INDIUM CORPORATION
TECHNICAL PAPER

Process and Solder Paste Considerations for BGA and QFN Voiding in a Tin-Lead Mixed System

Authored by: Derrick Herron; Lewis Seifreid and Ed Wheeler, Trenton Technology.

Abstract

Voiding has been a major challenge in the electronics industry for decades and BGA voiding has continuously been a serious concern. However, in today's market, bottom terminated components such as QFNs have become an even bigger concern with regard to voiding. Numerous studies have been devoted to trying to solve this problem.

In this study, a basic look at solder paste properties and reflow process parameters were examined in a tin-lead solder system. It was found that through the use of a solder paste with a high oxidation barrier and wide process window, along with an optimized reflow profile, voiding underneath both QFNs and BGAs was reduced or nearly eliminated.

Keywords: voiding, solder paste, BGA, QFN, tin-lead, bottom terminated component

Introduction

A great deal of work has been done to determine how to reduce voiding under the thermal pads of QFN components. Most of the work has been focused on lead-free systems and has involved techniques such as changing the design of the board pads [1], changing the stencil design to limit the amount of solder paste deposited [2], and using preforms to increase the ratio of metal to flux under the thermal pad before reflow [3].

The drawbacks with these approaches are that a design change is needed to the board, the stencil, or both, or the additional step and cost of adding preforms is needed. As a side note, this last concern is not overly costly when using common alloy tin-lead or tin-silver-copper preforms and already having pick-and-place equipment in place.

When a PCB manufacturing facility encounters unacceptable voiding while building boards for a customer, design changes are not the initial desired approach. This is especially true when unacceptable voiding is seen, not only in QFNs, but also in other components such as BGAs, that cannot necessarily be helped through the use of preforms or a design change.

Two specific initial approaches can be tried. Firstly, the reflow profile can be adjusted. Secondly, if the reflow profile has been optimized with regard to all components on the board, a different solder paste can be tried.

In this study, a benchmark tin-lead solder paste was compared to a solder paste with a large process window, compatible with both tin-lead and lead-free systems. Testing was done in a real-world application.

The affect of solder paste choice on the amount of voiding seen in the resulting solder joints was examined. QFN and BGA components, specifically, were analyzed.

Materials

The board tested in this study was a double-sided, highly-populated board approximately 9" long by 5.5" wide by 0.010" thick. Board pad metallizations were ENIG.

Quad-flat no-leads (QFNs) were Intersil ISL41334 6mm x 6mm components with ten leads per side and a matte tin finish.

BGA components of various types were also attached.

The two solder pastes used were:

- An industry standard halide-free paste specifically designed for use with tin-lead eutectic and near-eutectic alloys, used in this test with 63Sn/37Pb Type 3 solder powder (Paste A).
- Indium8.9HF Solder Paste, a versatile halide-free material with a high oxidation barrier, having a wide process window for use with traditional tin-lead alloys as well as SAC alloys, used in this test with 63Sn/37Pb Type 3 solder powder (Paste B).

Procedure

Boards were printed with solder paste using an automated printer with a 4mil-thick laser cut stencil. On QFN thermal pads, a windowpane pattern was designed into the stencil.

The bottom side of the board was printed and populated with an automated pick-and-place machine. The bottom side was reflowed using a forced air convection oven.

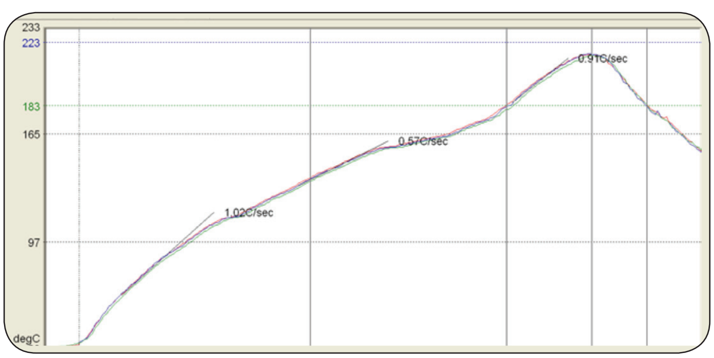

Figure 1. A typical tin-lead ramp-to-peak reflow profile.

