doi:10.1017/S1431927622002835
Microsc. Microanal. 28 (Suppl 1), 2022

Quantifying Pb in Microelectronic Electrodes to Mitigate Sn Whisker Growth with the Use of Energy Dispersive X-Ray Spectroscopy (EDS) and Image Analysis

Luis Jauregui*, Rebecca Wheeling and Jeier Yang

Sandia National Laboratories, Albuquerque, NM, USA.
*Corresponding author: ljjaure@sandia.gov

100% Sn-coated electrodes are widely used in microelectronic applications, but a risk to their reliability is the potential growth of Sn whiskers. Sn whiskers can grow up to several millimeters in length, are unpredictable, and can cause short circuits (See Figure 1). One common strategy used to mitigate the growth of Sn whiskers is to apply Pb to the electrode [1]. Although the mechanism through which Pb mitigates whisker growth is not well understood, Pb concentrations above 3wt% are considered safe. In this study we used energy dispersive X-ray spectroscopy (EDS) and image analysis techniques to quantify Pb along the surface of microelectronic electrodes to assess their safety.

EDS is the ideal technique to identify the presence of Pb in the electrodes, particularly where the Pb concentration is high or where the Pb is below the detectable limit of EDS. However, due to its qualitative nature, EDS alone is not sufficient [2]. When the Pb concentration is low, but detectable, it is difficult to reliably say whether Pb is above or below the 3wt% threshold. To address these edge cases, we took advantage of the high Z difference between Sn & Pb and performed image analysis on backscatter electron (BSE) Images. These BSE images were straightforward to segment into Pb and Sn components, allowing us to use the known densities of the elements, to then calculate the Pb concentration in the electrodes.

All data for this study was collected in a Zeiss Supra 55VP with an Oxford X-Max 80mm^2 EDS detector. Images and EDS spectra were collected at a voltage of 20KeV with a beam current of ~2nA. EDS Spectra was collected at 3 separate regions for each electrode. If the lowest detected Pb concentration was 10wt% or higher, the part was deemed safe. If there was no Pb detected through EDS in any of the 3 locations, then the part was deemed to be high risk. If the Pb concentration through EDS was below 10wt%, but detectable, we proceeded with image analysis as a secondary measurement. All image analysis and calculations were done with MATLAB. BSE images were segmented into three: Pb, Sn, and unknown. Unknown refers to foreign objects which obscured part of the electrode. These unknown regions were excluded from our calculations. An additional challenge was the topology of some of the electrodes, which would cause some Sn to be misidentified as Pb. To address this, a background subtraction was enough to remove any major topological effects (See figure 2). Once the BSE image was processed, the number of Sn and Pb pixels were counted. Then, using the known densities of Sn (7.27g/cm^3) and Pb (11.34g/cm^3) we calculated the Pb wt%.

This approach provides us with the bandwidth to analyze a large volume of samples, while also giving us the confidence that in the edge cases we have the precision to distinguish between high risk and low risk electrodes. While image analysis provides us with the precision needed, it is also a bottle neck in the workflow. Ideally, EDS would be the only tool utilized. In the future, a systematic study with Sn and Pb standards will compare EDS and image analysis results to characterize the precision of EDS at varying Pb concentrations. Some early results have shown that EDS agrees with image analysis to within 1wt%, but further work must be done before the amount of image analysis required is reduced [3].

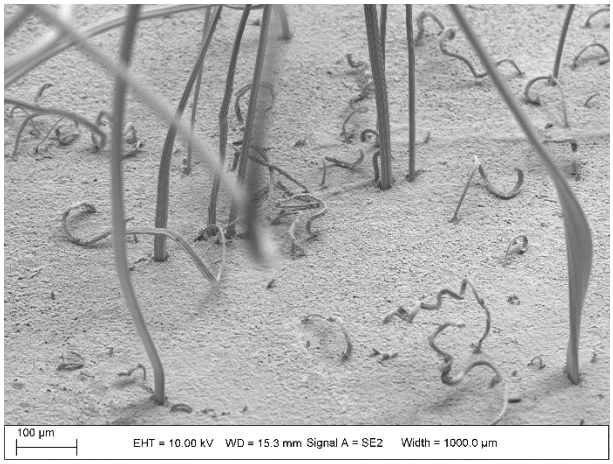

Figure 1. An example of Sn whiskers growing on a Sn surface.

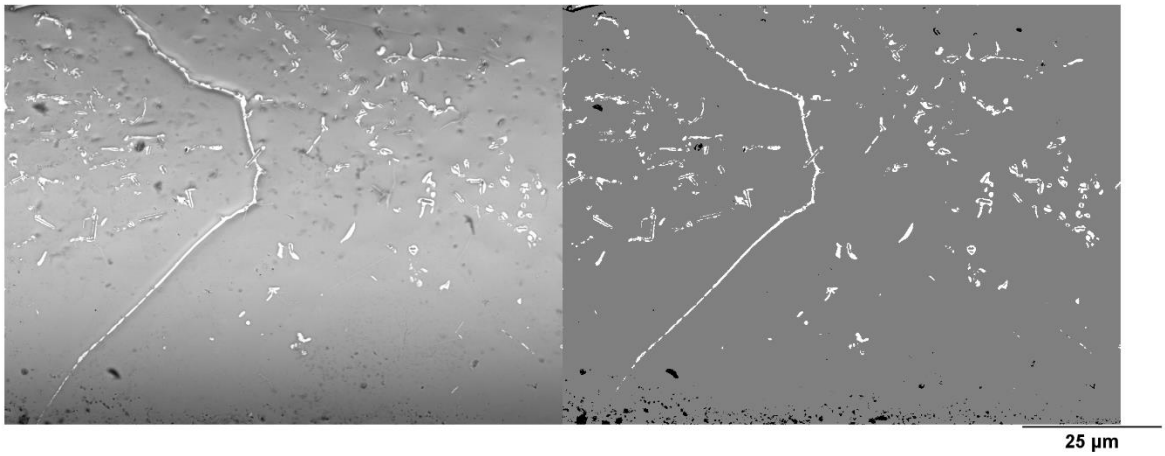

Figure 2. One of the original, unprocessed BSE images on the left. On the right is the same image after a background subtraction and segmentation, this electrode had a measured Pb concentration of 3.7wt%.

References:

[1] King-Nigh Tu et al., Lead-Free Electronic Solders **1** (2006), p 281. doi:10.1007/978-0-387-48433-4_18
[2] Joseph I. Goldstein et al., in "Scanning Electron Microscopy and X-Ray Microanalysis",4th ed. Joseph I. Goldstein et al., (Springer, New York) p.296.
[3] SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

https://doi.org/10.1017/S1431927622002835 Published online by Cambridge University Press