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, GSCF and other institutions have been observing the susceptibility of Schottky diodes to destructive (i.e., non-destructive) single-event effects (SEEs) [1-5]. During the course of this work, four responses were observed in the diodes during the heavy-ion irradiations, and they are shown below (Figs. 1-4). The diodes used in this work come from diodes used on an instrument for a specific NASA mission. During the course of this work, the diodes were subjected to heavy-ion irradiations as well as x-ray and gamma irradiations, as much as 82 ¥ under the worst case conditions, and thus, these tests caused the failure to become more visible when tested in SIMS. The results of these tests and the subsequent failure analysis on the tested DUTs are presented in this paper.

Partly Analyzed in This Work
The diodes analyzed in this work were 6843CCU3 from two different manufacturers, Microsemi and International Rectifier (IR). These parts are dual contact Schottky diodes with a reverse voltage rating of 68 V. All of the parts analyzed were operated at 68 ¥, and a reverse voltage of 50 ¥ was applied to the devices. The automated tests were performed using the NASA Furnace Beam Line (FBL). It is estimated that the bias voltage of the diode is high enough to cause the device to fail at a rate of 1 ¥ in 10 years [6].

Catastrophic Failure – SN5
The DUT was then cross-sectioned at the location of the failure identified in the beam image, and the silicon was examined. A high-magnification photomicrograph image (Fig. 14a) of the failure is shown below. The DUT failed to be observed through the beam image, and the silicon was examined at the location of the failure because the SEM image is visible in low-magnification optical image of the DUT. The failure was identified with the SEM, and it was subsequently cross-sectioned. A different approach was then taken, where the bond wires, bond pad, and Schottky barrier metal were chemically etched and removed (Fig. 14b). On the surface of the diode, a few observations were made (Fig. 14c), and these observations were identified with the SEM (Fig. 14d). The silicon was examined at the location of the failure because the SEM image is visible in low-magnification optical image of the DUT. The silicon was examined at the location of the failure because the SEM image is visible in low-magnification optical image of the DUT.

Degradation and Failure – SN2
The DUT was then cross-sectioned at the location of the failure identified in the beam image, and the silicon was examined. A high-magnification photomicrograph image (Fig. 15a) of the failure is shown below. The DUT failed to be observed through the beam image, and the silicon was examined at the location of the failure because the SEM image is visible in low-magnification optical image of the DUT. The failure was identified with the SEM, and it was subsequently cross-sectioned. A different approach was then taken, where the bond wires, bond pad, and Schottky barrier metal were chemically etched and removed (Fig. 15b). On the surface of the diode, a few observations were made (Fig. 15c), and these observations were identified with the SEM (Fig. 15d). The silicon was examined at the location of the failure because the SEM image is visible in low-magnification optical image of the DUT. The silicon was examined at the location of the failure because the SEM image is visible in low-magnification optical image of the DUT.

Conclusions
When a Schottky diode experiences enough degradation to cause the post-irradiation electrical parameter measurements to be out of specification, failure analysis appears to show that the event generates such extreme heat that the materials become molten. A filament is then created that displaces the metal into the bulk silicon and can also displace silicon to the surface of the diode.

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Failure Collection