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Comparative Analysis of Radiation-Induced Effects on a Commercial AlGaN/GaN HEMT

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A comparative study of the robustness of commercial high electron mobility transistors based on gallium nitride (AlGaN/GaN HEMT) under exposure to different types of ionizing radiation, including X-rays (10 keV), gamma rays (1.25 MeV), and monoenergetic fast neutrons (14 MeV). The main objective is to investigate the underlying physical mechanisms of each radiation type's interactions with the device structure, evaluating their implications on electrical properties. Through this analysis, a characterization methodology is developed to estimate transistor robustness for extreme environmental applications. To compare the semiconductor structure's tolerance to these three radiation sources, the following characteristic parameters were acquired: threshold voltage (VTH), maximum transconductance (gmmax), leakage current (Ioff), subthreshold swing (S), and channel resistance (RDSON), before, during, and after radiation exposure. Analysis of these parameters identified charge trapping and release mechanisms at device interfaces and/or oxides, primarily due to total ionizing dose (TID) effects. Additionally, changes associated with displacement damage (DD) were observed. However, no significant cross-section for single-event effects was detected, confirming device robustness against this type of radiation. The analyzed devices, model GS61008T (GaN-Systems), were irradiated in ON (biased, VG = 5 V) and OFF (unbiased) modes. Results showed excellent functional recovery after TID up to 360 krad(Si), with
lesser degradation in the ON mode. Interaction with gamma rays (60Co, 1.25 MeV) indicated combined effects of TID and DD, possibly due to Frenkel pair generation by secondary electrons from Compton scattering, whereas X-rays (10 keV) behavior was dominated by the photoelectric effect, facilitating exclusive TID effects analysis. Discrepancies in electromagnetic radiation effects prompted inclusion of fast neutron irradiation (14 MeV), revealing specific displacement damage characteristics. Results highlighted significant contribution of atomic displacement damage (DD) in GaN HEMTs degradation, emphasizing radiation source selection being crucial in device characterization and qualification. Specifically, 60Co irradiation proved suboptimal for isolated TID evaluation due to overlapping structural damage induced by DD. For specific TID studies, 10 keV X-rays are recommended, where photoelectric effect predominates, minimizing secondary scattering interference. Thus, meticulous radiation source selection is essential to ensure test accuracy and correct estimation of device robustness in critical applications.

Altas energias

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