Goddard Space Flight Center

GSFC NASA ADVISORY

1. Advisory Number
NA-GSFC-2004-01

2. Subject
Indium Solder Encapsulating Gold Bonding Wire Leads to Fragile Gold-Indium Compounds and an Unreliable Condition that Results in Wire Interconnection Rupture.

3. Manufacturer
N/A

4. Manufacturer CAGE Code
N/A

5. Federal Stock Code
N/A

6. Part/Material/Process Number
N/A

7. Lot Date Code/Batch Code/Serial Number
N/A

8. Controlling Spec/Document Number
N/A

9. References
N/A

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11. Problem Description and Details:

A NASA GSFC satellite recently experienced cessation of laser beam activity for a laser after 36 days of on orbit operation. This was attributable to a laser diode failure. The laser diode root cause failure mechanism was the degradation of the gold bond wires by indium solder. At the interface region of gold and indium, the gold bond wires were transformed to fragile gold-indium intermetallics, which eventually resulted in an electrical open after a number of thermal cycles.

See page 2 for the gold-indium intermetallic degradation mechanism and the laser failure mechanism.

See page 3 for Figures 1 and 2. Figure 1 depicts the diode array gold wire bonds that are immersed in indium solder. Figure 2 is a magnified view of Figure 1, which illustrates the gold wire bonds encased in indium.

See page 4 for figures 3 and 4. The University of California, Lawrence Livermore National Laboratory, and the Department of Energy under whose auspices the work was performed provided Figure 3 that illustrates the growth of gold-indium intermetallics at room temperature. Dr. George G. Harman of the National Institute of Standards and Technology provided Figure 4, which depicts gold-indium intermetallics that formed after terrestrial stress testing at the gold wire bond to indium metallization interface of a GOES weather satellite IR detector.

12. Action Recommended:

1) All flight projects should perform a Destructive Physical Analysis (DPA) on a representative sample of laser diodes and detectors to inspect for the presence of indium in contact with gold.
2) All flight projects should review their projects to ensure that any gold wire (e.g. gold wire bond) is not in contact with indium or an indium alloy (i.e. indium solder).

13. Technical Point of Contact

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14. Date Prepared
Sept. 23, 2003

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16. Released by: *(Signature)*
Original signed by
GSFC NASA Advisory Coordinator

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17. Date Released
October 2, 2003

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11. Problem Description and Details: *(Continued from page 1)*

Gold-Indium Intermetallic Degradation Mechanism:

Indium reacts with gold to form a succession of gold-indium intermetallic compounds. Consequently, the original gold mechanical and thermal properties are degraded by this intermetallic reaction. The brittle gold-indium intermetallics cause an unreliable electrical interconnection. An electrical open can occur if there is an interconnection rupture of the fragile intermetallic region. The intermetallic rupture could occur as a result of thermal cycling.

The Goddard Materials Branch has demonstrated that the gold-indium intermetallic formation occurs significantly even at room temperature and at an enhanced level at elevated temperatures. The volume of the gold-indium intermetallic section occupies approximately four times the original volume of the consumed gold. Figure 3 is a cross-section of the gold wire with a formation of gold-indium intermetallics, which shows that a similar volume increase occurred after about 90 months at room temperature.

Laser Failure Mechanism:

As illustrated in Figure 1, the gold wire bonds of a diode array are immersed in indium solder. This indium solder was used as the attachment material to secure adjacent diode arrays. Apparently, in the assembly process, the indium solder reflowed into the wire bond region and encapsulated these wire bonds in the process. When the molten indium solder encapsulated the gold wire bonds, there was a rapid growth of gold-indium intermetallics. Afterwards, the intermetallic growth continued but at a slower rate. The brittle intermetallics eventually fractured due to fatigue failure after a number of thermal excursions. After fracture of a given wire, the remaining wires conduct more current, thereby accelerating the thermal excursions. When enough wires fracture, the remaining ones melt; the last ones vaporize. During gold wire vaporization, a multi-amp current results which causes the given laser diode array to destruct. Since the laser diode arrays are connected in series, the destruction of one diode array results in an inoperable laser.

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Figure 1 Gold wire bonds immersed in indium solder on diode array bar.

