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

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Introduction

- 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.
- One common strategy used to mitigate the growth of Sn whiskers is to apply Pb to the electrode [1].
- 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.

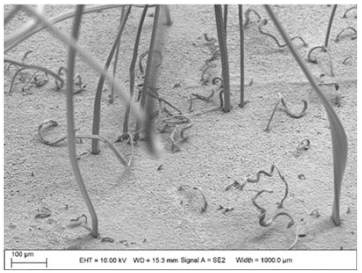

Figure 1. SEM image of Sn whiskers growing on pure Sn solder.

Limitations of EDS

- EDS is ideal for identifying the presence of Pb in electrodes.
- 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.

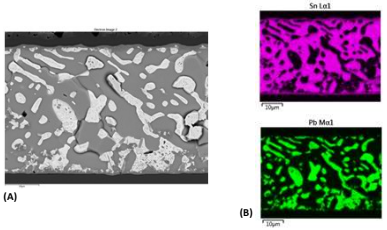

Figure 2. (A) BSE image of SnPb solder, showing high contrast between the Sn and Pb. (B) EDS maps of Sn La and Pb Ma of the same location.

Workflow

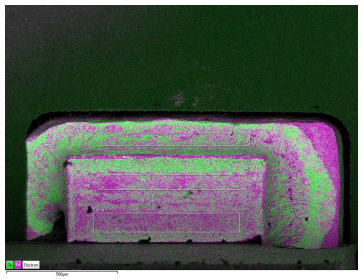

Figure 3. SEM/EDS map layered image showing the distribution is Sn and Pb on an electrode.

Entire electrodes are first mapped in EDS to characterize the Pb coverage over the entire surface, and identify any potential areas low in Pb.

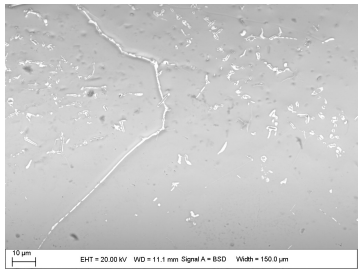

Figure 5. BSE image of an area in the electrode with a low but detectable amount of Pb.

If EDS finds that the Pb content is below 10Wt%, but detectable, then high contrast, BSE images are collected of the area in question.

$$Pb_{wt\%} = \frac{\rho_{Pb} n_{Pb}}{\rho_{Pb} n_{Pb} + \rho_{Sn} n_{Sn}}$$

Equation 1. Pb concentration in weight percent.

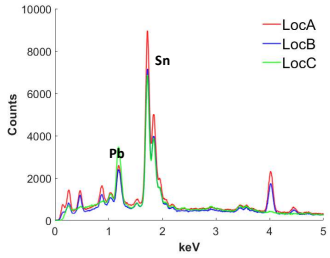

Figure 4. EDS spectra of the 3 location marked in figure 3.

EDS spectra are collected at specific regions, and the Pb content is quantified. If the Pb content is high (above ~10wt%) on all regions, the part is considered safe. If Pb is not detectable in any of the regions then we can be confident that it is below 3Wt% and it is not safe. In the example above all Pb contect was above 10Wt% .

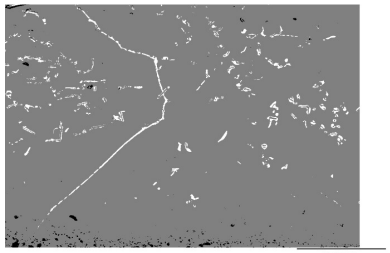

Figure 6. Fig 5 after segmentation into Pb (white), Sn (gray), and "junk" (black).

The BSE image is processed as needed, in most cases a simple segmentation is enough, but in the case shown here flat fielding was necessary to minimize any topological effects in the image. Dark pixels are thrown out.

Once the image has been processed, Pb and Sn pixels are counted, and the Pb concentration is calculated using the equation to the left. In this example the Pb concentration was measured to be 4.3Wt%. Part is considered safe.

Conclusions and Future Work

- Due to the convenience of automation with EDS this method allows for high throughput of samples
- Image analysis provides accuracy and precision when confronted with an edge cases
- A study is underway with the use of PbSn solder standards to better understand the accuracy and precision of both standardless EDS and image analysis at varying Pb concentrations (3, 5, 10 and 20Wt% Pb). The graph below shows preliminary results.

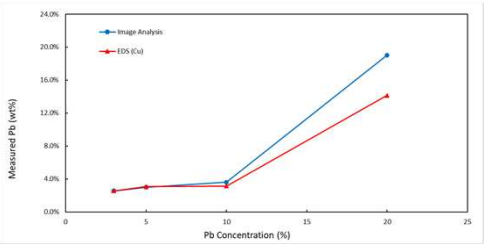

Figure 7. Measured Pb concentration on SnPb standards utilizing EDS and image analysis.

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.

Acknowledgements

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