GODDARD SPACE FLIGHT CENTER

Failure Analysis Report

Voltage Multiplier, Hybrid, Positive Output
Mfr.: Voltage Multipliers, Inc (VMI)
P/N: HM402P10
DC: 0228
SN: None

Investigator
C. Greenwell (562)

Project
STEREO
System
IMPACT/SWEA
Requester
A. Reyes (562)
Initiated Date
10/29/03

Background

STEREO/IMPACT Problem Report PR-6001 documented an intermittent high voltage output from the HM402P10 voltage multiplier. The failure was observed during low temperature (-70C) qualification testing. It was also noted that the output recovered while coming back to ambient temperature. The HM402P10 device was replaced and qualification testing down to –70C was repeated with no anomalies.

Additional investigation revealed that the assembly with the voltage multiplier was temperature-cycled several times down to –70C, and that the intermittent failure was eventually present even at ambient temperature, and that it was also intermittent at ambient temperature.

The device was submitted to the GSFC Parts Analysis Laboratory for failure investigation.

Part Description

The HM402P10 is a hybrid assembly, positive output, voltage multiplier that converts an AC voltage input into a DC voltage output. This particular device accepts up to 900V peak-to-peak at 20-100kHz input and produces up to 4000Vdc at 200uA output.

The device is constructed with an alumina substrate/base-plate, two monolithic, segmented capacitors and 10 discrete surface mount diodes interconnected with 1.5 mil (0.0015 inch) aluminum wires. The assembly is encapsulated with a glass-filled epoxy material similar to that of common plastic encapsulated microcircuit (PEM) devices. Three external leads, GND, VIN and HV(out) are soldered to pads on the alumina substrate.

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Manufacturer:	VMI	Date Code:	0228

Analysis and Discussion

External examination revealed a small round anomaly in the potting material near the VIN lead. This feature was not an artifact or cause of failure. The package had a hand-written "X" marked across the top surface, possibly identifying it as bad. Figures 1 and 2 show external views of the device.

Radiographic inspection revealed no anomalies but did reveal many construction features previously described. As expected, the aluminum interconnect wires were not visible in radiographic inspection. Figure 3 shows top and side view radiographic images of the device.

Electrical testing showed the device was non-functional. An input of up to 60Vp-p at 20 to 50 kHz produced only a 1Vp-p ripple voltage output at the input test frequency. Testing over a temperature range was not performed.

Due to the failure mode and the device construction it was decided to use oxygen plasma ashing to deprocess the device. This process is very slow but introduces no artifact. It does, however, remove organics, making the possibility of revealing foreign material and contamination unlikely. Alternatively, chemical deprocessing is likely to produce artifacts and destroy evidence of foreign material and any contamination present.

The potting material was removed until the tops of the diodes were visible. At this point, compressed air necessary to remove the ash inadvertently broke several wires bonded to the diodes. Figure 4 shows the device at this stage of deprocessing.

Importantly, optical inspection showed that the aluminum bond wire at diode D9 had lifted from the bonding surface instead of breaking at the neck-down region, as expected for adequately-bonded wires. Figures 5 and 6 show these results. The wire and diode were examined using energy dispersive spectroscopy (EDS). This technique revealed very little alloying of the aluminum and gold, indicating that a poor bond existed at this location. Figures 7 and 8 show the x-ray dot maps of gold and aluminum for these interface surfaces.

As previously mentioned, all the other wires that broke during deprocessing broke at the wire neck-down and left a bond wire "foot" present at the diode. Figures 9 through 11 show several examples of this expected result.

Conclusion

It appears most likely that the cause of intermittent failure of the HM402P10 voltage multiplier observed by the STEREO/IMPACT/SWEA team was the result of a poor wire bond at diode D9 that lifted due to thermal expansion and contraction of the molding material. The wire bond was defective at manufacture, and its subsequent fracture and failure was exacerbated by temperature stress.