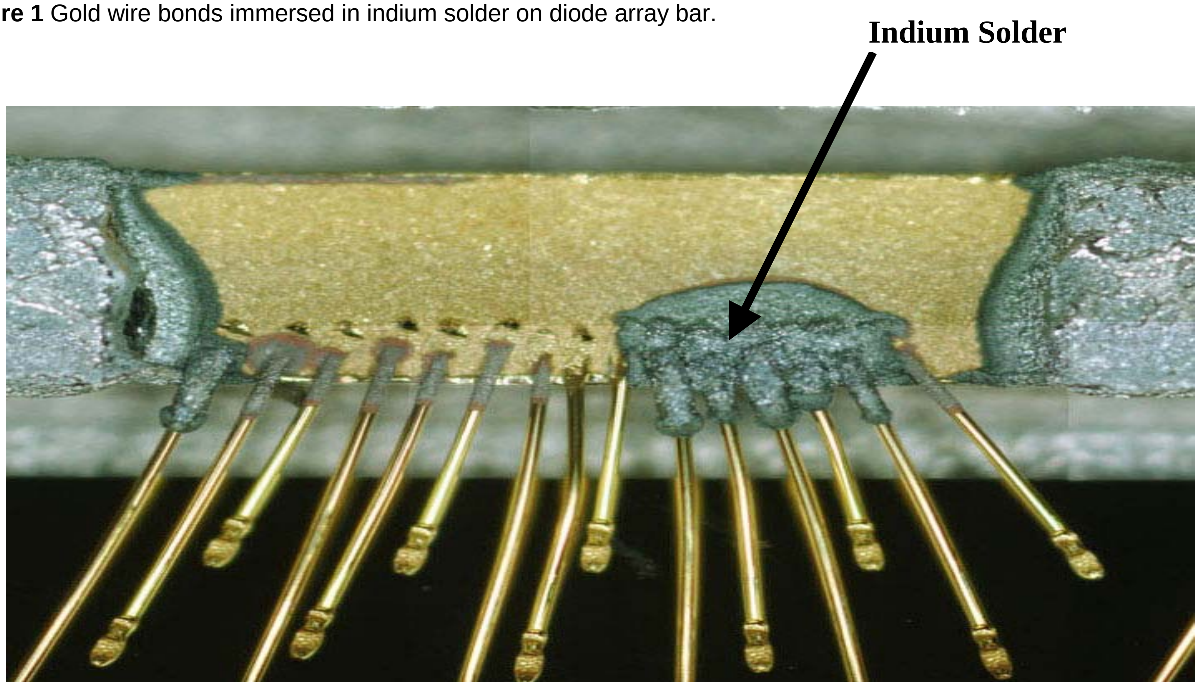

Figure 2 A close up view of the gold wire bonds encrusted with indium on the diode array. The encrusted gold has been transformed into a gold-indium intermetallic that is mechanically brittle.

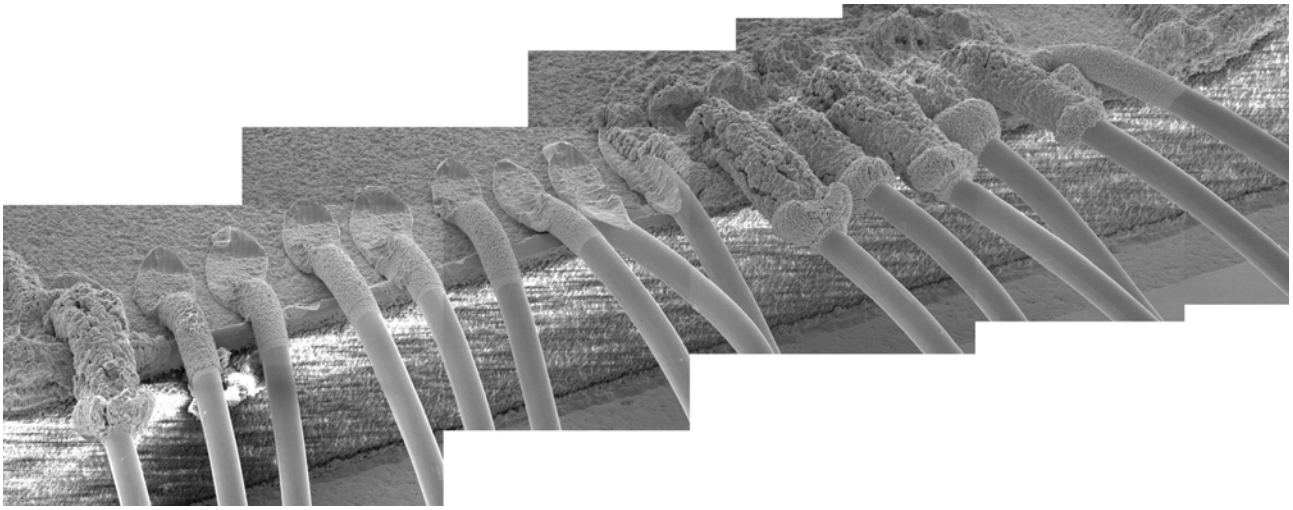

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Figure 3 Photo (Gold wire cross-section surrounded by indium) is courtesy of the University of California, Lawrence Livermore National Laboratory, and the Department of Energy under whose auspices the work was performed. Arrows and dotted line are added to illustrate how the original gold wire has shrunk in diameter and also shows the development of an intermetallic compound section that has grown after approximately 90 months at room temperature.

