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Indium Solder Problems [1]

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Indium solders are increasingly being used in a variety of applications because of their low melting temperatures, excellent bonding, and lack of lead but their use can present problems for both analysts and customers. These solders, either pure indium or indium alloyed with other metals, allow for the joining of thermally delicate materials, such as electronic components, with essentially no worries about thermal damage or environmental concerns associated with lead. Problems arise from several of the properties of indium including its softness, its ability to alloy with other metals, and the very thing that makes it valuable, its low temperature melting point.

In the recent past, I and some of my colleges have been asked to study/analyze solder joints which utilize indium but we have all run up against insurmountable preparation problems. In the normal course of preparing cross-sections, one would expect to cut the specimen with a diamond saw, grind with increasingly finer grits of silicon carbide, and polish with diamond, alumina, or colloidal silica. But, indium is extremely soft and all the various particles mentioned above as well as sawing debris will tend to become embedded in the indium. In addition, intermetallic compounds (IMC's) or harder alloy components in the solder will be concentrated on the cross-section surface as the softer indium is polished away. The longer one polishes the specimen, the more contaminated it will become. A classic case of this concentration of hard particles is illustrated in a recent paper discussing the use of indium to bond gold-plated parts [2]. Using the phase diagram supplied by the authors, the description of the pre-heated joint, and their calculation that the joint would contain 10 wt. % Au and 90 wt. % In, one can determine that the solder would contain about 25 % $AuIn_2$ IMC. The SE image supplied shows a polished surface with about 95 % IMC grains. Clearly, the softer, pure indium has been polished out and the harder, IMC grains concentrated.

Newer technologies like Focused Ion Beam sample preparation would seem to be the answer but this is not necessarily true. Because of the problems associated with traditional preparation, a couple of my colleagues (P. G. Kotula and J. R. Michael, pers. com.) tried to cut a FIB section through a Sn-In solder joint. The thin slice produced was highly porous. Like most FIBs, their instrument uses gallium ions. The In-Ga phase diagram reveals that the eutectic temperature is 15.7° Celsius (60.26° Fahrenheit). The indium rich areas alloyed with gallium, melted, and leaked out of the sample. FIB's using ions other than gallium may work but these also must be investigated carefully.

Indium has a strong affinity for gold and this is used to advantage in many applications where gold platings are applied to aid the bonding of parts. But this affinity may cause loss of joint integrity if any of the gold plated surfaces represent an "infinite" supply of gold for the formation of $AuIn_2$. This IMC will form immediately on melting of the indium solder and continue to grow rapidly even at slightly elevated temperatures [3] thus draining the indium from the solder joint region. Figure 1 shows cross-sectioned Ga-As laser diode chip soldered to a gold plated copper heat sink. Repeated thermal testing of the part caused the indium in the solder joint to react with the extensive gold plating on the copper heat sink and drain out of the joint (Fig. 2). The resultant loss of thermal conductivity caused the part to fail.

References

[1] This work was conducted at Sandia National Laboratories, a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under Contract DE-AC04-94AL85000.

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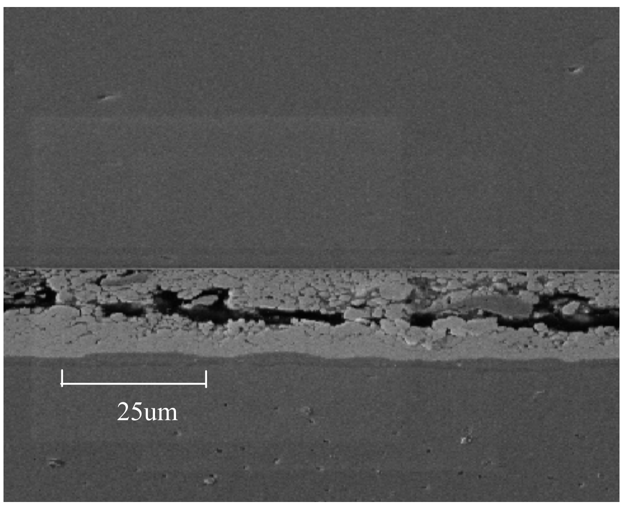

Fig. 1. SE image of an In solder joint where the In has drained out to react with excess Au plating.

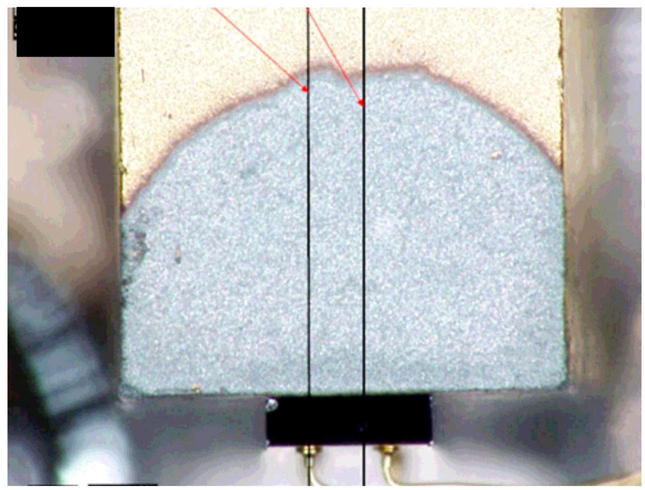

Fig. 2. Optical image of $AuIn_2$ salient formed by reaction of the In solder and excess Au plating. The In came from the bond between the chip at the bottom of the image to the Au-plated Cu heat sink.

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