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Microstructure Enhancement Using Ion Beam Milling

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Microstructure analysis, typically a key component of any failure analysis, relies on optimum sample preparation to produce reliable data. However, sample preparation has become more challenging in recent years due to high-technology materials, complex assemblies, and smaller components. Although mechanical cross sectioning, polishing, and chemical etching are sufficient for many applications, broad-beam argon ion milling (AIM), using high-energy ion bombardment to remove material or modify the surface of a specimen, provides an additional level of quality and clarity for critical and difficult-to-prepare samples for SEM and light microscopy inspection.

With the ion gun directing energetic argon ions toward the specimen at a low angle of ion incidence with respect to the sample surface, material is gradually removed at the atomic level - cleaning and polishing the sample. This technique is especially useful for multiphase materials with low hardness or soft constituents that present a challenge to obtain undeformed, scratch-free, flat specimens by mechanical polishing. Polishing by ion milling at low-angles produces flat surfaces with no deformation or other disturbance of the material microstructure. Figure 1 shows tin plating on a copper substrate with an intermetallic layer and very thin copper oxide layer under the tin.

Surface modification to produce contrast or microstructure can be realized with higher milling angles up to 90°. This provides a great advantage for medical devices and other components consisting of noble metals, like gold and platinum, or corrosion-resistant alloys bonded to less noble metals, which are frequently difficult or impossible to prepare with chemical etching. Figure 2 compares traditional preparation of a tantalum-stainless steel weld joint where the fusion zone microstructure is obliterated during etching to a microstructure clearly resolved after ion milling. Microstructure contrast with ion milling is also useful or extremely fine structures that can be obscured by chemical etching.

For failure analysis, the ion mill produces specimen surfaces with no chance of smearing over cracks or other fine flaws. Figure 3 shows very fine cracks at the fusion boundary of a laser weld joining dissimilar metal alloys. The ion milling also eliminates potential contamination at flaws that could be introduced during mechanical polishing. The substrate surface flaws in Figure 1 contain silicon oxide, which could be mistaken for polishing media residue if the sample had been mechanically polished.

Additionally, the ion mill can be used to directly prepare cross sections by cutting through a sample with the argon-ion beam. This is effective for samples that are difficult to section mechanically, such as semiconductors, multi-layer structures, or material combinations with large hardness differences. Multi-layer structures are revealed without the distortion that can occur with mechanical polishing, and sections are located with high accuracy on microscopic components.

Finally, the ion mill can be used f to expose internal component layers for failure analysis. Since material removal parameters can be closely controlled with ion milling, subsurface conditions can be revealed with significant mechanical damage or chemical attack. Typical uses of this technique are exposure of surface contamination on packaged integrated circuits and flaws under plating layers on printed circuits.

