# Fill the Void VI: A Study of the Impact of Solder Alloy on Voiding in Solder Joints

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**ABSTRACT**

Voiding in solder joints is an ongoing concern for printed circuit board assembly (PCBA) manufacturers and original equipment manufacturers (OEMs). Voiding can lead to electrical circuit interference, thermal dissipation issues, and potential mechanical weakness in the solder joint. Several papers have presented reliability data showing that voids in solder joints do not cause issues unless the voiding is excessively high or concentrated on one plane within the solder joint. As bottom terminated components (BTCs) become increasingly popular, the potential for voiding in solder joints has increased. One major concern with voids in solder joints is the difficulty of rework. It can be challenging to reduce voiding through traditional rework processes. Voiding limits are often imposed on PCBA manufacturers for specific components. These voiding concerns lead electronics manufacturers to find ways to minimize voiding potential.

This paper is the 6th paper in a series of Fill the Void papers on the topic of reducing voiding in solder joints. There are two major mechanisms for void formation. The first mechanism for void formation is gas entrapment in the solder joint. Entrapped gasses come from volatile materials in the flux, air gaps in the solder paste print, and gasses from PCB and component residues. The second mechanism for void formation is incomplete wetting or flow of the solder. When the solder alloy does not completely wet both the PCB pads and component leads, gaps in the solder joint are not completely closed with solder. The solder alloy chosen has an impact on both gas entrapment and wetting or flow. Different alloys have different densities and surface tensions which impacts the ability of gasses to escape the solder joint. The solder alloy also impacts the wetting or flow and the ability to close the gaps to create a solder joint.

In this work, voiding was studied with respect to solder alloy and stencil design. Several solder alloys were tested including Sn63/Pb37, SAC305, SN100CV (SnBiCuNi), and LF-C2 (SnAgBiCu). These alloys were used in the same solder paste flux medium, and with the same reflow profile to determine the effects of solder alloy on voiding. QFNs with a 10 mm body were used and voiding was measured in the thermal pad solder joints. Prior work has shown that increasing the gap size in the solder paste print can increase voiding. The stencil design was varied on the thermal pads to determine how gap size (web width) affects wetting and flow of the solder alloy. The data was summarized, and recommendations given to help the reader to "Fill the Void."

Key words: voids, solder joint, solder alloy, quad-flat no-lead component (QFN), thermal pad, stencil design.

**INTRODUCTION**

Voiding in solder joints is a common issue for many PCBA manufacturers (Figure 1).

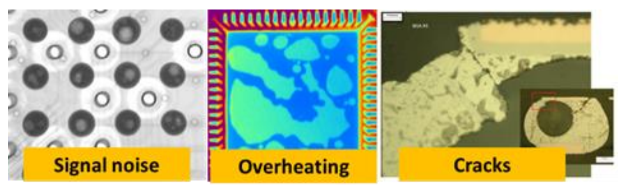


**Figure 1**. Voids in solder joints.

Voids in solder joints can lead to signal noise, component overheating, and potentially cracks in the solder joints. These issues are also caused by many other things besides voids. PCBA manufacturers often have void limits imposed by their customers, which may be tighter than limits from industry standards. Common void limits from IPC standards are shown below:

IPC J-STD-001H [1] & IPC-A-610G [2]
- 30% max area in BGAs
- 50% max area in QFN thermal pads

IPC-7093A BTCs [3]
- < 30% area typical on thermal pads (J-STD-001)

IPC-7095C BGAs [4]
- < 25% area and < 50% diameter Class 1&2
- < 20% area and < 45% diameter Class 3

Void limits may have a connection to a history of solder joint failures or may be imposed as a safety factor to prevent possible failures. In either case, PCBA manufacturers are required to meet voiding limits which can be challenging. There are many ways to mitigate voiding in solder joints, including modification of stencil design and choosing solder alloys with low voiding potential.

