Analysis of the Effect of Etchpit Defects on Breakdown Voltage

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Introduction

A lot has changed since the Diode Array etchpit problem first arose six years ago, when an etchpit caused some first-electrical-test rejects at a Raytheon supplier. Advances in computing power since then present the opportunity to review the etchpit phenomenon with semiconductor process simulation software that is a powerful adjunct to the experience, intuition, and back-of-the-envelope calculations utilized before.

Raytheon, in collaboration with Silvaco, used the ATHENA-ELITE process simulator and the ATLAS device simulator to model the formation and electrical performance impact of etchpits. A cross-section of one mesa in the diode array is shown in Figure 1 for reference.

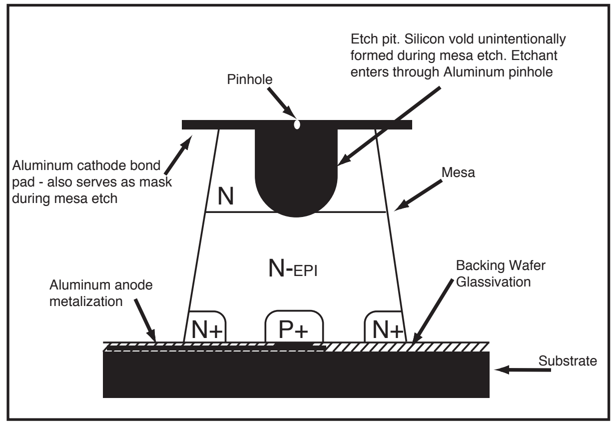

Figure 1. Schematic of Diode Array Mesa with etchpit defect

Simulated Etchpit Formation

Silvaco's ATHENA-ELITE process simulator reproduced the isotropic etch used for mesa formation on this air-isolated device. When a pinhole defect was introduced in the mesa mask, ELITE produced an etchpit which closely resembled the typical rounded etchpit shape. Compare Figure 2 (ATHENA output) and Figure 3 (actual etchpit cross-section). This simulation corroborates what Raytheon learned from the supplier's fab engineers - that a pinhole in the mesa mask can lead to formation of an etchpit.

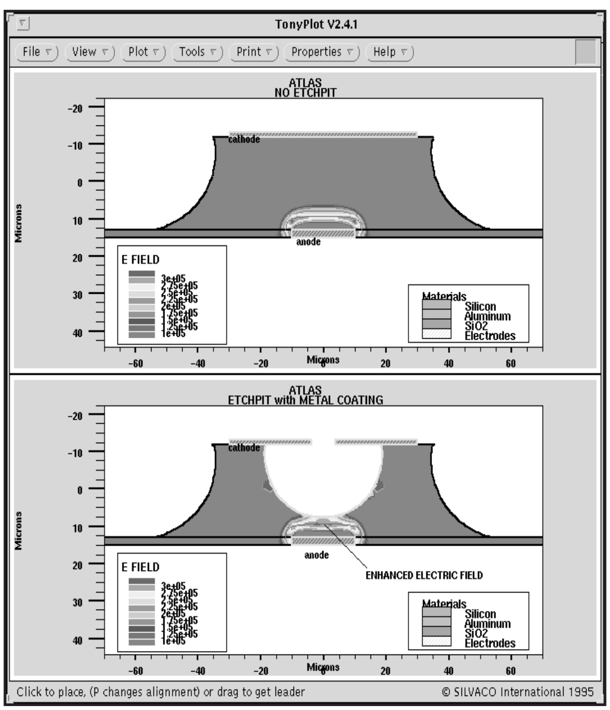

Figure 2. Electric field distribution in structures with and without etchpits.

Having successfully modeled the formation of an etchpit, the ATHENA-generated etchpit structure was handed off to Silvaco's ATLAS device simulator. Device simulators use material properties and dopant concentration to determine charge distributions, electric fields, and basic current-voltage properties of silicon structures. With ATLAS the electrical performance impact of an etchpit could be examined.

Etchpit Electrical Impact

The investigation of 1989-1990 determined that the etchpits would cause a problem when they were both filled with aluminum[1] and deep enough to reach the vicinity of the junction.

In the extreme case, deep metal-filled etchpits will short-circuit the diode junction. It was theorized that etchpits that came close to the junction, but did not touch, would cause reduced reverse breakdown voltage. Because such devices were extremely rare, however, the low breakdown voltage condition was never observed in the laboratory. Thus it became an interesting candidate for ATLAS simulation.

