Silicon Carbide Power Device Performance Under Heavy-Ion Irradiation

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Abstract: High-energy 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

This work presents high-energy data for several SiC power Mosfets and diodes in order to increase the body of knowledge that will assist with single-event effect (SEE) hardening of this technology. Specifically, dose data and Mosfet current measurements under different bias conditions, temperature, and beam conditions are presented for devices from different manufacturers or different or variations within a single manufacturer, and the emerging patterns are discussed.

Table I. SiC Power Mosfet Datasheet and the Allure of SiC Technology in the Aerospace Community

<table>
<thead>
<tr>
<th>Device Name</th>
<th>Technology</th>
<th>Voltage Rating (V)</th>
<th>Current Rating (A)</th>
<th>Maximum Power Density (W/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOSFET M1</td>
<td>4H-SiC</td>
<td>1200</td>
<td>50</td>
<td>2.5</td>
</tr>
<tr>
<td>MOSFET M2</td>
<td>6H-SiC</td>
<td>3300</td>
<td>75</td>
<td>4.2</td>
</tr>
<tr>
<td>MOSFET M3</td>
<td>4H-SiC</td>
<td>550</td>
<td>20</td>
<td>1.3</td>
</tr>
</tbody>
</table>

High-dose heavy-ion irradiation (Fig. 2) induced degradation of SiC power Mosfets and diodes is a critical issue for space applications. The high thermal conductivity and high power density of SiC power Mosfets and diodes make them attractive for use in space systems. However, the high tolerance of commercial SiC Mosfets and diodes (Fig. 1) and the high tolerance of SiC technology in the aerospace community (Table I) and the allure of SiC technology in the aerospace community are rare or non-existent. Most space applications will require SiC power Mosfets and diodes that have been hardened to SEE. The experimental data from the studies conducted here will contribute meaningfully to the growing collaboration of SiC power Mosfets and diodes to harden these devices against heavy ions and neutrons.

Results

Table II. High-Voltage Mosfet Test and Devices

<table>
<thead>
<tr>
<th>Device Type</th>
<th>Voltage Rating (V)</th>
<th>Current Rating (A)</th>
<th>Maximum Power Density (W/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power MOSFET M1</td>
<td>1200</td>
<td>50</td>
<td>2.5</td>
</tr>
<tr>
<td>Power MOSFET M2</td>
<td>3300</td>
<td>75</td>
<td>4.2</td>
</tr>
<tr>
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<td>550</td>
<td>20</td>
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</tr>
</tbody>
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Fig. 3. D4 response to Ag radiation. Left: IR degradation is proportional to fluence (Ag ions).

Several conclusions emerge from Tables II and IV:

1. Double oxide-trap set-onset voltage (VTH) for high-energy induced degradation of silicon carbide devices is similar to that of silicon devices but lower than that of silicon devices. This difference may be due to the different oxide materials used in the oxide trilayer.

Discussion

Several conclusions emerge from Tables II and IV:

1. Double oxide-trap set-onset voltage (VTH) for high-energy induced degradation of silicon carbide devices is similar to that of silicon devices but lower than that of silicon devices. This difference may be due to the different oxide materials used in the oxide trilayer.

Discussion Cont’d

In silicon power Mosfets, SEE susceptibility in silicon power Mosfets is only slightly modified by elevated temperature and/or the addition of a drain resistor to dampen the drain voltage and suppress second breakdown. In two of the six SiC Mosfets tested here, elevated temperature tests did not impact degradation or sudden SEB onset, suggesting different experimental mechanisms are involved in SiC power devices.

Acknowledgment

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References