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Appended Images:

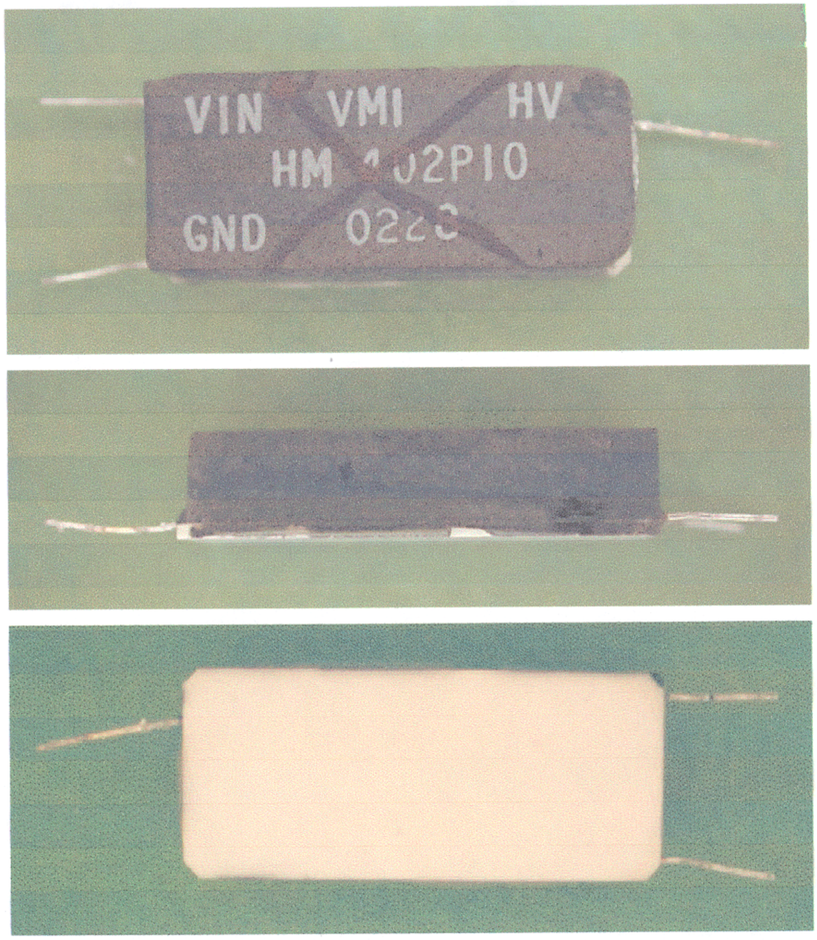

Figure 1. External views of the VMI HM402P10 hybrid voltage multiplier.

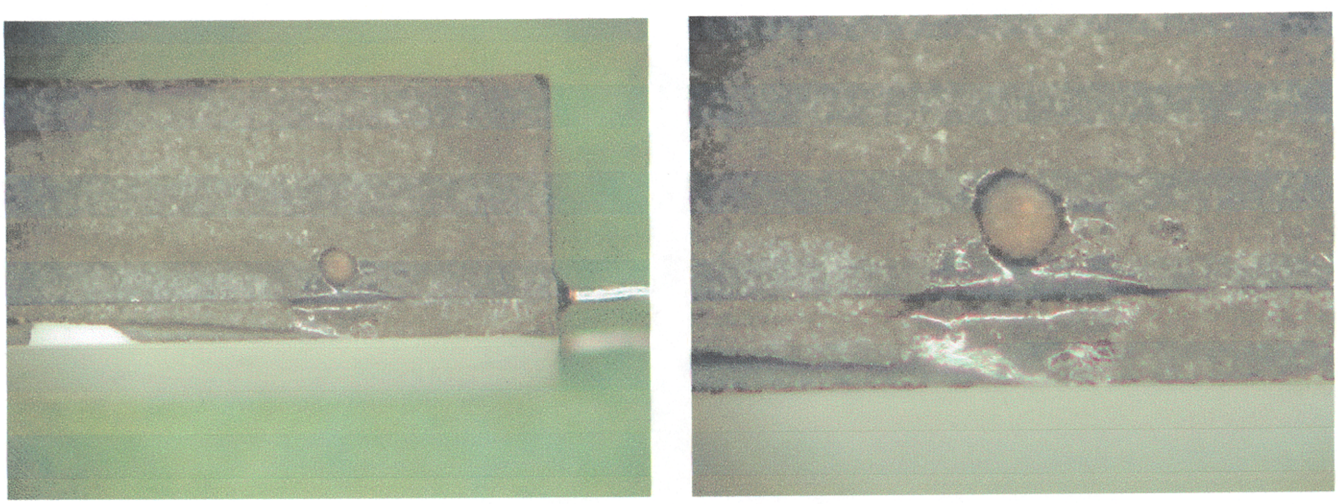

Figure 2. Anomaly in the potting material near the VIN lead.

