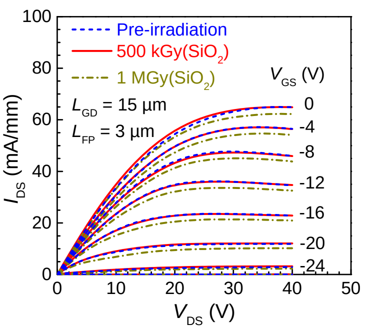

Fig. 1. Effect of 500 and 1,000 kGy(SiO_2) γ-ray irradiations on DC I_{DS}-V_{DS} characteristics of Ga_2O_3 MOSFET.

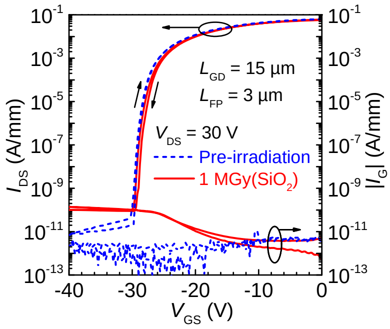

Fig. 2. DC transfer characteristics of Ga_2O_3 MOSFET before and after 1-MGy(SiO_2) γ-ray irradiation.

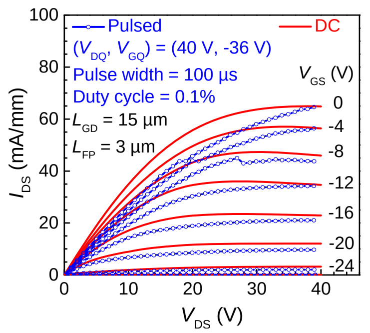

Fig. 3. DC and pulsed I_{DS}-V_{DS} characteristics of Ga_2O_3 MOSFET after 500-kGy(SiO_2) γ-ray irradiation.