A Diffusion-Deformation Multiphase Field Model for Elastoplastic Materials Applied to the Growth of Cu6Sn5

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2016

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Tin coatings are commonly used in the electronics industry to protect components from corrosion and also to increase solderability. Depositing tin on a copper substrate will lead to the formation of intermetallic compounds (IMC) at the interface between the substrate and the coating. At room temperature the intermetallic compound Cu_6Sn_5 is formed. A small amount of IMC is necessary to achieve a good bonding between the substrate and the coating. However, in the presence of too much IMC, the mechanical properties of the coating will degrade due to the brittleness of the intermetallic phase. With time, the IMC layer will grow thicker due to diffusion of copper atoms into the tin coating. The growth of the IMC is associated with a volume expansion that gives rise to stresses in the Cu and Sn layers. The compressive stresses developing in the Sn layer are believed to provide the driving force for tin whisker growth. Tin whiskers are nearly perfect single crystals growing out of the tin coating. Whiskers are known to cause short circuits of electronic components and several cases of catastrophic failure attributed to tin whisker growth have been reported. Even though tin whiskers are a well known problem, the underlying mechanisms of whisker growth are not fully understood.

To shed light on the mechanisms causing whisker growth, a coupled diffusion-deformation multiphase field model has been developed. The equations governing the evolution of the microstructure are derived in a thermodynamically consistent way using the concept of microforce balance laws. Furthermore, the model takes into account fast grain boundary diffusion between IMC grains as well as plastic deformation of the microstructure resulting from the volume expansion of the IMC. Preliminary results suggest that, for room temperature ageing, the growth of the IMC is linear with time, and that the curvature of the IMC layer decreases with time. This is in accordance with experimental data reported in the literature. It is also seen that plastic deformation occur in both the Cu and the Sn layer. The size of the plastic zone varies depending on the initial curvature of the IMC layer. For IMC layers with a high curvature, the plastic zone extends further into the Sn layer than for IMC layers with less curvature. The model also predicts that the growth of the Cu_6Sn_5 phase leads to a compressive stress state in the Sn layer. This suggests that intermetallic compounds growing in the interface between a Cu substrate and a Sn coating can generate the compressive stress necessary for whisker growth.

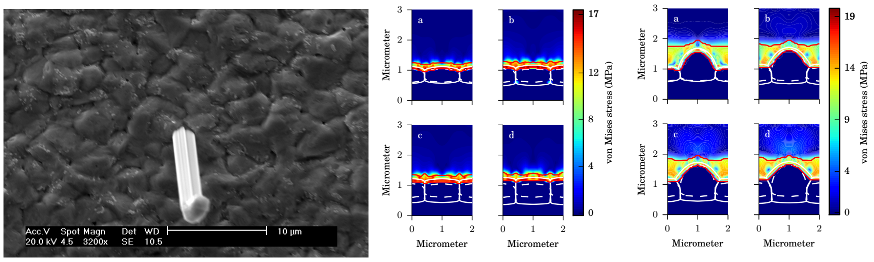

Figure 1: **Left: SEM image of a tin growing out of an electrodeposited tin surface. Right: Evolution of the von Mises stress in the Sn layer for two different initial conditions at four different times; a) 150 h, b) 300 h, c) 450 h, and d) 600 h. The red contour indicates the plastic zone.**