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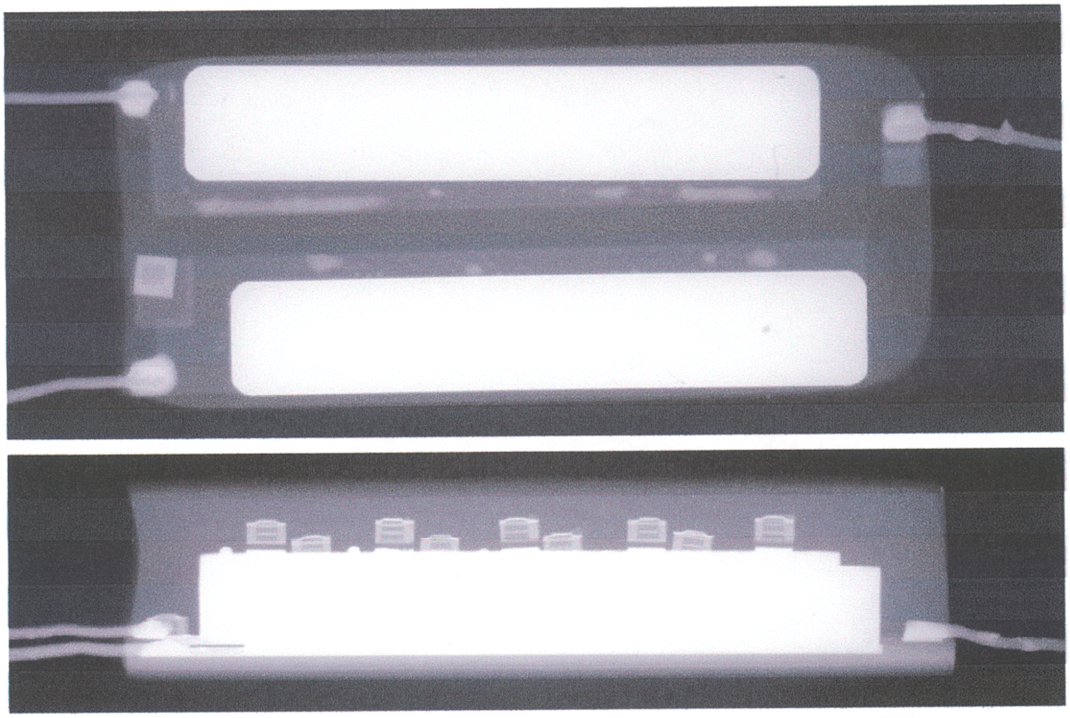

Figure 3. Radiographic images of the HM402P10 device. The large rectangular white objects are two monolithic segmented ceramic capacitors. Nine discrete surface mount diodes are mounted on the capacitors and one is mounted on the substrate near the GND lead.

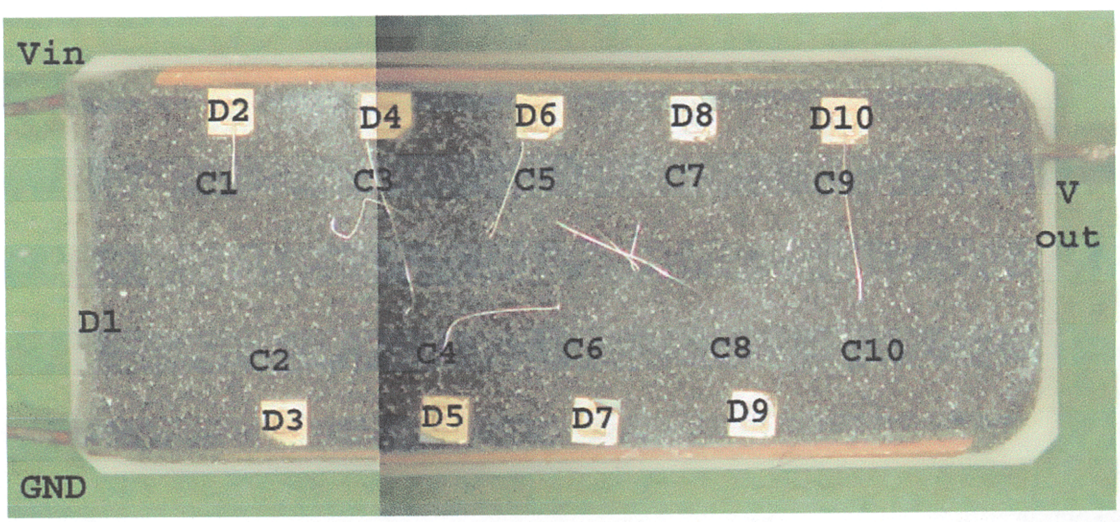

Figure 4. This view shows the device at an intermediate deprocessing stage. The tops of the diodes are revealed (except D1). The aluminum bond wires were inadvertently broken due to the blow-off process necessary for residue removal after oxygen plasma ashing.

