VOIDING CONTROL BENEATH BOTTOM TERMINATED COMPONENTS USING SOLDER FORTIFICATION® PREFORMS

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ABSTRACT
One of the biggest challenges facing the electronics industry today is voiding in the solder joints that connect bottom terminated components to PCBs. This solder voiding, especially on thermal pads, can lead to hot spots and a reduction in the life of the component and the overall assembly. Limited improvement is gained from making modifications to the profile and solder paste alone. Without careful design considerations, it is also difficult to obtain precision in the level of voiding from one component to another. In the past, thermal pad design and the use of thin, custom-sized solder preforms placed into solder paste at the thermal pad have been studied. This paper looks at a new approach using readily available solder fortification® preforms. These preforms are automatically placed into the paste of the thermal pad before the QFN component is placed, forcing the component to sit at an angle to allow for outgassing of flux during reflow before the solder fortification preform melts, then allowing the component to come to rest in its final desired orientation.

It has been determined that this approach can both decrease the level of voiding found in the solder joints beneath bottom terminated components and also decrease the amount of variation in this value. While this paper focuses on this technique when used with SAC305, it is versatile enough to be used with other alloys commonly available in paste and solder fortification preform forms. This method also has the added benefit of being fully compatible with current manufacturing processes, adding only extra placement steps without the need to change reflow profile, equipment, etc. This easy and inexpensive modification to current processes can have a big impact on the reliability of the final product.

Key Words: QFN, bottom termination, void, preform, solder fortification preform, solder paste

INTRODUCTION

Bottom terminated components are currently being used in SMT assembly at a higher rate than ever before. Common components include MOSFETS and IGBTs that act as control switches. A 2011 IHS iSuppli research estimate of the IGBT market in China predicted that revenue would more than double to 975 million USD by 2014[1]. Another common bottom terminated component is the QFN, a key feature of which is the ground pad used for heat dissipation away from the die. Sufficient solder coverage is needed for adequate thermal transfer from the die, into the solder, and subsequently into the board away from the component. Voids create points of poor thermal transfer and hot spots within the component, possibly leading to its early demise.

During the soldering process, volatile components in the flux vaporize. When these volatiles are unable to escape from the body of the solder, they create voids. Bottom terminated components have very low stand-off, meaning the gap between component and board is very small. Large solder paste deposits are enclosed on top and bottom, leaving only a very small amount of surface area around the edges through which volatiles can escape during the soldering process. When gasses are still entrapped as the molten alloy cools and solidifies, voids are left within the solder joint.

Generally, advances in stencil design and profile optimization can reduce voiding. The drawback is that changes in stencil and pad design must be used with a compromise between adequate thermal and electrical conductivity across the joint and a need for control of voiding. Data has shown that it is difficult to maintain consistent voiding under 15%[2,3].

One method of decreasing voiding is to use a soaking profile. This can allow for longer time for volatiles to form and escape, thus reducing voiding in the final solder joint. Studies from Indium Corporation show that a long soak time just below the melting point of the solder alloy can help to reduce voids, but this can have a negative effect on very small components and solder paste deposits[4]. Components include 01005 and 0201 chips along with 0.35 and 0.4mm pitch BGA components. On these components with very small solder paste deposits associated with them, excessive soak could cause graping and head-in-pillow defects. This would result in an unwanted decrease in production yield[5].

Conversely, another study at Indium Corporation has shown that a short ramp-to-peak profile can also limit voiding. In this case, the solder is allowed to melt, form a metallic bond to pads and components, and then cool and harden before volatile solids in the flux are given a chance to vaporize[6]. Figure 1 gives a linear representation of the recommended profiles for lead-free solders.

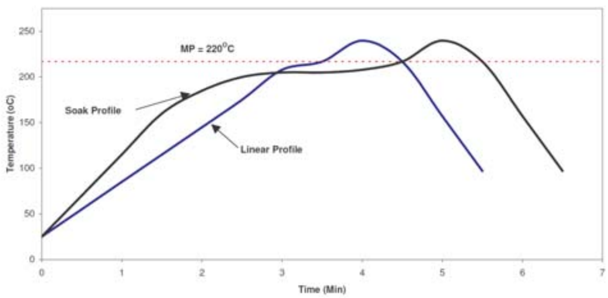

Figure 1. Typical soak and ramp-to-peak profiles used for lead-free solder pastes.

