Failure Analysis of Heavy-Irradiated Schottky Diodes

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

Introduction

Over the past several years, GECIS and other institutions have been discussing the impact of Schottky diodes to electronics (and non-destructive) single-event effects (SEE) [1-5]. During the course of this work, the parts were observed in the diodes during the heavy irradiations, and they are shown below (Figs. 1a-1c). The diodes used in this work come from devices used on an instrument for a specific NASA program. These devices are used in several different applications, including as such as 82 V under the worst case conditions. Thus, these parts needed to be tested to determine their SEE sensitivity. The results of these tests and the sub-surface failure analysis on the tested die are presented in this work.

Catastrophic Failure – SN5

The DUT was then cross-sectionalized at the location of the failure identified in the IR image, and the cross-section was imaged. A high-magnification optical image (Fig. 10a) and a secondary electron microscope (SEM) image (Fig. 10b) of the DUT are shown below. The failure location is clearly observed from the Schottky metal down through the silicon. A close-up SEM image of the failure location is shown below. The Schottky metal shorted to the diffusion via an arsenic column located in the silicon, and the Schottky metal became displaced to the surface. Like with SN5, there was a significant change in the forward I-V curve (Fig. 12b) after the beam was turned off. However, when the beam was turned back on (Fig. 12c), the failure location was no longer visible. For SN2, even with 100 V applied, no failure locations were observed in the IR images (Fig. 7a). Some or all of the column shorted to the silicon, but it was not visible in the IR image.

Degradation and Failure – SN2

The DUT is then cross-sectionalized at the location of the failure identified in the IR image, and the cross-section was imaged. A high-magnification optical image (Fig. 10a) and a secondary electron microscope (SEM) image (Fig. 10b) of the DUT are shown below. The failure location is clearly observed from the Schottky metal down through the silicon. A close-up SEM image of the failure location is shown below. The Schottky metal shorted to the diffusion via an arsenic column located in the silicon, and the Schottky metal became displaced to the surface. Like with SN5, there was a significant change in the forward I-V curve (Fig. 12b) after the beam was turned off. However, when the beam was turned back on (Fig. 12c), the failure location was no longer visible. For SN2, even with 100 V applied, no failure locations were observed in the IR images (Fig. 7a). Some or all of the column shorted to the silicon, but it was not visible in the IR image.

Degradation

The DUT is then cross-sectionalized at the location of the failure identified in the IR image, and the cross-section was imaged. A high-magnification optical image (Fig. 10a) and a secondary electron microscope (SEM) image (Fig. 10b) of the DUT are shown below. The failure location is clearly observed from the Schottky metal down through the silicon. A close-up SEM image of the failure location is shown below. The Schottky metal shorted to the diffusion via an arsenic column located in the silicon, and the Schottky metal became displaced to the surface. Like with SN5, there was a significant change in the forward I-V curve (Fig. 12b) after the beam was turned off. However, when the beam was turned back on (Fig. 12c), the failure location was no longer visible. For SN2, even with 100 V applied, no failure locations were observed in the IR images (Fig. 7a). Some or all of the column shorted to the silicon, but it was not visible in the IR image.

Conclusion

When a Schottky diode experiences enough degradation to cause the post-irradiation electrical parameter measurements to be out of specification, failure analyses are performed to identify the root cause of the damage. Because the damage occurs solely at the Schottky metalization interface, this analysis is critical. Much can be learned from this analysis. If the failure generates such extreme heat that the material becomes brittle, a failure will be seen that creates a microcrack in the bulk silicon and can also damage silicon to the surface of the diode. This damage can occur due to a number of reasons, including the voltage derating of 50% is recommended when testing will not be conducted. Testing will be conducted on the light side under the application-specific bias conditions, then a derating similar to power MOSFETs is recommended, in which the maximum reverse voltage that may be used is 75% of the last passing voltage.

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References