A typical tin-lead ramp-to-peak profile, like the one shown in Figure 1, was used for the comparison between the benchmark tin-lead and the Indium8.9HF solder pastes. The peak temperature was 215°C, at 4 minutes, 45 seconds from the start of the ramp at room temperature. This profile had previously been optimized for Paste A.

Once the bottom side was completed, the board was flipped and the top side was assembled in the same fashion.

X-ray imaging was done using an Agilent 5DX machine.

Results

Voiding was reduced on the QFN packages using Indium8.9HF Solder Paste as compared to the benchmark material, as seen in Figure 2.

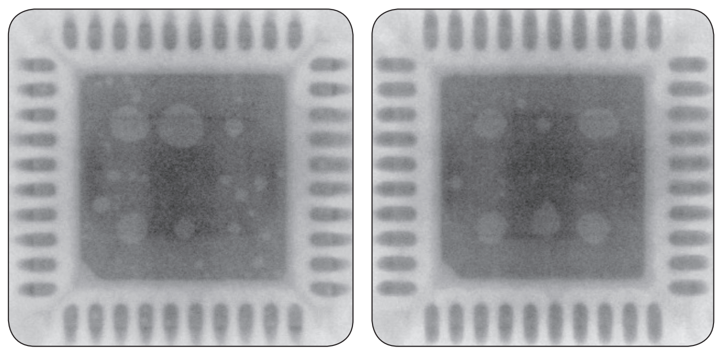

Figure 2. Representative voiding under QFN with Paste A (left) and Paste B (right).

A much more dramatic difference was seen between Paste A and Paste B when the BGA components were examined, as seen in Figures 3 and 4. Paste B, with its larger process window and stronger oxidation barrier, virtually eliminated voiding in the BGA components on the board.

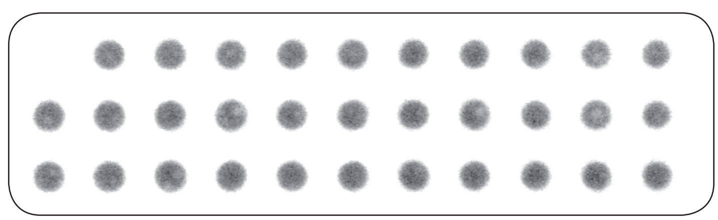

Figure 3. Representative BGA voiding with Paste A.

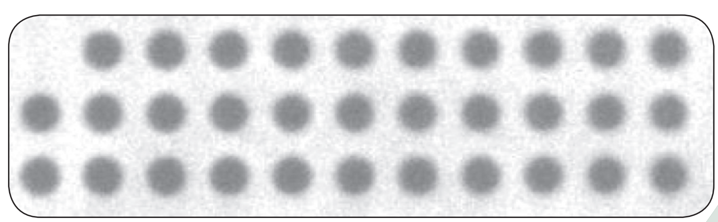

Figure 4. Representative BGA voiding with Paste B.

Discussion

It is known that voiding can come from entrapped flux in the solder joint [5]. Since flux is working to remove oxides from the solder, any metal that has oxide on its surface has the potential to also have flux adhered to it. Both Paste A and Paste B have high wetting strength and can readily remove oxides. However, Paste B has the added attribute of a high oxidation barrier. After initial oxides are removed, it will work longer to prevent further oxides from forming. This will allow for more flux volatilization and escape to the perimeters of the forming solder joint rather than entrapment within the solder body.

With regard to reflow profile, the ramp-to-peak profile was used in the attempt to decrease voiding as much as possible while creating the best process conditions. In previous work [1], it was found that two types of profiles work best for limiting voiding underneath QFNs: a short ramp-to-peak profile or a long hot soaking profile. With the short ramp-to-peak, solder is reflowed and cooled again before the flux solids have a chance to outgas. With the long hot soak profile, solder is reflowed and allowed to cool only after flux solids have had a chance to fully vaporize.

