Coupling crystal plasticity and mass diffusion to study whisker formation in polycrystalline tin coatings

Aritra Chakraborty*, Philip Eisenlohr*, and Pratheek Shanthraj†

* Chemical Engineering and Materials Science
Michigan State University
428 S Shaw Ln, East Lansing, MI 48824, USA
e-mail: chakra34@egr.msu.edu, eisenlohr@egr.msu.edu, web page: http://chems.msu.edu

†Max-Planck-Institut für Eisenforschung GmbH
Max-Planck-Str. 1
40237 Düsseldorf, Germany
e-mail: p.shanthraj@mpie.de, web page: http://www.mpie.de

ABSTRACT

Formation of whiskers on the surface of polycrystalline metallic coatings is observed for a couple of materials and substrates. Economically most relevant are tin (Sn) coatings on copper (Cu) substrates as those are very frequently employed in the electronics industry. The growth of long tin whiskers can lead to short circuits that render electronic equipment useless and, therefore, have been an area of significant research interest, in particular since the regulatory ban on lead resulted in increased downstream processing temperatures that affect the deliberately controlled microstructure of previously deposited coatings [1].

Despite considerable characterization and modeling efforts in this field, the prediction of whisker growth locations and associated mitigation is elusive at the moment [2]. It is believed that whisker formation is one possible way for the coating to relieve stress resulting from swelling due to intermetallic compound (IMC, mainly Cu_6Sn_5) growth and net Cu uptake starting at the interface between the Sn grain boundaries and the Cu substrate. The evolution of diffusive and convective (via plastic deformation) mass flow of tin in response to the continuously increasing volume fraction of IMC is a coupled problem at the heart of whisker formation. To simulate the coupled response of a Sn coating on a Cu substrate as a function of time, the open-source software DAMASK [3] is utilized to integrate (i) the elastoviscoplastic response of strongly anisotropic Sn, (ii) the time-dependent growth of IMC resulting in local volume dilation close to Sn grain boundaries (GBs), and (iii) volume changes mediated by vacancy diffusion that is concentrated within the GB network, into a multi-physics simulation framework that will allow to study which aspects are decisive for whisker generation. Among the open question we aim to help clarify are the role of (i) initial texture in connection with the plastic and elastic anisotropy of tin, (ii) hydrostatic stress gradients, and (iii) grain boundary plane inclination.

REFERENCES

[1] K. Zeng and K. N. Tu. Six cases of reliability study of Pb-free solder joints in electronic packaging technology. *Materials Science and Engineering: R: Reports*, 38(2):55–105, 2002.

[2] E. Chason, N. Jadhav, F. Pei, E. Buchovecky, and A. Bower. Growth of whiskers from Sn surfaces: Driving forces and growth mechanisms. *Progress in Surface Science*, 88(2):103–131, 2013.

[3] F. Roters, P. Eisenlohr, C. Kords, D. D. Tjahjanto, M. Diehl, and D. Raabe. DAMASK: the Düsseldorf Advanced MAterial Simulation Kit for studying crystal plasticity using an FE based or a spectral numerical solver. In O. Cazacu, editor, *Procedia IUTAM: IUTAM Symposium on Linking Scales in Computation: From Microstructure to Macroscale Properties*, volume 3, pages 3–10, Amsterdam, 2012. Elsevier.