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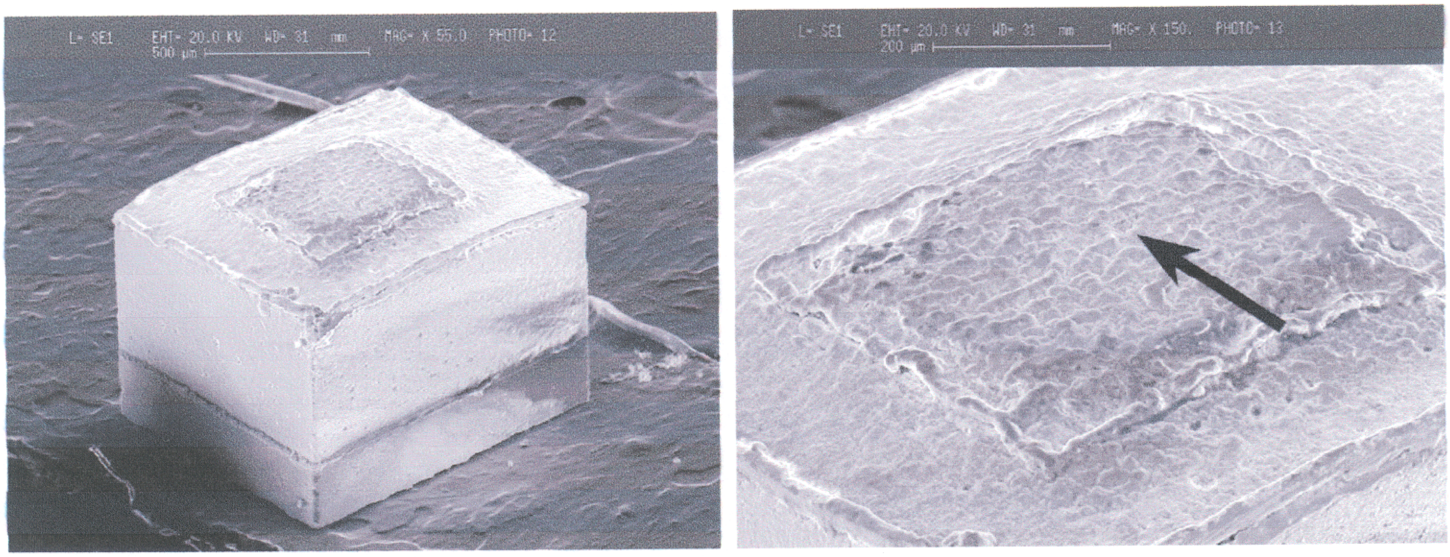

Figure 5. SEM views of diode D9 after removal from the assembly. The arrow in the right image points to where the aluminum bond wire was located on the diode.

