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Whisker Formation and Stress Relaxation in Tin Thin Films

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A significant mechanism for stress relaxation in tin films is the spontaneous formation of tin whiskers, hillocks, and other surface defects in response to compressive film stresses. The formation of tin whiskers in particular is a serious problem in microelectronics reliability. Electronic component are electrically joined to circuit boards by Sn-based solders. If tin whiskers form bridges between adjacent components or component leads, a catastrophic short circuit can occur, thereby undermining the performance of the electronics. Surface defects form within the film and grow from their bases, in very low numbers compared to the number of grains in the microstructure, a result of a mechanism or a set of mechanisms that must distinguish between the low population of "active" grains relative to remainder of the microstructure. The thermodynamic driving force for surface defect formation, the microstructural features characteristic of electrodeposited tin and their influence on the specific types of stress relaxing defects that form will be discussed.

Of special focus will be the changes in the local driving forces that lead to a transition between whiskers and hillocks. Hillock growth as shown in Figure 1 reflects stress relaxation by translation of the grain out of the plane of the surface (ledges) and translation of the grain boundary in the grain boundary plane as a result of, first, stress-driven grain boundary migration, and later, curvature-driven grain boundary migration (terraces). The hillock schematic in Figure 1 illustrates the time evolution of the defect as it grows from its base; the formation of ledges and terraces with the position of the triple junction line with time corresponding to ridges that terminate at the film surface. When grain boundary migration does not occur, a whisker forms. Figure 2 shows fine scale details of a whisker: the shape of the initial grain from which the whisker formed including its grain boundary grooves, similar to hillocks, the changes in whisker diameter with whisker height, including in this case a decreasing then an increasing diameter, and the ridges along the whisker parallel to the film surface that reflects the non-continuous nature of whisker growth. Transitions in morphology with film composition, electrolyte, and texture are formalized in a defect phase diagram for the Sn-Cu-Pb system as shown in Figure 3. Transitions were observed in the defect densities, the morphologies of hillocks and whiskers with Cu and Pb additions, and the coexistence of certain defect types, aiding in understanding the role of grain boundary pinning in hillock and whisker formation. Open questions regarding whisker formation in tin and other systems will be presented.

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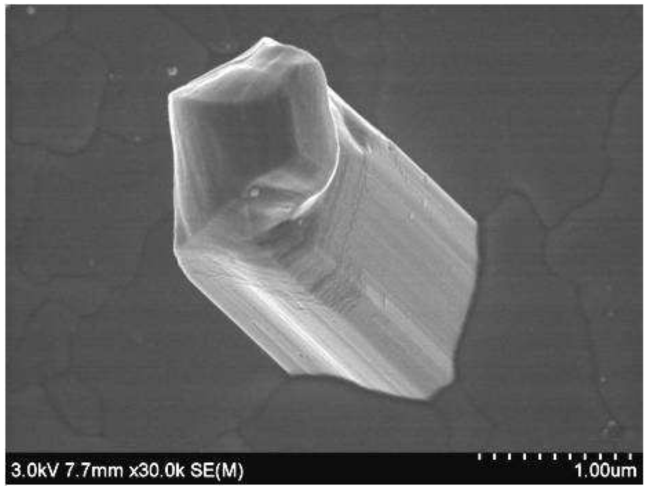

FIG. 1. Microstructure of a tin whisker growing from an electrodeposited tin film showing fine scale details of whisker growth. Note the shape of the grain boundary intersection of the whisker with the film and the grain boundary grooves on the film surface.

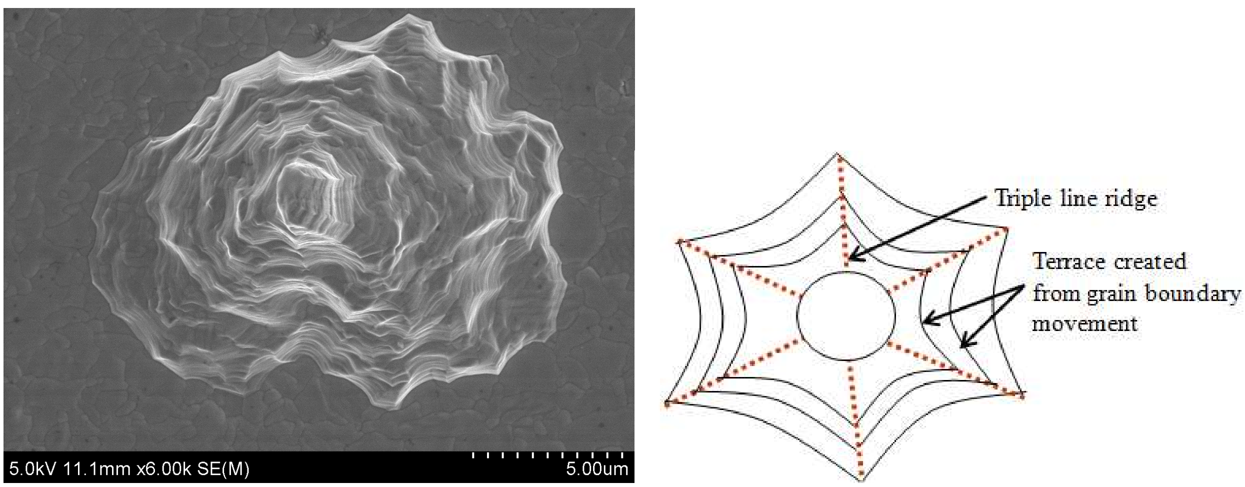

FIG. 2. Top view of a hillock formed on a tin electroplated film (left). Schematic on right indicates the microstructural features of the hillock reflecting the microstructural evolution as the hillock grows within the film.

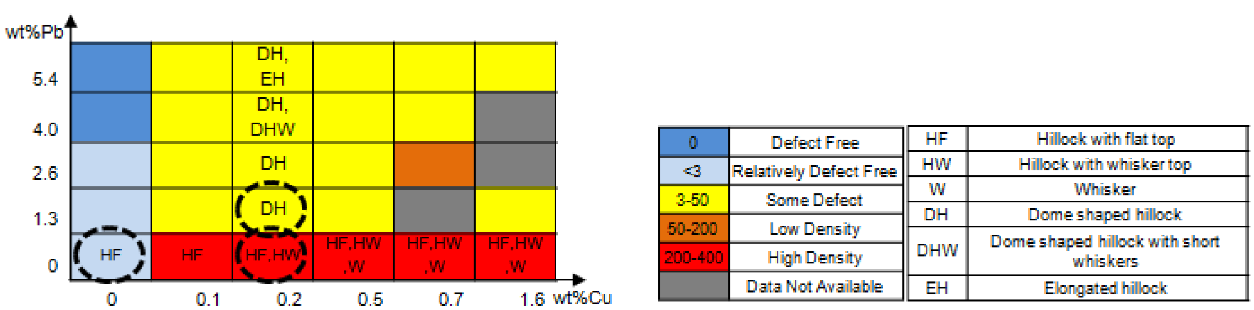

FIG. 3. Defect phase diagram on the left showing the density and morphology of surface defects with additions of Cu and Pb to Sn films.

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