It is clear that from a process standpoint, there is no magic bullet type of process that will decrease voiding to acceptable levels under bottom terminated components in all situations. It can also be noted that solder paste manufacturers produce great variety in their materials. While one solder paste flux vehicle may consistently produce large and numerous voids in these solder joints, others may be quite good in most circumstances. It is always good to work with your solder paste manufacturer to determine the best paste and flux qualities to meet the needs of your application.

Present work focuses on a novel idea that will be compatible with any solder paste used for SMT attachment of bottom terminated components. In this study, solder fortification preforms were placed beneath bottom terminated components in order to provide a twofold benefit, the first being that more solder volume is added to the joint without the addition of flux, and the second being that the preform actually holds the component up off of the majority of the paste in order to allow for more surface area from which volatiles can escape during reflow.

EXPERIMENT

In order to best simulate real-world process conditions, standard solder pastes, test boards, and components were used in this evaluation.

Solder Paste

Indium10.1, a low voiding, SAC305, no-clean solder paste was used in the evaluation. Powder size was Type 4.5 with the metal load optimized for printing.

Test Boards

A dummy test board was used for SMT assembly. Each board was composed of three panels, each containing four QFN components.

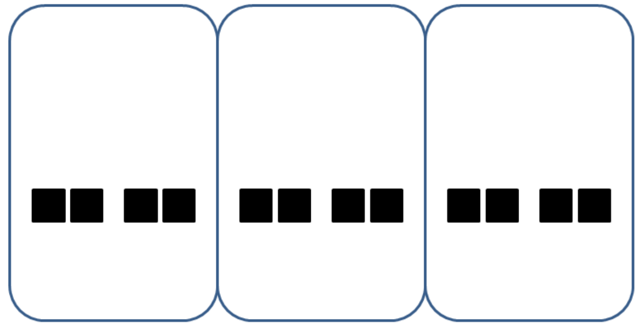

Figure 2. A representative image of the test board used in evaluations along with locations of QFN placements.

Components

Dummy QFN components available from Practical Components were used to represent bottom terminated components. The QFNs were 10mm x 10mm with designation A-MLF68-10mm. The ground plane was a large 7.75mm square.

Solder fortification preforms were also SAC305 alloy and were formed in sizes of either 0.010″ x 0.020″ x 0.010″ (0.254mm x 0.508mm x 0.254mm) (0201) or 0.020″ x 0.040″ x 0.020″ (0.508mm x 1.016mm x 0.508mm) (0402). Preforms were packaged on tape-and-reel for ease of automated placement.

Stencil

The stencil used was a 0.004″ (0.102mm) thick laser cut stencil with a windowpane aperture design on the thermal pads of the QFNs, as seen in Figure 3. The pattern was made up of nine 0.088″ (2.235mm) square apertures with a spacing of 0.020″ (0.508mm) between squares. No nano-coatings were used.

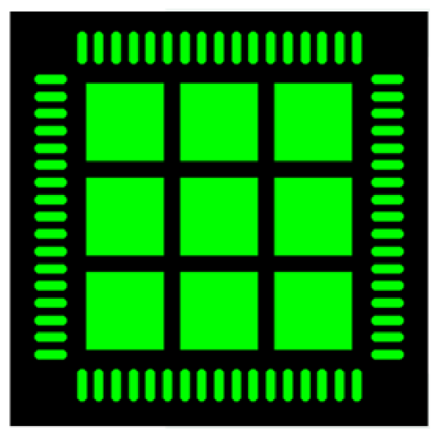

Figure 3. Aperture design for solder paste printing onto PCB QFN pads.

EXPERIMENTAL PROCEDURE

Solder paste was printed onto dummy PCB boards using standard methods. Using automated pick-and-place equipment, solder fortification preforms were placed into the paste deposits on the QFN thermal pads as defined in Figure 4.

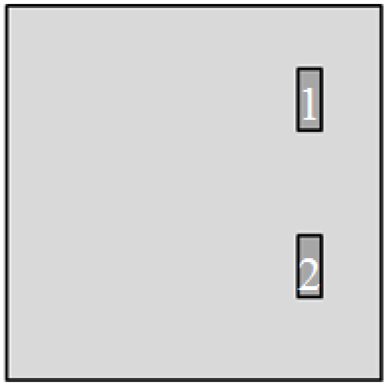

Figure 4. Representation of preform placement on QFN thermal pads. Square represents the entire 7.75mm square thermal pad.

