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Analysis of Adhesion Failures of Thermally Treated Tin-plated Copper Using AES

One of the most common non-precious metal finishes on electronic components is pure tin or tin/lead plated directly over copper. It is inexpensive, and its properties and performance issues are well understood. In many applications, it has endured well under the test of time.

Newer applications, however, call for more aggressive manufacturing cycles. Higher soldering or molding temperatures, longer cure times and several passes through a range of temperature profiles can stress this proven technology.

Occasionally, adhesion failures occur at the tin-copper interface after prolonged aging at elevated temperature. Auger Electron Spectroscopy is used here to investigate those failures.

The Auger phenomenon, discovered first by the French Physicist P. Auger in 1925[1], is illustrated in Fig. 1. A high-energy electron (or X-ray) beam ejects an inner core electron creating a "hole." This situation is unstable and is quickly re-occupied by an outer layer electron. When an electron jumps from the outer layer to the inner layer, energy is released. This released energy ejects a second electron, known as the Auger electron. The kinetic energy of the Auger electron is very characteristic for individual elements and can therefore be used for elemental identification and analysis.

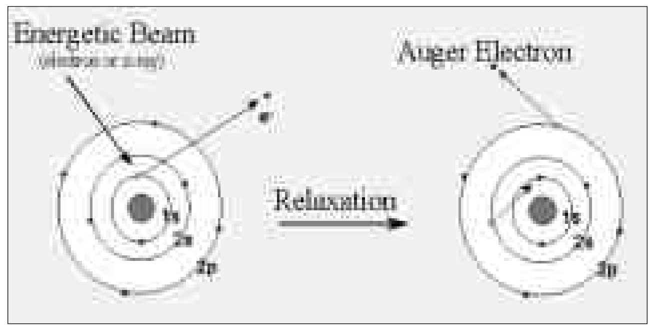

Fig. 1—Schematic diagram of Auger process. An Auger electron is ejected from the outer shell of an atom after excitation by the primary beam.

Problem

A tin-lead (SnPb) alloy, plated over a copper (Cu) plated copper alloy, shows good adhesion immediately after plating. The deposit is found to flake upon bending after multiple thermal processing cycles in subsequent manufacturing operations. Auger Electron Spectroscopy (AES) is used here on each side of the interface to identify composition and possible causes.

Analysis

Fresh interfaces were prepared by bending the sample, which was then quickly transferred into the ultra-high vacuum chamber of the Auger microscope. Several AES spectra were taken on both sides of the failed interface. Figure 3 shows the typical AES spectra for the two surfaces as prepared

Fig. 2—SEM photo of typical adhesion failure. After heating, the SnPb deposit separates cleanly from the Cu substrate, exposing a dark-colored interface.

and after 5 minutes of sputtering to remove ~30 nm of the surface. Sn, Cu, O, C, Pb and Cl were identified. The underside of the peeled back top film was found to consist of a thin layer of Sn oxide covering a CuSn intermetallic compound. The surface of the substrate was found to be composed mainly of Cu oxides. A layer of carbon was found in both cases but was almost entirely removed during the sputtering operation. This may have been due to environmental exposure or it may indicate inclusion of the additives used in the plating process.

The depth distributions of Sn, Cu, C, Pb and O have been also measured on both surfaces and are plotted in Figs. 4 & 5. These confirm the previous findings but also add depth and composition information to the surface films.

In Fig. 4, it can be seen that the underside of the SnPb flake is rich in Cu at the interface suggesting that Cu_3Sn has formed to a depth of ~1000nm. This tapers off as the bulk SnPb is approached at ~2000 nm. A mixture of Cu_3Sn and Cu_6Sn_5 is likely present in this region.

A schematic diagram of the deduced structure is shown in Fig. 6.

