Sn-Pb wetting to Pb-free components: designing reliability into the process

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For a long time, a common complaint when initiating the changeover to lead-free electronics manufacturing was the poor availability of lead-free components. But now that component manufacturers have caught up with the rest of the lead-free movement, the opposite situation is more likely today: there is a high probability that Pb-free components will be used in Sn-Pb processes. On the one hand, this may be a decision forced by availability, to the extent that even industry sectors that are exempt from the RoHS directive may have no choice but to source Pb-free terminated components and/or Pb-free plated boards. On the other, it may be a more unwitting choice, since vendors do not always identify when changes in plating occur, and what those changes are.

A variety of Pb-free component lead finishes is now available, with pure Sn, Sn-Bi and Au-Pd-Ni being the predominant three, and components with different finishes are often used on the same board. Board finishes themselves are also changing (see EMSNow column at http://www.emsnow.com/npps/story.cfm?ID=9784), so it is highly likely that in today's Sn-Pb process, during reflow the Sn-Pb solder will be interacting with one or more Pb-free finishes at the same time, causing subtle changes in the mechanism of joint formation, as described below.

In any reflow soldering process, particles in the solder paste melt, while the component and board plating dissolves and fuses with the solder to form a continuous solder joint. Where the plating or component lead finish is Sn-Pb and the paste and process are also Sn-Pb based, the plating melts along with the solder paste to form a known good solder joint. When the plating and component lead finishes are of some material other than Sn-Pb, such as pure Sn, Sn-Bi, Au-Pd-Ni, or another alternative, the component lead finish and board plating either dissolve – in the case of the gold in Au-Pd, for example – into the molten solder, or diffusion occurs and a continuous solder joint is formed through the merging of the plating and the solder paste. This is by no means a recent observation; a number of Pb-free platings, for instance Au-Pd-Ni, have been available for several years, and for the most part the minor changes in the physical and chemical complexities of the joint-making process have not given cause for concern.

However, having worked with several customers to manage the transition to lead-free manufacturing, there have been one or two anomalies that are worth noting, since other assemblers may also have noticed – or wish to check for – similar problems. One particular customer uses Pb-free terminated components with Sn-Pb solder paste on current devices, and a vehicle module electronics assembler noticed incomplete wetting on leads of one QFP device. To 'fix' the problem, the reflow profile was adjusted to give more heat input… but this turned out to be only a short-term solution, as the resulting change narrowed the process window and took the process parameters close to the specification limits on several other parts.

Another customer, building powder control devices, experienced similar issues with wetting on SOIC devices. Once again, an attempt was made to adjust the reflow profile to compensate, but this time, reflow adjustments alone were not enough to achieve the extent of wetting necessary to pass inspection.

In both cases, a longer-term solution was clearly needed. To act as a stepping-stone between Sn-Pb and Pb-free manufacturing, a solder paste formulation was designed using similar raw materials, activators, and other components as next-generation Pb-free solder pastes, but intended for Sn-Pb based processes. The extra activity and wider reflow window capabilities that resulted were sufficient to overcome the wetting issues observed at both electronics manufacturing locations.

While there is hope for the compatibility of the simpler Pb-free components with the Sn-Pb process, the situation where area array devices are concerned is, unfortunately, very different: when running a Sn-Pb process in which a Pb-free bumped BGA or CSP is used instead of a Sn-Pb bumped device, the results are generally not that good. The melting temperature of the SAC alloys typically used for bumping Pb-free devices is 217°C, whereas the Sn-Pb solder paste melts at 183°C. During reflow, this can give rise to incomplete melting of the bump, in turn leading to a high stress condition in which the bump is elongated in the vertical direction, rather than fully collapsed. The resulting solder joint microstructure may also exhibit different compositions along different layers, potentially leading to premature solder joint fatigue[1]. There is not a simple materials-based solution to this problem – it is one that will only truly disappear when a fully Pb-free process is adopted.

In summary, there are a number of actions that the vigilant assembler can take to minimize the likelihood of unexpected problems:

- insist that suppliers inform/identify when changes occur in the finish applied to articles used in production;
- track changes in the electronics manufacturing process – pay particular regard to increased regularity of certain defects occurring;
- profile the reflow oven correctly, and check regularly that the profile is not being altered to attempt a ‘quick fix’ for what may be a serious underlying process problem;
- use the most appropriate assembly materials for the process – your suppliers will have encountered most problems that manufacturers and assemblers experience, and they may have an off-the-shelf solution.

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About the author

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Brian chairs the IPC's underfill handbook committee (J-STD-030) and co-chairs the solder paste standards committee (J-STD-005). He is also program chair for IEMT 2005, and an active member of SMTA. His published works include a course on failure analysis for SMTA, two chapters for electronic engineering handbooks, and numerous papers for trade publications.

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[1] Hillman, et al., CMAP 2005, Toronto, 2005