Preform placement was as outlined:

- No preforms placed (Control)
- One 0201, placed at location 1
- Two 0201s, placed at locations 1 and 2
- One 0402, placed at location 1
- Two 0402s, placed at locations 1 and 2

QFN components were placed onto the board in a subsequent step. Since preforms were thicker than the solder paste deposits, QFN components were forced into an angled position due to the driving force of the pick-and-place nozzle competing with the stopping force from the contact with the solder fortification preform.

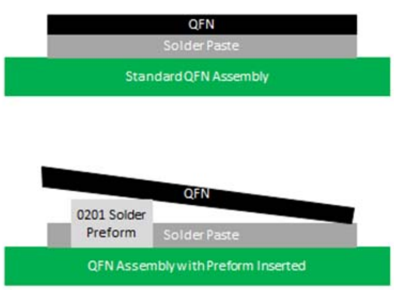

Figure 5. Representation of QFN component when placed with and without a solder fortification preform beneath it.

After component placement, boards were reflowed with a forced air convection oven using a ramp-to-peak linear profile. X-ray was used to examine solder voiding in the die areas of thermal pads under QFNs. Two boards of each characteristic were studied.

RESULTS

An x-ray program was created to ensure that all test boards were examined under the same conditions. Representative x-ray images of voiding for each situation can be seen as follows.

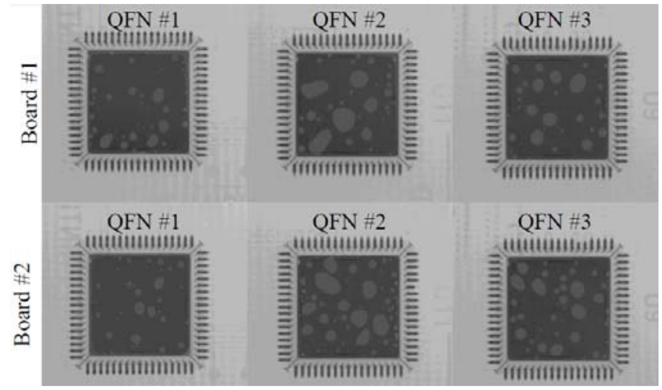

Figure 6. QFNs attached with solder paste, no solder fortification preforms used.

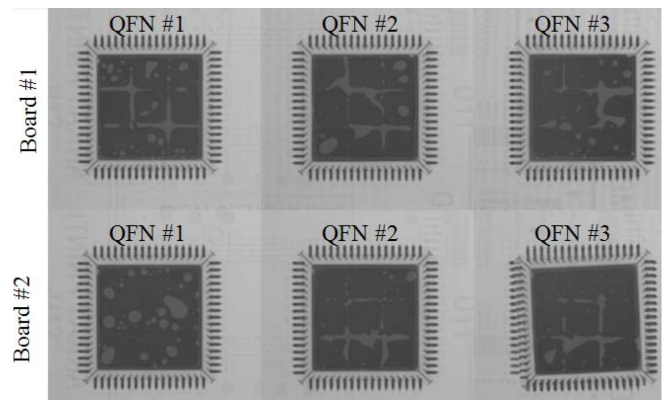

Figure 7. QFNs attached with solder paste, one 0201 solder fortification preform used on each.

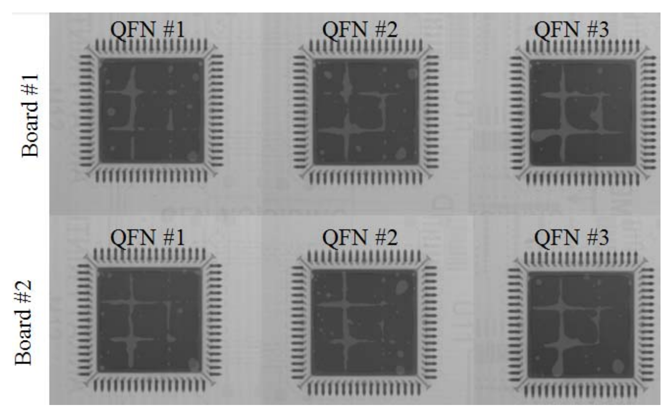

Figure 8. QFNs attached with solder paste, two 0201 solder fortification preforms used on each.

