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Focused Ion Beam Characterization of Low Melting Point Metals at Cryogenic Temperatures

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The high fusibility of low melting point metals makes them vital for a variety of technological applications such as electroplated and evaporated indium (In) solder bump interconnects in heterogeneously integrated devices. In is often used for these types of applications as it has a low melting point of 156°C, but characterization challenges associated with indium have limited a full understanding of its microstructure and thus behavior in associated devices. In particular, cross sectional milling of indium solder bumps using a Ga^+ focused ion beam (FIB) at room temperature has resulted in the creation of voids and thus inaccurate characterization. Manipulating the milling technique by decreasing the ion beam overlap from a typical 50% overlap to non-overlapping milling points can greatly reduce the voids and artifacts but does not fully remedy the problems and requires a trial-and-error approach. Development of reliable and reproducible cross sectional milling techniques is crucial to understanding of the process/property relationships in important low melting point metals.

One theory for the problems observed is that Ga and In create a eutectic composition, [1] and if that were the case, one would not expect the same artifacts in samples milled with the Xe^+ plasma beam. In this work, we first duplicated the previous efforts at room temperature using a 30kV Ga^+ ion beam with a cleaning cross section milling pattern to rough mill at 9.3nA followed by a 0.79 nA cleaning and a 0.43nA polish. This produced the expected voids in the sample as displayed in Figure 1(a). Secondly, we used a 30kV Xe^+ plasma ion beam with a cleaning cross section milling pattern to rough mill at 200nA followed by 60nA and 15nA surface polishing. Again, this produced voids in the sample - shown in Figure 1(b) - indicating that the Ga^+ beam is not the culprit of voiding. Lastly, the sample was mounted on a Aquios cryostage in a ThermoFisher Helios 5 Laser PFIB. The sample was cooled to ~-150C and stabilized for ~60 minutes prior to milling using the same Xe^+ milling parameters as with the room temperature test. In all the samples milled with these conditions, there were no voids identified as illustrated in Figure 2. In addition, In microstructures could be readily identified. We surmise that the ion beam is locally heating the indium and possibly increasing the sputter yield [2]. Additionally, the prevalence of voids at the interface material could be the result of increased ion scattering or poor heat transfer issues. Cryogenic temperature milling of low melting point metals is a reliable solution to the ability to prepare cross sections that are representative of the sample [3].

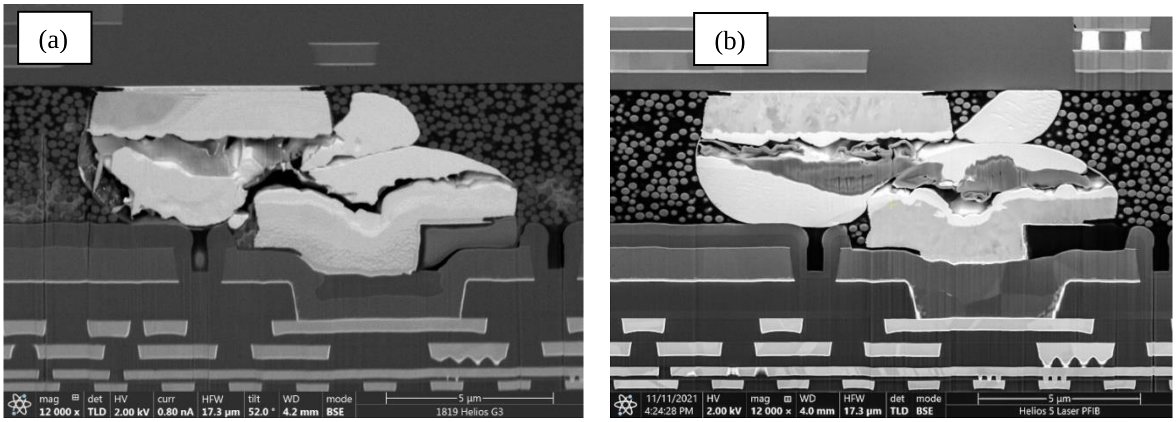

Figure 1. Void formation at room temperature using Ga^+ (a) and Xe^+ Plasma (b)

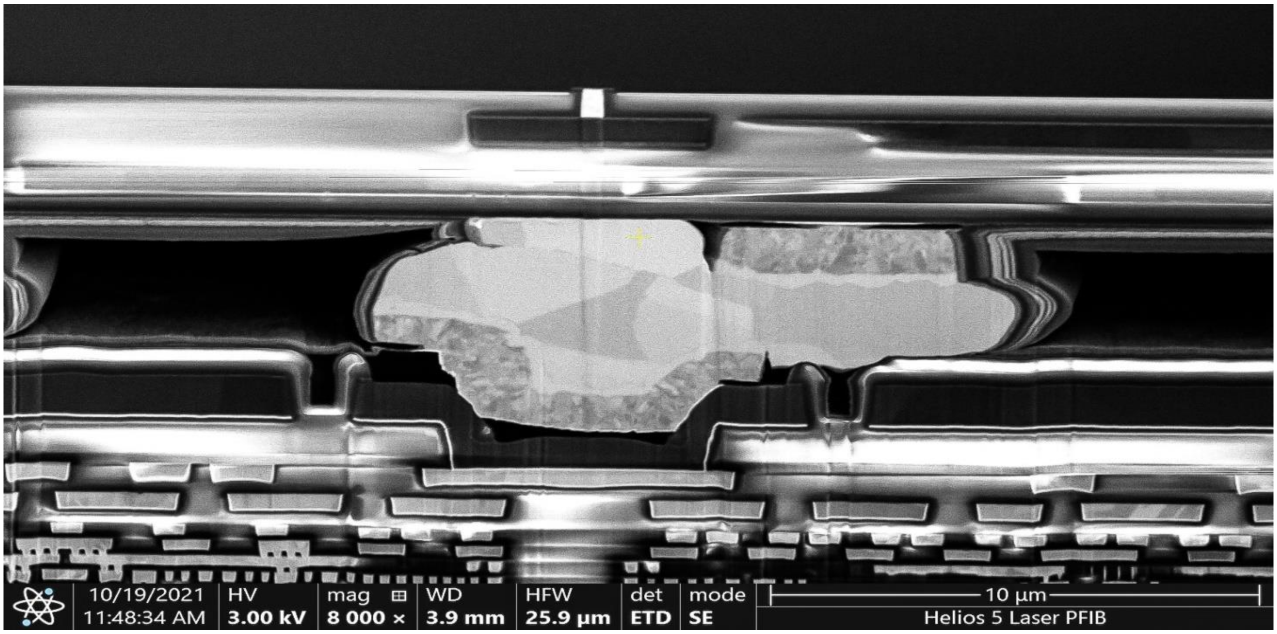

Figure 2. Indium bump milled with plasma beam at -150°C

References:

[1] LD de Morais, S Chevalliez and S Mouleres, Microelec. Reliability **54** (2014), p. 1802.
[2] RS Nelson, Philosophical Magazine **11**(110) (1965), p. 291.
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