在CSP或BGA底部填料过程中，有几个可能产生空隙的原因。需要小心选择焊膏和底部填料并小心进行组装。底部填料应在元件下快速流动，而且流动图形不应在流动中带空隙。硬化后不应产生因分子量低的成份排气造成的空隙。应选择适合多种焊膏的底部填料，或适合多种底部填料的焊膏。应避免使用助焊剂残留会产生气泡的焊料，因为这些气泡可能造成严重的空隙。而且，应采取措施避免水分。

Preventing Voids in CSP and BGA Underfill Encapsulants

Karl Loh and Edward Ibe

The right underfill can be as effective as the best solder paste.

CSPs and BGAs are capable of surviving thermal cycling requirements without being encapsulated, but are not designed to withstand repeated mechanical shock. Yet handheld devices must survive drop testing. In mobile phones, in which the PCB is directly under the keypad, withstanding repeated keypad actuation is also important. For automotive and military electronics, vibration and more severe thermal cycling become critical.

For CSP and BGA encapsulation, the proper underfill encapsulant must be easy to handle and process, and must yield void-free encapsulation. Properties such as storage conditions, pot life, dispensability, underfill flow speed and cure time are paramount to handling and processing. In devices where a reworkable underfill encapsulant is required, ease of rework is important. But, these properties are meaningless if void-free encapsulation cannot be achieved.

There are three major sources of voids:

- Voids generated by the underfill encapsulant.
- Voids generated by interactions between underfill encapsulant and flux residues.
- Voids generated by other assembly materials.

Voids from underfill encapsulant. Underfill needs to flow quickly under a component. This is typically achieved by performing capillary flow at an elevated temperature, perhaps as high as 90°C. To increase flow rate, manufacturers might reduce the viscosity of underfills by incorporating more volatile, lower molecular weight species. These materials can outgas and generate voids in the underfill during elevated temperature cure. Although this is a potential source of voids, manufacturers generally solve this problem through careful selection of ingredients.

Underfills can trap voids during flow. A flat, even flow front during underfill flow is desirable. **Figure 1** shows two underfills flowing from right to left. The flow front of one is very flat and smooth. The other shows an underfill with a poor flow front with many fingers. These fingers can close upon themselves, trapping a void. They can be caused by improper size and/or size distribution of any particles present in the composition. Also, improper wetting can result in fingering and voids. Consequently, these parameters are carefully designed and controlled by the underfill manufacturer.

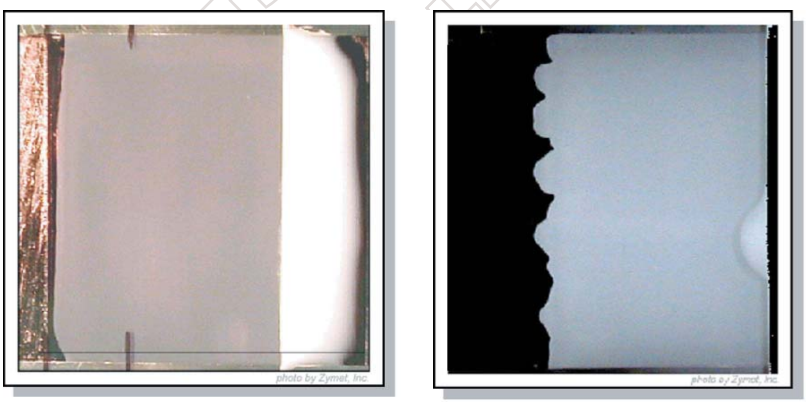

FIGURE 1: The ideal underfill flow front (left) is flat and smooth, while a poor flow front (right) can have fingers that trap voids.

Interactions between underfill encapsulant and flux residues. Some contributors to voids are difficult for the underfill manufacturer to control. For example, underfills can generate voids through interaction with other assembly materials. Generally, soldermasks and solder are well understood and are relatively inert. However, flux residues can contain active ingredients that may interact with underfills to form voids.

