Introduction

This work presents heavy ion and proton test data for various trench-gate power metal-oxide-semiconductor field-effect transistors (MOSFETs) ([Table I]). Devices evaluated include the first (and only) radiation-hardened trench-gate power MOSFET, as well as non-hardened commercial and both in- and out-of-pulse automotive-grade MOSFETs. Typically, x-ray testing environments for single-event effects (SEE) in power MOSFETs are established using ions with atomic number (Z) > 25 and high linear energy transfer (LET) (>25 MeV·cm²/mg) energy deposits in silicon to a depth of several microns. It is impractical, however, to thoroughly evaluate non-hardened vertical trench-gate power MOSFETs with x-ray ion data related to high-reliability chamber and short-duration space missions such as CubeSats ([Table II]). Trench-gate power MOSFETs are evaluated in both catastrophic SEE and degradation due to localized ionizing dose effects from heavy ions ([Fig. 1]). Device commercial Si7414DN is explored in this work.

Test Methods

Part Preparation

In the case of acid-etching or manufacturer-supplied unlidded devices, the sample was placed on a 2.5-cm silicon substrate. Single-Event Testing

- Gate-source voltage (VGS) held at 0 V (off-state) for most cases
- Drain-source voltage (VDS) increased by 0.5% of rated VDS before each 10 MeV·cm²/mg increment (10%)
- Post-irradiation gate stress (PGS) test performed and BVGS ramped after each run
- Other optional measurements: Gate threshold voltage (VT), drain leakage current (IDSS) & VDS voltage drop curves

Failure Criteria

- Gate current (IG) exceeding manufacturer specification during beam-run or PGS test
- BVGS failed by manufacturer specification and sudden increase in IDSS after irradiation

Test Setup

- Heavy Ion Tests ([Figs. 3-5]):
  - Decapsulation via acid-etching or manufacturer-supplied unlidded.

Results: N-Type Commercial & Automotive

The Vishay Si7414DN commercial and SQS460DN automotive 60-V MOSFETs differed in susceptibility to single-event burnout (SEB) as a function of ion species & LET ([Fig. 3-9]; Table I). Discrete increases in ID were observed in both devices, with the Si7414DN exhibiting possible lateral behavior (see Fig 9). LET = 31 MeV·cm²/mg premonitors 200-MeV proton tests performed without sufficientcapacitance ([Fig. 10]; decomposition of two common opto- (Fig. 18) whose onset VDS corresponds to the heavy-ion threshold VDS for SEE, suggesting these may be questionable SEE events.

Discussion & Conclusions

Commercial, automotive, and radiation-hardened trench-gate vertical power MOSFETs were evaluated for SEE sensitivity. The single-event test environments for the commercial and automotive-grade devices is difficult to define due to the extent of the part-to-part variability. In some cases, a broad distribution may be present. A standard radiation-hardness assurance procedure typically is a derating factor (typically 0.75, per [10]) to the highest passing VDS of the sample that failed at the lowest VDS. This approach is likely inadequate given the extent of the part-to-part variability. For example, the data in Fig. 17 suggests NTF5116P, which can be operated safely up to 17 V, the application of a single-event test at one-sided tolerance limit (KTL) to these data results in 30 V, indicating a large sample size is needed to determine the distribution of failures.

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