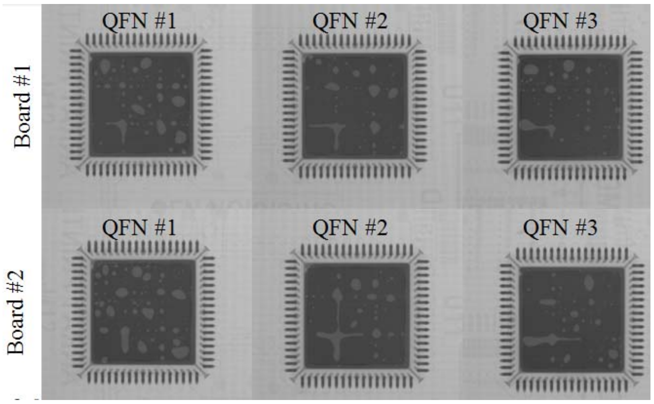

Figure 9. QFNs attached with solder paste, one 0402 solder fortification preform used on each.

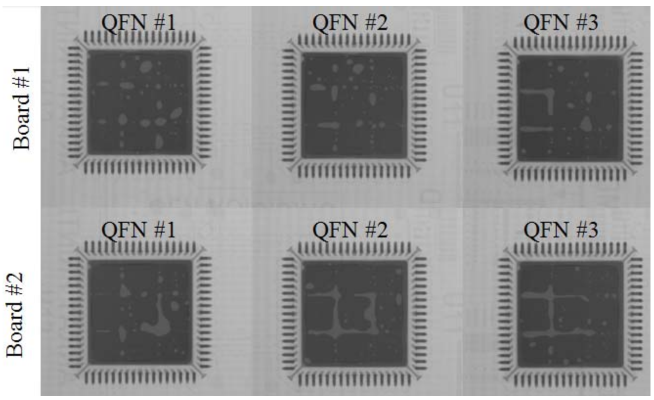

Figure 10. QFNs attached with solder paste, two 0402 solder fortification preforms used on each.

X-ray analysis software was used to determine the percentage of voiding beneath the die area of the QFN in relation to the total area. Findings were charted for ease of comparison.

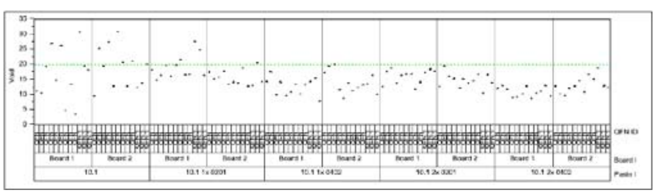

Figure 11. Percentage of the total solder joint under the QFN die that is made up of voids for each test condition.

The chart in Figure 11 shows a data point for each QFN on each board tested with regards to the total percentage of voiding underneath the die area of the QFN. A green line has been placed at 20% to aid in comparison.

DISCUSSION

Examination of the x-ray images taken of the solder joints formed in the study quickly shows an interesting result. Solder joints formed without solder fortification preforms show a solid square of solder coverage across the thermal pad while the solder joints formed with the addition of a solder fortification preform show remnants of the windowpane pattern of the print. It is believed that this is related to the solder fortification preform holding the QFN component up off of the paste until after reflow has begun, thus leaving less chance for capillary action forces to act on the molten solder between the board pad and component pad than in the case with no preform. It can be inferred that the capillary action forces during reflow are stronger than the flow forces of the molten solder and flux that were used.

Also of note when examining the images is that some QFNs became skewed relative to their intended position on the board. After noting this finding the reflowed boards were carefully examined and the number of skews noted.

Preform	Number of Preforms	Number of Skews
None	0	0
0201	1	5
0201	2	0
0402	1	3
0402	2	0

Figure 12. The number of skewed components seen for each condition after reflow out of a total of 24 components.

It was noted that skewing was only seen when one solder fortification preform was used and placed off-center under the QFN. Since the one preform was placed at position 1, as seen in Figure 4, it can be inferred that the preform is acting as a pivot point for the QFN as the placement machine presses it onto the board. In cases where two preforms were placed under the QFN, as indicated in Figure 4, a tilt force was created, keeping the orientation as expected.

Based on the two findings discussed, further work to study the effects of stencil design and preform placement orientation have been planned.

While these results are interesting and relevant, the main goal was to see if the use of solder fortification preforms underneath a QFN component could lead to reduced voiding in the solder joint of the thermal pad. Examination of the results shown in Figure 11 does show a decrease in voiding when solder fortification preforms are used beneath the QFN component. This can be clearly seen using statistical analysis, as shown in Figures 13 and 14.