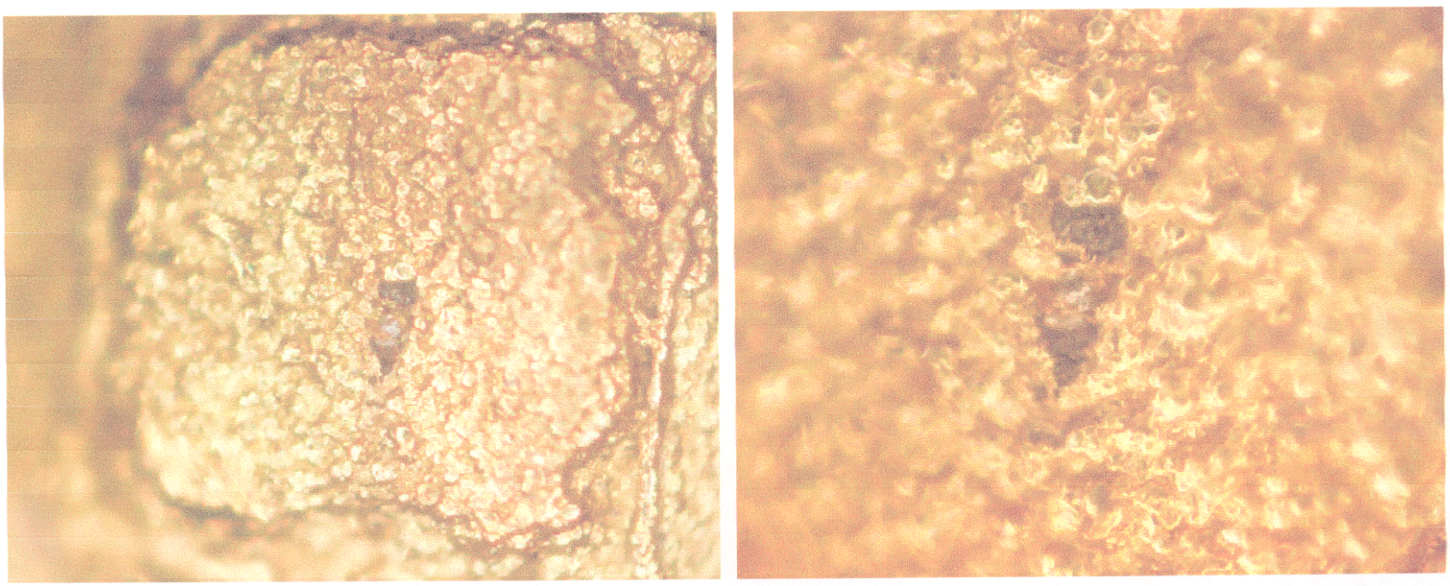

Figure 6. Optical images taken prior to removal of D9 from the assembly show the same area and the remaining wire bond foot-print on the gold plated surface.

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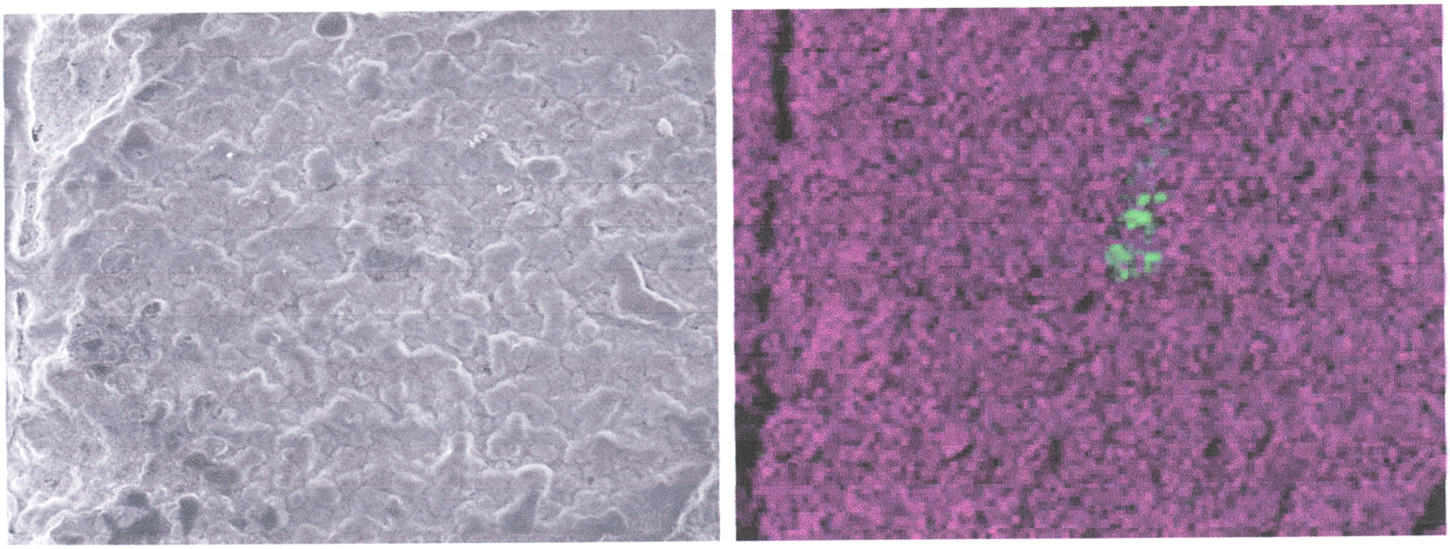

Figure 7. SEM and EDS x-ray dot map images of the diode surface where the aluminum bond wire was attached on D9. In the dot map at right, purple represents the element gold and green represents aluminum.

