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Worst-Case Scenario Analysis of TID Effects in Commercial NMOS Power Transistors

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This study investigates the influence of dose rate and total ionizing dose (TID) on the operational performance of commercial-off-the-shelf (COTS) semiconductor devices to identify worst-case usage scenarios. While radiation-hardened components offer optimized resilience, their limited availability and high cost often compel the use of low-cost COTS devices in harsh environments, such as aerospace applications. Therefore, understanding radiation-induced degradation mechanisms in these commercial components is essential.

We evaluated the radiation effects on IRLZ34N HEXFET-type NMOS power transistors through in-situ electrical characterization. The devices were exposed to 10 keV X-ray irradiation for one hour under grounded (OFF-bias) conditions, at varying effective dose rates ranging from 2.45 ± 0.2 to 100 ± 5 krad(Si)/h. Key characteristic parameters, including threshold voltage (V_{TH}), transconductance (g_m), on-resistance (R_{ON}), output conductance (g_d), and intrinsic gain (A_v), were extracted before, during, and after irradiation.

The experimental results demonstrate that TID degradation is strongly dependent on the applied dose rate rather than exposure time alone. Devices irradiated at lower dose rates (2.45 ± 0.2 and 10 ± 0.5 krad(Si)/h) exhibited minor parameter variations, indicating that charge recombination and relaxation processes effectively compensate for charge trapping within the oxide layer. The onset of measurable parametric sensitivity was observed at 31.62 ± 1.6 krad(Si)/h. Conversely, the device exposed to the highest dose rate of 100 krad(Si)/h presented the most severe degradation, characterized by significant shifts, transconductance fluctuations, intrinsic gain reduction, and an increase in. These severe effects are attributed to the enhanced accumulation of oxide-trapped charges and interface states. Ultimately, this work highlights that higher dose rates significantly accelerate parametric degradation, providing valuable insights into the qualification of low-cost COTS components intended for radiation environments.

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