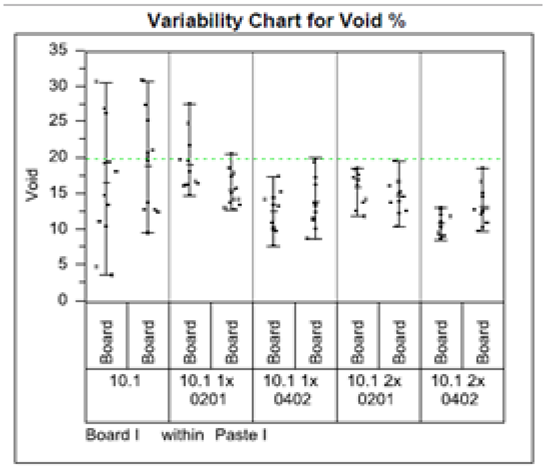

Figure 13. Variability chart of percent voiding in various tested conditions.

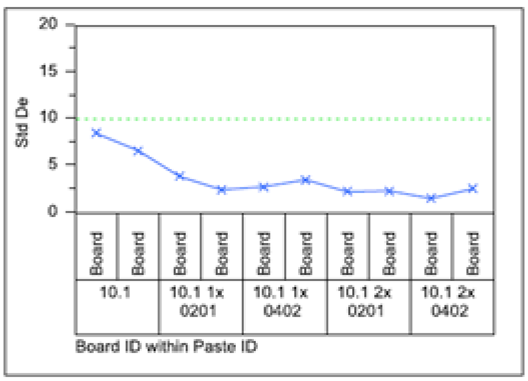

Figure 14. Standard deviation of percent voiding in solder joints examined.

It has been seen in the industry that the percentage of voiding on the thermal pad of a QFN can vary greatly from board to board and component to component, even under the same conditions. In this experiment, when only solder paste was used, percentage of voiding beneath the die did indeed vary greatly. The percentage of voiding ranged from below 5% to greater than 30% with paste alone, as seen in Figure 13. Figure 14 clearly shows that the deviation dropped significantly when a solder fortification preform was used in conjunction with the solder paste.

Figure 13 also shows that voiding decreases by increasing solder volume with the addition of the solder fortification preform. However, a clearer picture is seen when the data is presented in a slightly different fashion, as seen in Figure 15.

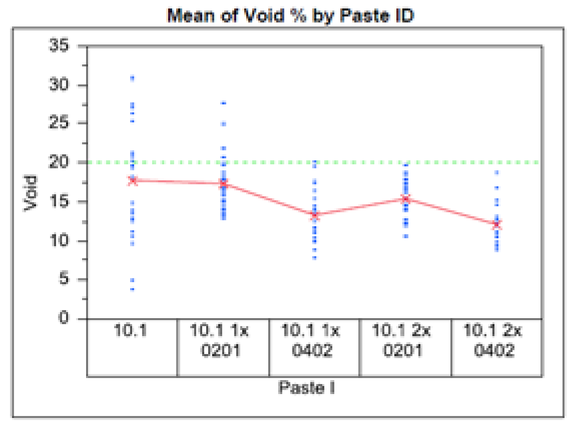

Figure 15. Mean values of percent voiding per condition.

It can be seen in Figure 15 that the value of the addition of 0201 solder fortification preforms is less than that of 0402s. The level of data scattering is greatly diminished with the presence of the preforms, but the mean values of voiding are very similar for paste alone, paste plus one 0201 preform, and paste plus two 0201 preforms. The average voiding seen with the addition of one or two 0402 preforms is visibly lower than with the other conditions.

CONCLUSIONS

It has been determined that the use of solder fortification preforms along with solder paste in the mounting of bottom terminated components to PCBs can aid in the reduction of solder voiding. The solder fortification preforms act to hold up one side of the bottom terminated component to allow for outgassing of the solder paste before the alloy melts and allows the component to come to rest on the paste surface.

Variability seen in the level of voiding from component to component is diminished with the use of solder fortification preforms as described in this work. Due to the observance of skewing when only one preform was placed off-center, it is recommended that two components placed along one edge of the pad be used. The use of 0402 preforms was found to be more effective at reducing voiding than when 0201 preforms were used.

This method of reducing voiding under bottom terminated components is desirable because solder fortification preforms are readily available for use in automated processes. Since placement equipment is most likely already being used, all that is needed is a reel of preforms and some additional placement steps in the current process. This easy addition to the process has been shown to provide very beneficial results.

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