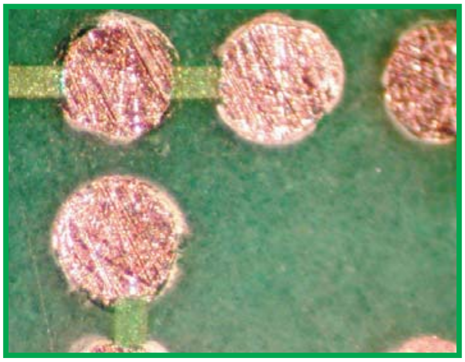

FIGURE 2a: Halo voids located near flux residues on a BGA pad.

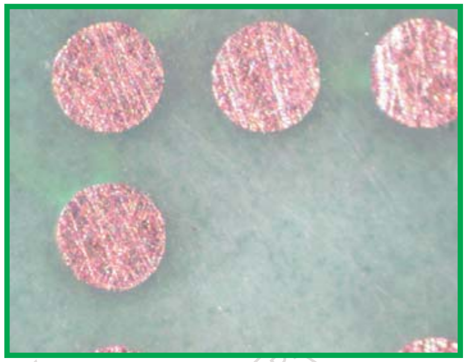

FIGURE 2b: A void-free BGA board made using compatible paste and encapsulant.

Figures 2a to 2c show BGAs assembled with two different solder pastes and underfilled with a single product. The BGAs are 0.5 mm pitch and have 84 I/Os each. They are assembled on FR-4 boards with an HASL finish and have been removed by lapping and polishing. **Figure 2a** shows halos surrounding several of the solder joints, near the flux residues. In **Figure 2b**, another solder paste (with good compatibility) is used and no halos or voids are present. **Figure 2c** shows an extreme case of poor compatibility. Halo voids are so large that they nearly bridge the gap between two solder joints. Components with voids this size are at risk of solder bridging if exposed to a second reflow profile.

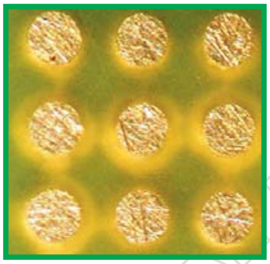

FIGURE 2c: Large halo voids like these can cause bridging.

A more extensive survey consisting of five underfills and eight eutectic no-clean solder pastes was performed. All materials were processed in accordance to vendor recommended conditions. **Figure 3** shows the number of halo voids found as a function of several underfills. For each underfill, one BGA was inspected for each of eight solder pastes, yielding a total solder joint population of 672. Full halos are distinguished from partial halos. Partial halos look like cresents and their sizes are not quantified here, but the trends are clear. All underfills exhibit some voids, but underfills D and E exhibit the fewest by far. These two underfills exhibit good compatibility to all the solder pastes.

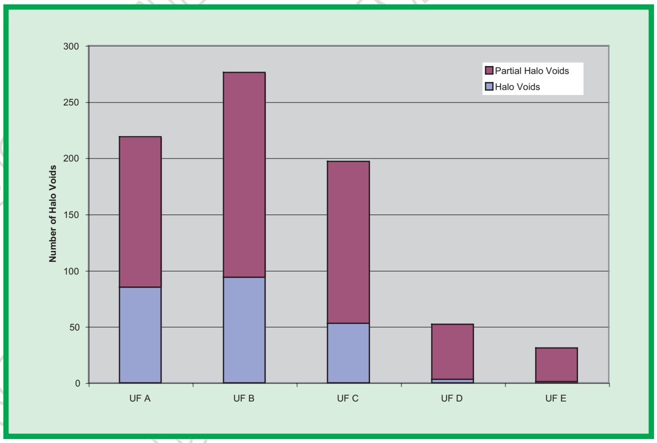

FIGURE 3: The number of voids can vary depending on underfill type …

Figure 4 shows the number of halo voids found as a function of several solder pastes. For each paste, one BGA was inspected for each of five underfills, yielding a total solder joint population of 420. All solder pastes exhibit some voiding. Solder pastes B and E exhibit the fewest. In solder paste E, all the voids are partial halo voids and are attributable to underfill B, the underfill found to generate the most voids. Solder paste E is described by its manufacturer as an ultra-low residue product.

