Understanding the Mechanisms Controlling Sn Whisker Formation

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Sn whiskers are a serious reliability problem in Pb-free electronics manufacturing. Whiskers (as in fig. 1) grow out of pure Sn coatings and have been responsible for numerous system failures, such as the Galaxy IV satellite. To increase our understanding of whisker growth, we have performed systematic measurements to quantify the whisker growth kinetics and the correlation between the formation of a Sn-Cu intermetallic compound (IMC), stress in the Sn and whisker nucleation. In situ SEM observations (fig. 1) have allowed us to observe how the whisker grows in real time. We find that there are no pre-existing defects where the whiskers first start to appear. In addition, in situ removal of the surface oxide is not sufficient to make the whisker grow, indicating that the underlying grain structure is critical to whisker nucleation. Simultaneous measurements of the IMC, stress and whisker density demonstrate the correlation among them for different layer thicknesses. Although the IMC grows continuously, the stress saturates at different values depending on the film thickness (and hence grain size). In each case, whiskers start to form only after the stress reaches its compressive saturation value. The smaller grain size has greater stress and therefore a larger density of whiskers. We are using these measurements to develop models of the stress (see figure 2) and whisker growth rate. This will allow us to both predict whisker formation for different microstructures and develop scientifically-based mitigation strategies.

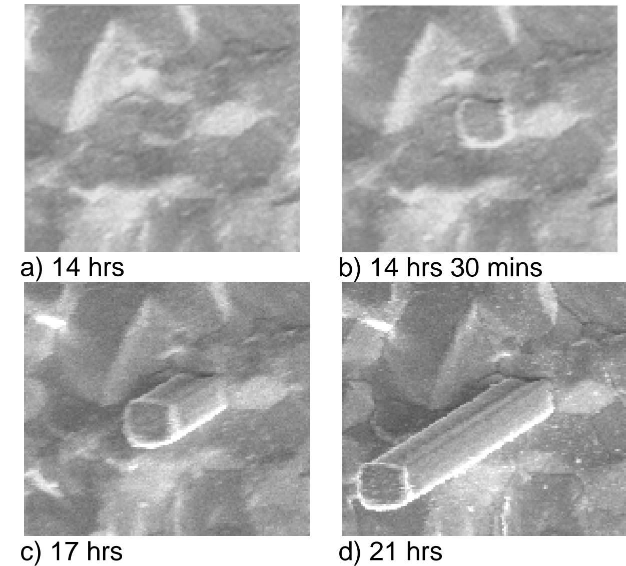

Fig. 1. Evolution of whisker during growth measured in real-time in SEM.

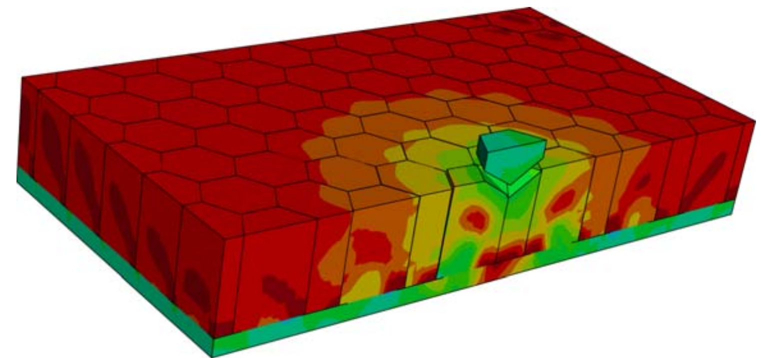

Fig. 2. Finite element analysis uses results of experiments to model stress evolution around growing whisker.