Challenges in lead-free soldering


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As we enter the post-July 1, 2006 era, most of the large PCBA factories in the world are running lead-free soldering. However, challenges remain, and process optimization is essential, particularly for soldering and rework of large, thick boards.

Wave soldering of large, thick boards.

Achieving acceptable wave solder through-hole fill on thick boards using currently available flux materials and components is a process challenge, especially with lead-free solder, due to the surface tension of lead-free solder alloys. There are additional concerns related to lead-free wave soldering that may impact plated through-hole (PTH) solder joint quality and reliability, such as voiding, orange peel, micro surface cracking, Cu leaching and dissolution. To address these issues, both process and design variables need to be optimized to improve through-hole fill for those challenging boards, as our study has indicated that there are strong correlations between design and process conditions (such as temperature, contact time, internal copper thickness) and hole fill.

Reflow soldering of large, thick boards.

Reflow profile development to minimize the temperature delta across the board, especially for large, complex boards with high thermal mass components mixed with low thermal mass components, is another process challenge. In terms of process conditions, conveyor speed, board orientation and oven zone settings are important parameters; for example, slowing conveyor speeds and having the short side of the board parallel to the conveyor can help reduce the temperature delta. In terms of design, product designers need to carefully consider the thermal balance based on Cu distribution in the PCB and the distribution of component thermal masses.

Rework of large, thick boards.

For large area array packages using lead-free solder, the key issues in rework include profiling, adjacent component temperatures, solder joint formation and metallurgical bonding. Rework equipment with a sophisticated mechanism to deliver thermal energy to the innermost solder joints of a large area array package, while minimizing the impact on the PCB and on the adjacent components, offers substantial advantages. For PTH rework, hole fill and Cu dissolution are important considerations, and both equipment and process optimization are significant factors.

Backward compatibility.

As early as 2002, the EMS Forum clearly stated that "area array packages with lead-free balls are not backward compatible" with the Sn-Pb soldering process. Currently, there are active studies on this scenario as several product categories may take advantage of the RoHS exemptions and continue to be built with Sn-Pb solder for some time to come, while the semiconductor industry has already moved to BGAs and CSPs with Sn-Ag-Cu (SAC) balls. This topic has been discussed in detail in a previous issue of this column, in terms of its impact on yield and reliability. The mixed alloy solder joint metallurgy and the Pb distribution through the solder joint for different package types and under various process conditions have been reported by us and others, and the results have shown that the solder paste amount (ultimately the Sn percentage in the mixed alloy) and the reflow temperature play critical roles in the mixed alloy assembly, both in terms of compositional homogeneity and voiding, with greater homogeneity for lower Sn content at higher soldering temperatures, and more voiding for mixed alloys.

In terms of reliability, our most recent study has shown that the sensitivity of the reliability of the mixed alloy solder joints to the process condition depends on the type of environmental loading. The assembly process conditions significantly affect the thermomechanical reliability of the mixed alloy solder joints. Thermal cycle testing has shown that mixed alloy samples reflowed at higher peak temperature performed better than those reflowed at a lower peak temperature. However, under a mechanical shock environment (such as drop test, shear test, and bending test), our results to date have shown no significant difference in the reliability of mixed alloy samples that were assembled at different process conditions. This difference in the sensitivity to the process condition is due to the different failure modes. Under thermomechanical loading conditions, the solder joint failure is generally within the solder and therefore is more sensitive to the microstructural characteristics of the solder which in turn is significantly affected by the process condition. For mechanical shock, on the other hand, the solder joint failure is typically interfacial in nature and therefore not as sensitive to the microstructural characteristics of the solder itself, thus less sensitive to the process condition.

More details on these topics can be found in our various publications as well as the recent book 'Lead-Free Solder Interconnect Reliability'.

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