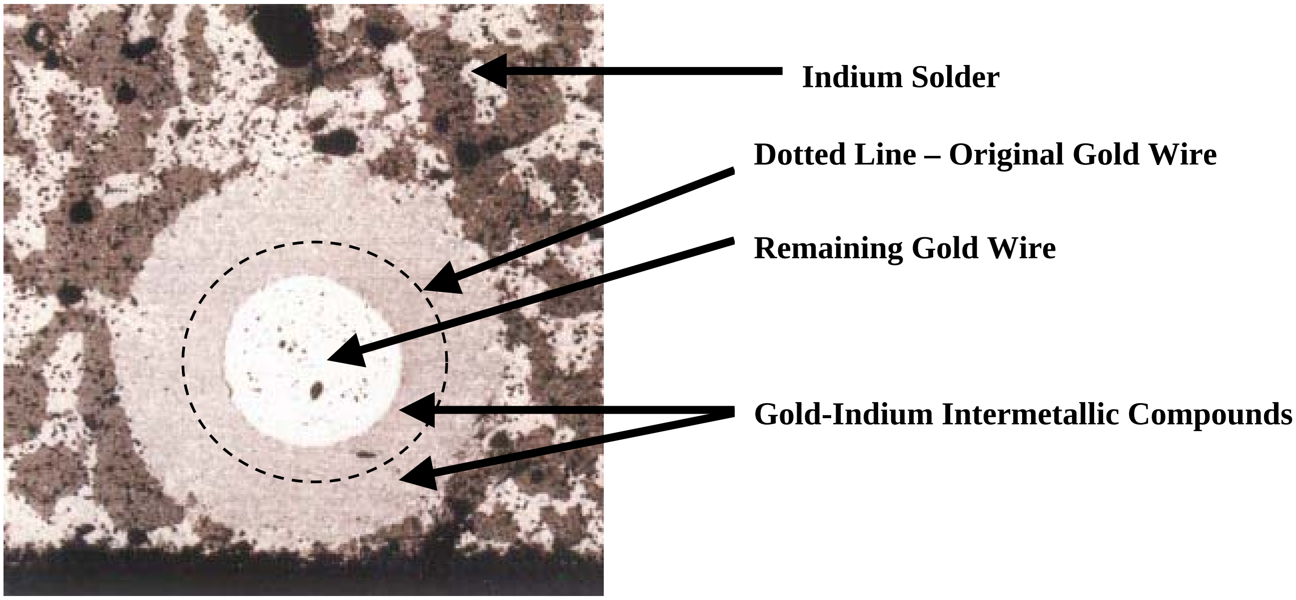
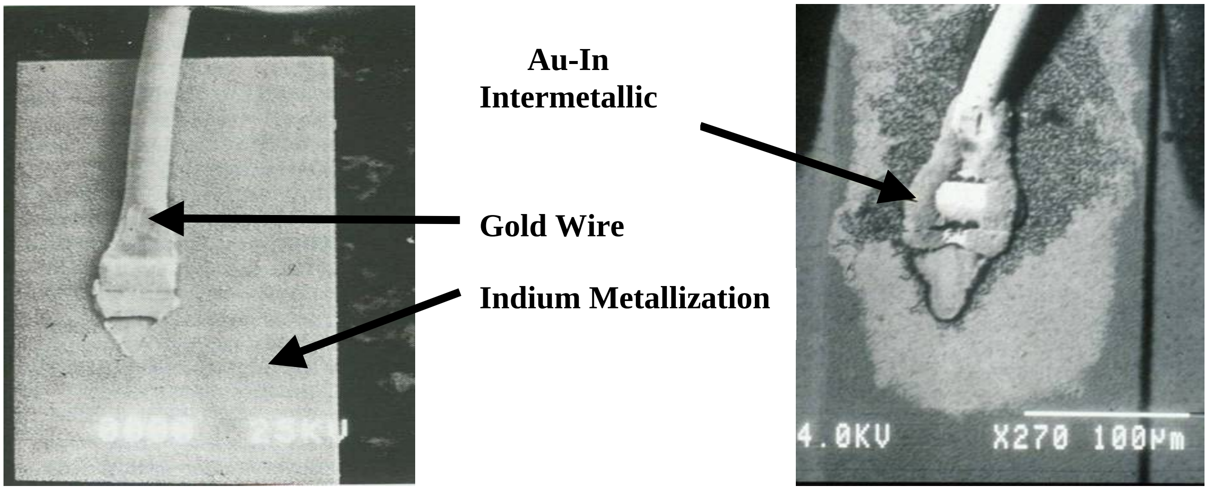


Figure 4 Photos are courtesy of Dr. George G. Harman of the National Institute of Standards and Technology (NIST).
GOES HgCdTe, 77K, IR detector (Wire is Gold, Pad is Indium: Intermetallics are Obvious!).
Low-Temperature Space Devices may be Damaged during Terrestrial Stress-Testing.



Before Stress Testing **After Stress Testing**