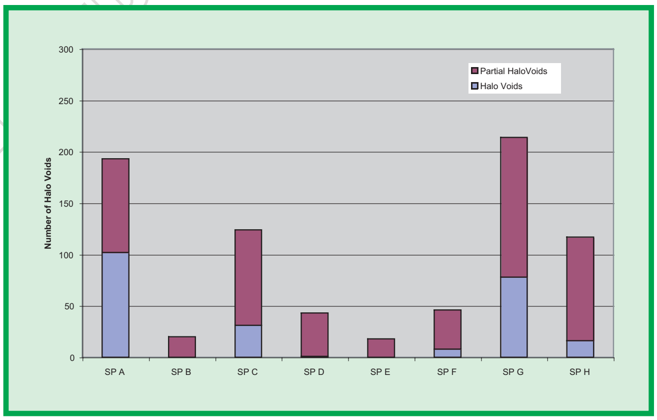

FIGURE 4: … And solder paste type.

When comparing the worst solder paste with the worst underfill, we find that the solder paste yielded 102 full halo voids out of a population of 420, 24% of the population. The worst underfill yielded 94 full halos out of a population of 672, 14% of the population. A comparison that includes the partial halos yields the same correlation: the percentage of solder joints with halo voids is higher with the worst solder paste than with the worst underfill. When we compare the best solder paste with the best underfill, we find that the solder paste yielded 18 total halo voids out of 420, 4.3% of the population. The best underfill yielded 31 total halo voids out of 672, 4.6% of the population. From this matrix of materials, we find that selecting the best underfill is as effective as selecting the best solder paste. Selecting the worst solder paste is more damaging than selecting the worst underfill.

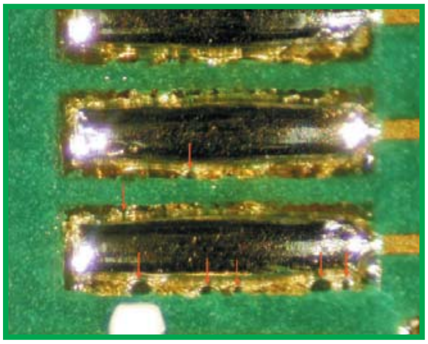

FIGURE 5a: Bubbles in flux residue before underfill.

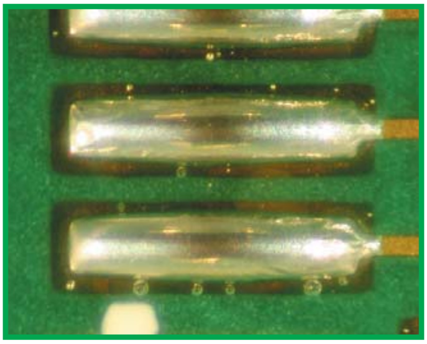

FIGURE 5b: Bubbles appear in the same spots after underfill flow but before curing.

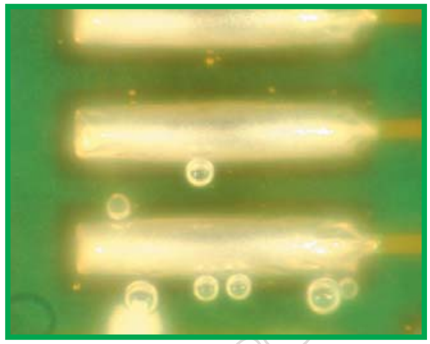

FIGURE 5c: After curing, the bubbles are even larger.

The results of this survey show that underfills that are compatible with a range of solder pastes are available. And, some solder pastes are compatible with a range of underfills. Both strategies are effective at eliminating or minimizing voids related to underfill/flux residue incompatibilities.