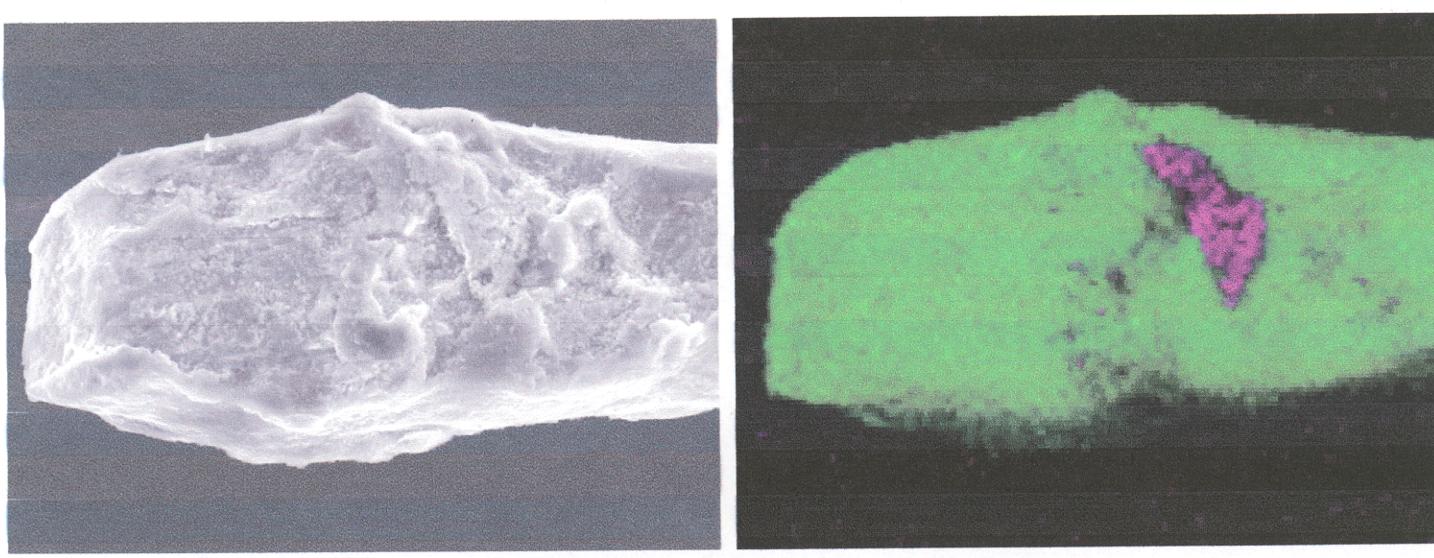

Figure 8. Images of the matching surface of the D9 aluminum bond wire. The surface shows insufficient alloying of aluminum-to-gold and gold-to-aluminum.

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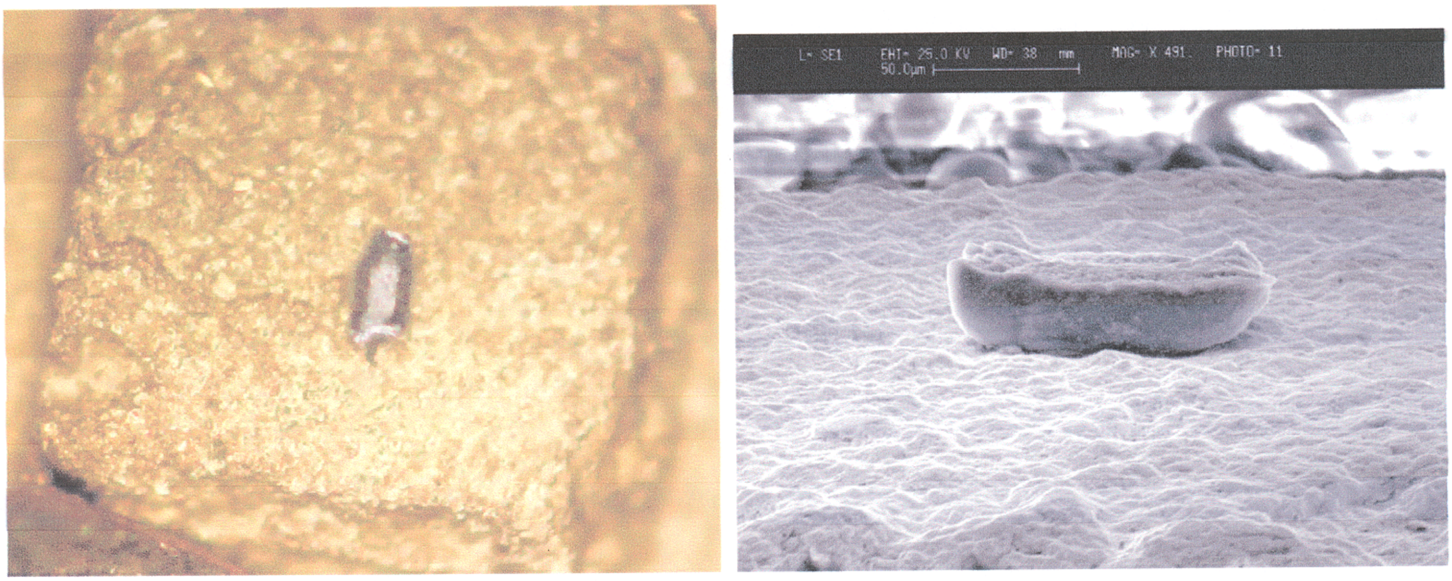

Figure 9. For comparison, optical and SEM images of the wire bond "foot" present on diode D7 are shown above.

