Failure Analysis of Heavy-Ion-Irradiated Schottky Diodes

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In this work, we use high- and low-magnitude optical microscopes, infrared camera images, and scanning electron microscope images to identify and describe the failure locations in heavy-ion-irradiated Schottky diodes.

Introduction

Over the past several years, GESDC and other industries have been developing the vulnerability of Schottky diodes to destruction (non-destructive) single-event effects (SEE) [1]. During the course of the work, failure responses were observed in the diodes during the heavy-ion irradiations, and they are shown below (Figs. 1-16). The diodes used in this work were a pair of diodes used on an instrument for a specific NASA mission. The diodes were exposed to heavy-ion irradiation at a low dose rate of 1.04x10^12 ions/cm^2/s with energies ranging from 50 to 340 MeV, corresponding to a fluence range of 1x10^14 to 3x10^16 ions/cm^2. The heavy ions were chosen to simulate the fast neutron environment of a satellite [2]. The diodes were qualified to the JANTXV standard, while the IR parts were qualified to the JANSX3 standard.

Past and Analyzed

The diodes analyzed in this work were 1N6843s from two different manufacturers, Microsemi and International Rectifier (IR). These parts are dual (common cathode) Schottky diodes with a reverse voltage rating of 80 V and are commercially available. The Microsemi parts were qualified to the JANTXV standard, while the IR parts were qualified to the JANSX3 standard. The failure response is similar between the manufacturers [3]. The failure behaviors are described in detail in Figs. 1-16. The diodes were exposed to heavy-ion irradiation at a low dose rate of 1.04x10^12 ions/cm^2/s with energies ranging from 50 to 340 MeV, corresponding to a fluence range of 1x10^14 to 3x10^16 ions/cm^2. The heavy ions were chosen to simulate the fast neutron environment of a satellite [2]. The diodes were qualified to the JANTXV standard, while the IR parts were qualified to the JANSX3 standard.

Table 1: Device Information

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Device</th>
<th>Series</th>
<th>Supply Voltage</th>
<th>JANTXV/ANSX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microsemi</td>
<td>1N6843</td>
<td></td>
<td>80 V</td>
<td>JANTXV</td>
</tr>
<tr>
<td>IR</td>
<td>1N6843</td>
<td></td>
<td>80 V</td>
<td>JANSX3</td>
</tr>
</tbody>
</table>

Catastrophic Failure – SN5

The DUT was then cross-sectioned at the location of the failure identified in the flat image. The surface was polished, and a secondary electron microscope (SEM) image (Fig. 4) of the failure is shown below. A void was created through the silicon with most of the event occurring at the metal/silicon junction (Fig. 13b). When examined in the low-magnification optical image, the failure was not visible (Fig. 13b); however, when the magnification was increased, a dark spot could be seen that was the failure location in SN7 (Fig. 13c). The silicon became displaced to the surface of the diode (Fig. 13d). This filament shorts the anode (bulk silicon) to the cathode while simultaneously displacing metal from the Schottky contact.

Degradation and Failure – SN2

For DUV, even with 100% applied, no failure locations were observed in the flat images (Fig. 2a). However, when the magnification was increased, a dark spot could be seen that was the failure location in SN7 (Fig. 13c). The silicon became displaced to the surface of the diode (Fig. 13d). This filament shorts the anode (bulk silicon) to the cathode while simultaneously displacing metal from the Schottky contact. The silicon then becomes displaced to the surface of the diode (Fig. 13d). This filament shorts the anode (bulk silicon) to the cathode while simultaneously displacing metal from the Schottky contact.

Conclusions

When a Schottky diode experiences enough degradation to cause the post-irradiation electrical parameter measurements to be in violation of the specifications, the device is considered failed. In this case, the post-irradiation parameter measurements returned with violation specifications. This filament shorts the anode (bulk silicon) to the cathode while simultaneously displacing metal from the Schottky contact. The silicon then becomes displaced to the surface of the diode. This filament shorts the anode (bulk silicon) to the cathode while simultaneously displacing metal from the Schottky contact. The silicon then becomes displaced to the surface of the diode.