ATLAS simulation of the etchpit structure created with ATHENA was used to determine the reverse-bias electrical performance of diodes with both empty and metal-filled etchpits of various depths.

The significant reduction in breakdown voltage[2] caused by a metal-filled etchpit is seen in Figure 4. This simulation result confirms the reduction in device breakdown voltage theorized during the etchpit investigation six years ago.

As is evident from the figure, only the deepest etchpits reduce breakdown voltage significantly. Etchpits up to 17 microns deep have no discernable effect. At 17 microns

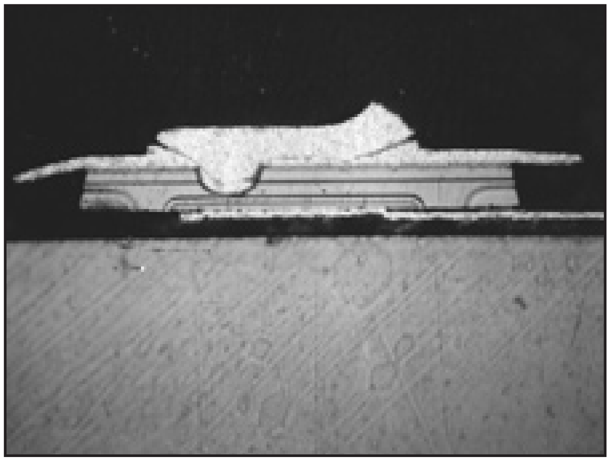

Figure 3. A photograph of a cross section of a short circuited MESA diode as a result of a pinhole.

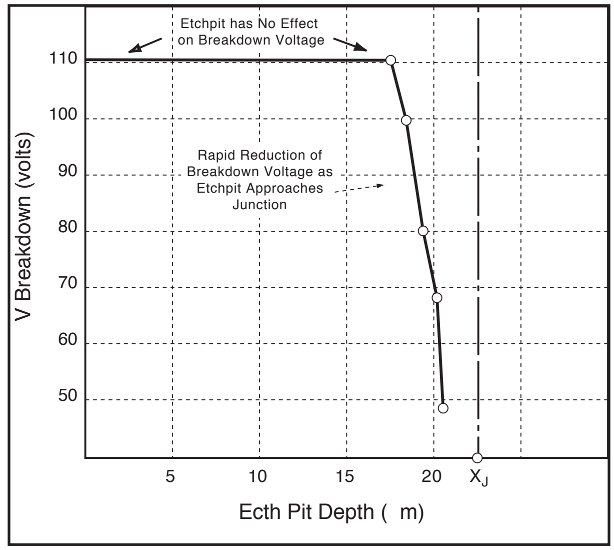

Figure 4. Breakdown voltage as a function of Etchpit Depth.

and deeper though, breakdown voltage is greatly reduced. The mechanism for this phenomenon is as follows: When the pit nears the depletion region surrounding the junction, the presence of a conductor in the pit "squeezes" the potential drop across the device. The higher e-fields which result from this squeezing increase the impact-induced carrier-generation rate, which leads to higher reverse leakage current, which in turn reduces the reverse breakdown voltage. This is shown Figure 2.

Simulation Results - Empty etchpit

Simulations showed that empty etchpits actually caused an increase in breakdown voltage. An increase of up to 20V was observed during simulation. This result will be be explored in future work.

Conclusions

Conclusions made in the '80s about the cause and effects of etchpits have been validated using Silvaco ATHENA and ATLAS process and device simulators. Further work could be performed on the diode array now that a virtual device exists. For instance, simulations could be used to determine the range of pinhole sizes necessary to create a deep etchpit. This data could then be used to examine the likelihood that such mask defects would pass visual inspection and be assembled. Also of interest would be performance of the device in the forward direction.

Notes

[1] Cross-sections of devices showed that a wire bond directly over an etchpit could fill the pit with aluminum from mesa metalization and bonding wire.

[2] Breakdown voltage was simulated at 25µA reverse current. The voltage shown in the plots should be used with care. Though the doping levels and geometries of the modeled part are close to those of the actual device, a quantitative analysis would require further refinement of the structure. Nevertheless, the approximately 115V breakdown of the simulated device is in the 100 to 120V range seen in actual devices.