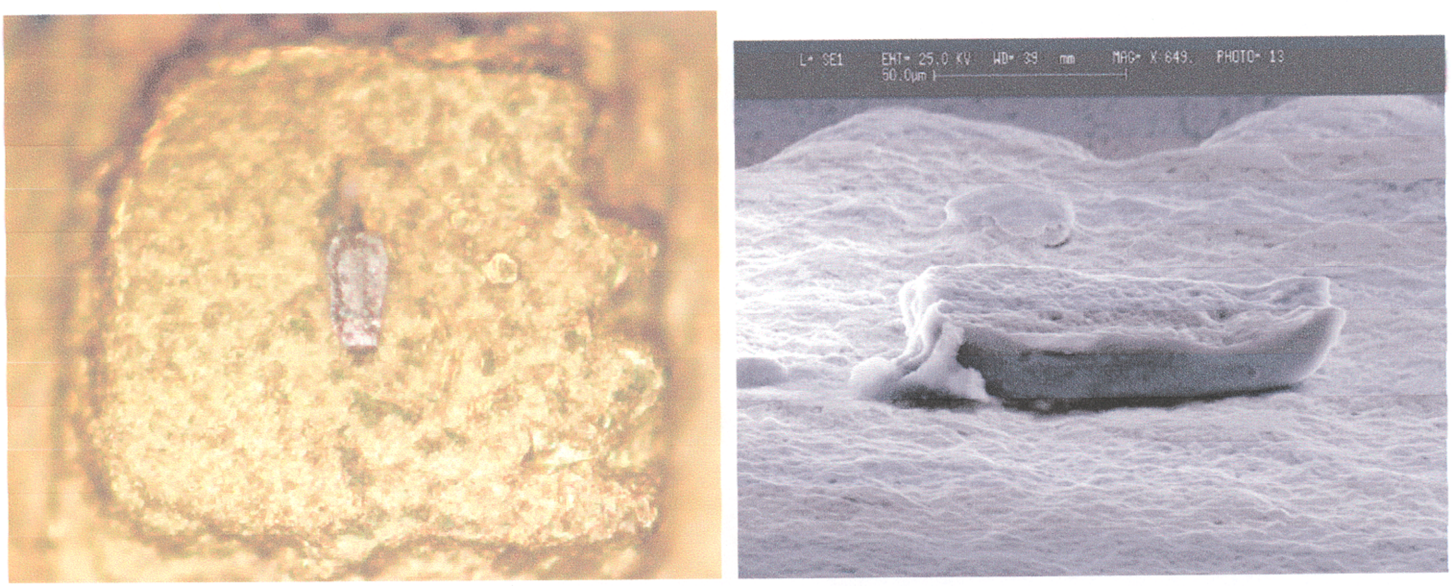

Figure 10. Optical and SEM images of the wire bond "foot" present on diode D8.