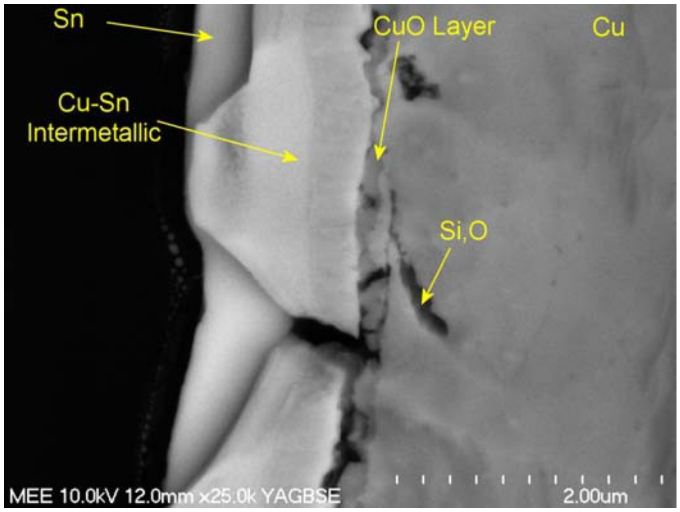
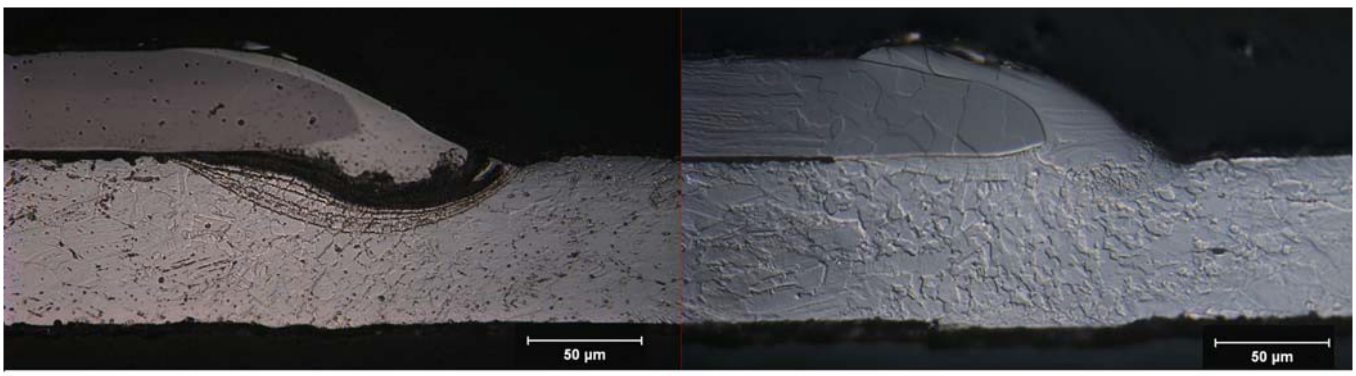


Figure 1. Microstructure of delaminating tin plating on copper substrate.



a) Mechanical polish and chemical etch

b) Mechanical polish, then ion milled

Figure 2. Comparison of traditional preparation (a) with ion mill (b) tantalum-stainless steel weld.

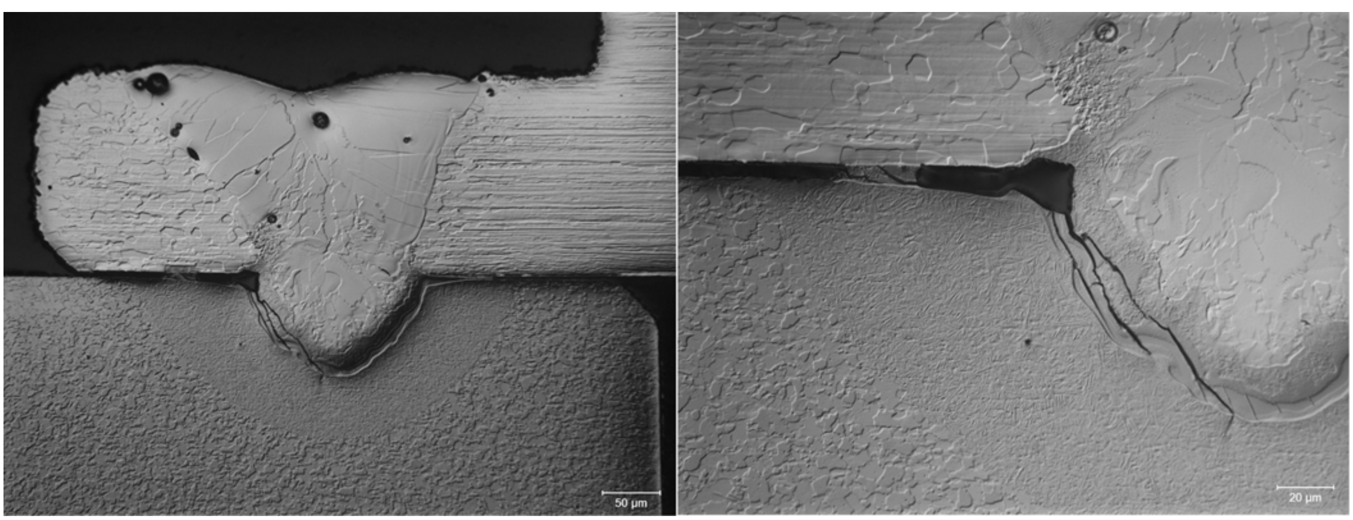


Figure 3. Ion-milled specimen showing microstructure and cracks at weld joining platinum to stainless steel.