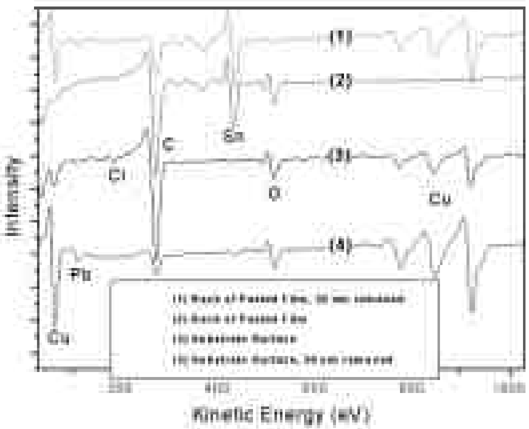

Fig. 3—Auger spectra of both sides of interface before and after sputtering.

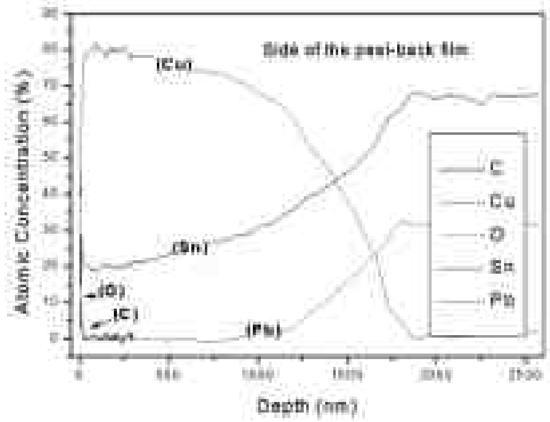

Fig. 4—Auger depth profile of the underside of the poorly adherent SnPb deposit.

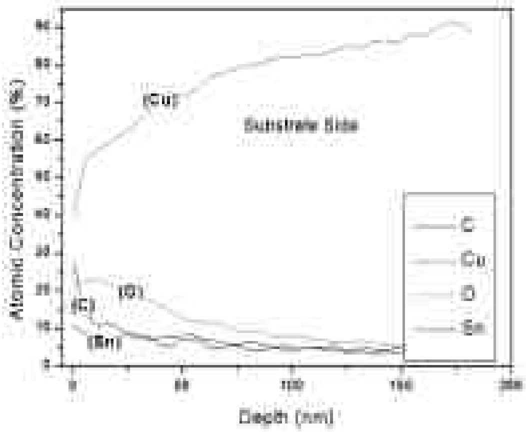

Fig. 5—Auger depth profile of the substrate surface.

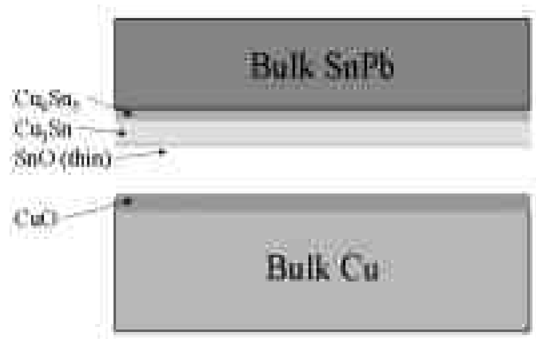

Fig. 6—Schematic diagram of intermetallic structures formed after heating and point of separation

Solution/Conclusion

It is apparent from the data on Figs. 3, 4 & 5 that a relatively thick intermetallic layer has formed at the Cu/SnPb interface. The majority of this layer is shown to comprise principally of Cu_3Sn, which is generally thought to be more brittle in comparison to Cu_6Sn_5. The formation of brittle intermetallics and their resultant fractures can generally be prevented by the application of a thin barrier layer of nickel plated between the Cu and Sn or SnPb deposits.[2] *P&SF*

References

1. Auger, P., *J. Phys. Radium*, **6**, 205 (1925).
2. Brouillard, M.J., *Proc., AESF SUR/FIN® 1999 Conference*, Cincinnati, OH.