Voids from other assembly materials. Voids can also emanate from other materials in the assembly, independent of any underfill/flux residue interactions. For example, voids can emanate from flux residues. In Figures 5a to5c, a glass slide has been placed over an array of pads that have been subjected to a soldering process. **Figure 5a** is an image of the flux residue prior to introduction of an underfill. Bubbles and cavities are present in the flux residue. In **Figure 5b**, the underfill has been introduced but not cured. Bubbles have appeared in the underfill, at the same locations as the bubbles and cavities in the flux residue. In **Figure 5c**, the underfill is cured. The elevated cure temperature has significantly enlarged the bubbles. Air pockets preexisting in the flux residue can be released into the underfill to form significant voids. To prevent the formation of such voids, select a solder paste whose flux completely releases entrapped air prior to hardening. Alternatively, a low-residue solder paste can be selected.

Another major source of voids is from moisture emanating from the board or component. **Figure 6a** shows moisture-induced voids after curing the underfill. The assembly had been stored at ambient conditions for many weeks prior to underfill. To drive off absorbed moisture, another specimen was baked at 125°C for 4 hours prior to underfill. In **Figure 6b**, we see that baking eliminated the moisture-induced voids. Typically, components and boards are supplied pre-dried in humidity-controlled packaging. Moisture is typically absorbed when components and boards are unpacked and left exposed to ambient conditions. To prevent moisture-induced voids, assemblies should be handled to eliminate or minimize moisture absorption. Control the time from unpacking of materials to assembly processing and the time from solder reflow to underfill. If extended storage is required after assembly and before underfill, store assemblies in a dry environment or bake them prior to underfill processing. If the components or boards have already absorbed moisture, baking them at 125°C for 4 hours will remove the moisture.

In a CSP or BGA underfill process there are several potential sources of voids. Careful selection of solder paste and underfill and handling of assemblies is required. Underfill should flow quickly under the component with a flow pattern that does not entrap voids during flow. Upon cure, it should not generate voids from outgassing of low molecular weight constituents.

When selecting materials, one should either select an underfill that is compatible with a wide range of solder pastes or a solder paste that is compatible with a wide range of underfills. A paste whose flux residues creates bubbles should be avoided. These bubbles can be released into the underfill to create substantial voids. Preferably, a solder paste containing a low-residue flux should be selected.

Moisture can be a significant contributor to underfill voids. Controls should be implemented to prevent components and boards from absorbing moisture. ■

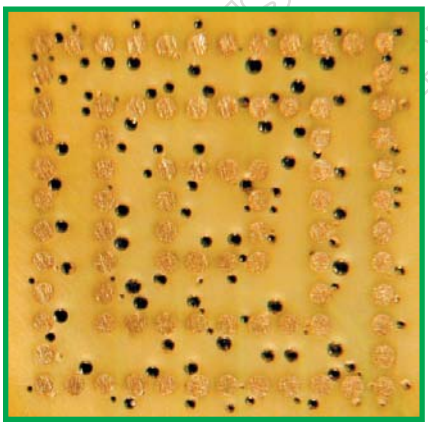

FIGURE 6a: Underfill cured with wet board.

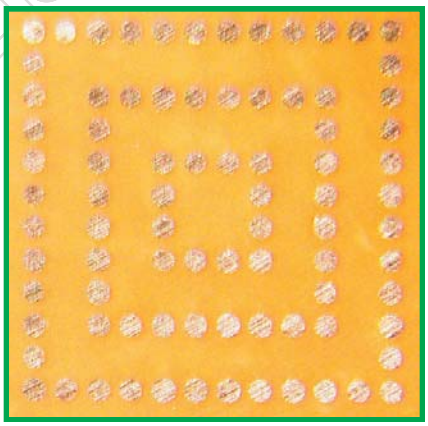

FIGURE 6b: Underfill cured with a baked board.

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