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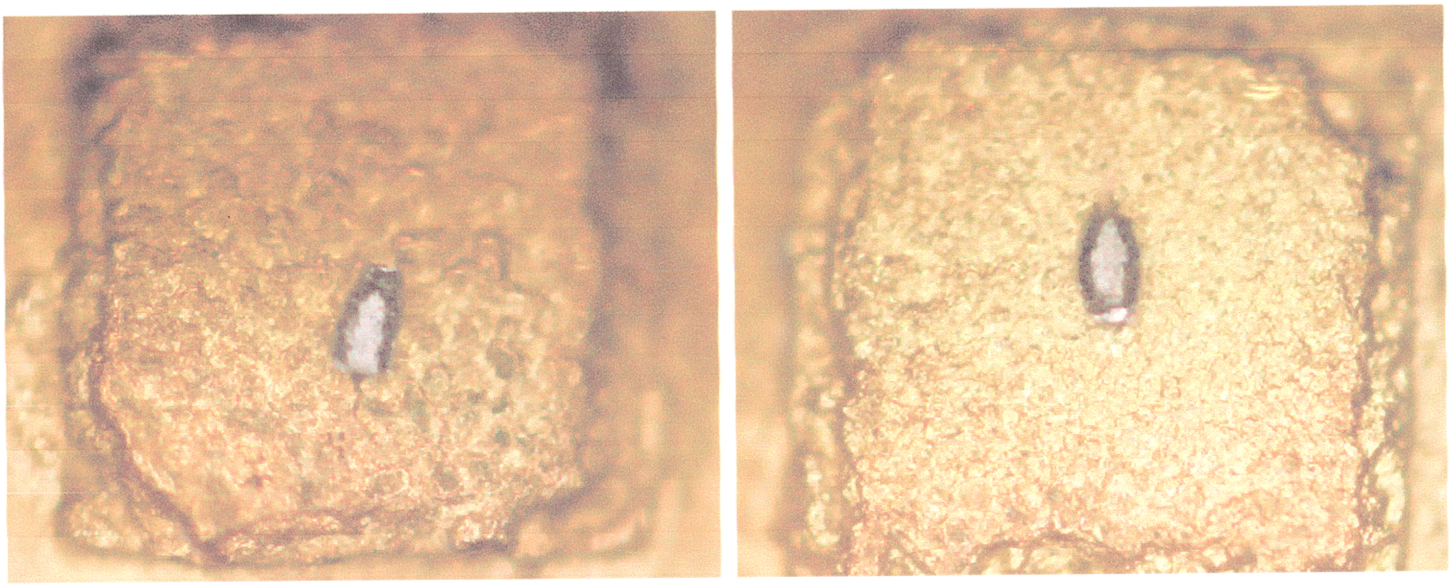
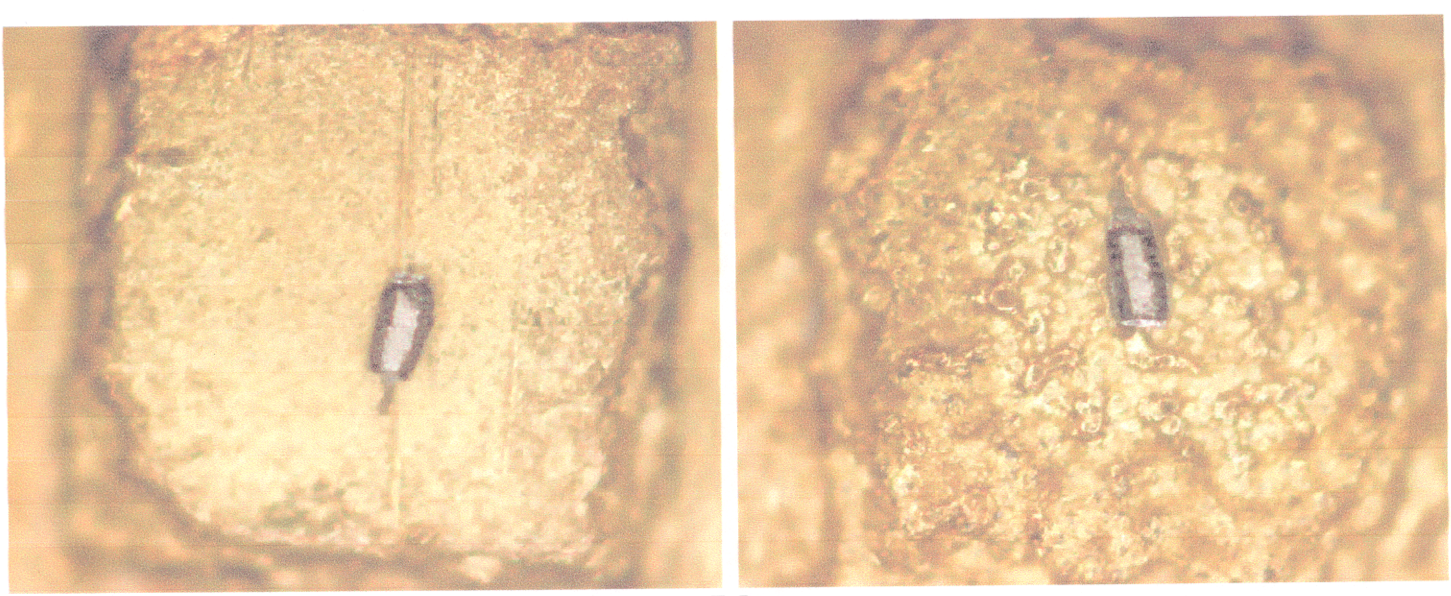


D3
D4



D5
D6

Figure 11. Optical images showing bond "foot" remnants on diodes D3, D4, D5 and D6.