Of the two types of profiles offering the best voiding characteristics, the ramp-to-peak profile is preferred for two reasons. First, that type of profile is gentle on components, with a steady temperature increase and a very limited time held at high temperatures. The second benefit comes from process time needed to complete one board. The long hot soak profile took nearly three additional minutes from entrance into the oven heating zones up to the final reflow peak.

With the question of process time in mind, Paste B was also run at a faster belt speed with all of the same oven settings. The time to peak dropped from approximately 4 minutes, 45 seconds to 4 minutes, 15 seconds. A large increase in voiding was observed, especially on BGA components as seen in Figure 5. The increase in voiding can most likely be attributed to less time allowed for flux outgassing to escape from the molten solder and less time for flux to clean oxides from the board and component metallizations to allow for proper wetting.

Conclusion

When voiding is prevalent in solder joints, there are various ways to combat it. With all processes being the same, voiding was decreased under QFN components and nearly eliminated in BGA components with a simple change of solder paste. The higher oxidation barrier present in the Indium8.9HF Solder Paste aided in oxide removal and the further growth of oxides during the soldering process. With less oxide, there is less area for flux to adhere to during reflow to form a void.

A short ramp-to-peak profile proved to give very low voiding. It was seen that the time to peak needed to be optimized in order to get the best compromise between quick process time; long enough time to clean oxides fully and allow for volatile outgassing; and time for full reflow and cool down before flux solids could volatilize and produce more voiding. In this particular combination of boards and components, a reflow profile with a peak at 4.75 minutes was best; however, in previous work, a peak time as short as 3.5 minutes was found to be acceptable.

In any case where voiding is an issue, whether under QFNs or BGA components, your solder paste manufacturer should be able to help through the use of an optimized process or a different paste choice to better suit your needs. In the case of tin-lead solder paste, Indium8.9HF Solder Paste appears to be a great candidate for reducing voiding.

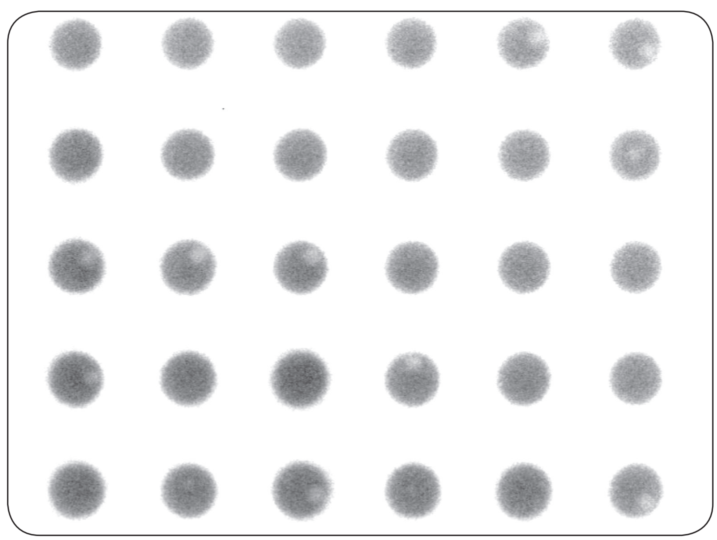

Figure 5. Voiding seen with increased process speed (contrast adjusted to clearly show voids).

References

1. Derrick Herron. "Thermal Pad Design and Processes for Voiding Control at QFN Assembly," IPC Apex Expo 2011.
2. Derrick Herron. "QFN Voiding Control Via Solder Mask Patterning on Thermal Pads," APEX, San Diego, CA, 21 February, 2013.
3. Seth J. Homer. "Minimizing Voiding in QFN Packages Using Solder Preforms," SMTAI, October 2011.
4. Harish Gadepalli. "Influence of Reflow Profile and Pb-Free Solder Paste in Minimizing Voids for Quad Flat Pack No-Lead (QFN) Assembly," Electronic Components and Technology Conference, 2009.
5. Ning-Cheng Lee. Reflow Soldering Processes and Troubleshooting – SMT, BGA, CSP, and Flip Chip Technologies. Boston: Newnes, 2001. Print.