Silicon Carbide Power Device Performance Under Heavy-Ion Irradiation

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Abstract: Heavy-ion induced degradation and catastrophic failure in SiC power MOSFETs and diodes are examined to provide insight into the challenge of single-event effect hardening of SiC power devices.

Introduction

Fig. 1. Benefits of SiC power technology as compared to silicon.

High Thermal Conductivity

High Breakdown Voltage

Mass Savings

Table: Summary of Discrete Power Device Test Results

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Technology</th>
<th>Part/Part Type</th>
<th>Voltage (V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power MOSFET</td>
<td>Vertical, planar gate double-diffused</td>
<td>7/4 1200 – 3300</td>
<td></td>
</tr>
</tbody>
</table>

Table: Summary of Power MOSFET Test Results at 0 VGS

Discussion

Several conclusions emerge from Tables II & IV:

- SiC power MOSFETs exhibit dramatically lower SEE compared to Si devices.
- SiC MOSFETs demonstrate greater SEE robustness, with the threshold for sudden SEE in mid-voltage devices (~10x vs. Si) and lower voltage devices (~ 1/100 vs. Si) than Si devices.
- SiC power devices exhibit much lower SEE than seen in Si devices, with the threshold for sudden SEE in SiC devices being ~10 - 100x lower than that of Si devices.

References


Fig. 2. Power MOSFET response to single event effects (SEE) irradiation range from no effect to leakage current degradation to sudden catastrophic failure.

Fig. 3. Table III: Summary of Discrete Power Diode Test Results

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Technology</th>
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<th>Voltage (V)</th>
</tr>
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<tbody>
<tr>
<td>Power Diode</td>
<td>PiN</td>
<td>1200</td>
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</table>

Fig. 4. SEB at a lower fraction of rated VR.

Fig. 5. SEB at a lower fraction of rated VR.

Fig. 6. Sudden SEB at a lower fraction of rated VR.

Discussion Cont’d

In silicon power MOSFETs, SEE robustness in mid-voltage devices (e.g., 1200 V) is often reduced by elevated temperature and/or the addition of a drain resistor to dampen the drain voltage and suppress second breakdown. In Si devices, the catastrophic effect is often due to a true single-event effect, but in SiC devices, it is often due to SEE-induced thermal runaway.

Acknowledgment

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Fig. 7. Sudden SEB on SiC devices.

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Fig. 8. Sudden SEB on SiC devices.

Fig. 9. Sudden SEB on SiC devices.