It is understood that solder pastes show different spread behaviors during reflow and have varying ability to close gaps between the printed solder paste bricks. Part of the

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spreadability of solder paste comes from the solder alloy portion of the solder paste which makes up 85 to 90% by weight of the solder paste. Solder alloys have different metallurgical properties which lead to different spread abilities during reflow (Table 1).

**Table 1**. Solder alloy properties.

| Property | Sn63/Pb37 | SAC305 | SN100CV | LF-C2 | TS B37 | Measuring method |
|---|---|---|---|---|---|---|
| Melting Range (°C) | 183 | 218-219 | 221-225 | 208-213 | 139-174 | DSC : 2°C/min 30-300°C JISZ3198-1 |
| Composition | Sn63/Pb37 | Sn3Ag0.5Cu | Sn1.5Bi0.7CuNi | Sn3.5Ag3Bi1Cu | Sn37BiX | |
| SG | 8.4 | 7.4 | 7.4 | 7.5 | 8.1 | @20°C |
| Tensile strength (MPa) | 53 | 48 | 52 | 90 | 99 | 10mm/min @25°C |
| Elongation (%) | 32 | 33 | 33 | 16 | 20 | 10mm/min @25°C |
| ε 0.2% (MPa) | 16 | 41 | 39 | 61 | 81 | 10mm/min @25°C |
| Young's modulus (GPa) | 32 | 51 | 56 | 55 | 47 | JIS Z2280 |
| Thermal expansion (ppm/K) | 25 | 23 | 24 | 24 | 22 | -40 - +150°C |
| Thermal conductivity (W/m·K) | 50 | 58 | 54 | 53 | | Laser flush |
| Thermal mass (J/(kg·K)) | 150 | 219 | 224 | 232 | | Laser flush |
| Electric conductivity (μΩm) | 0.14 | 0.14 | 0.14 | 0.16 | | 4 terminal bridge |

The stencil pattern used to print the solder paste plays a role in the spreadability of the solder paste. Webs are used in the stencil design for larger thermal pads to break up the printed solder paste area into smaller bricks (Figure 2).

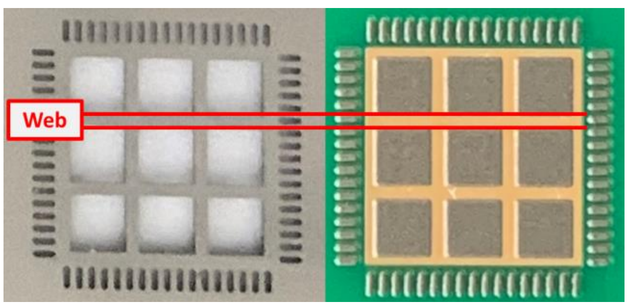



**Figure 2**. Web gaps in the stencil and solder paste print.

Webs in the stencil create gaps in the solder paste print. Gaps in the solder paste print reduce the volume of solder paste which reduces potential for float or skew of the component and reduces the risk of bridging between the thermal pads and I/O pads. Web gaps also allow for gas escape routes which minimize voiding potential. In some cases, the stencil design may create gaps in the printed solder paste that are too wide or have too much area to successfully close during reflow. This leads to voiding in the solder joints.

Stencil manufacturers typically design stencils to optimize the solder paste print process with respect to certain defects, like voiding. Stencil manufacturers do not know which solder paste is being used, or the spreadability of that solder paste. Therefore, the stencil design may create situations where the solder paste will not be able to completely fill the gaps, and lead to high voiding in the solder joints.

The intent of this work was to vary the web (gap) widths in the printed solder paste for QFN thermal pads, and to determine how different solder alloys spread to fill those gaps. Different solder alloys also have different potential to trap gasses which affects voiding. Voiding in the solder joints was used as the metric to determine the ability of the solder alloy to release gasses and fill the gaps. The overall goal is to find methods to "Fill the voids" in solder joints.

**PRIOR WORK**

Lentz and Smith [5] tested voiding in QFN thermal pad solder joints with 4 stencil designs including a standard 9-window pane, a diagonal window pane, a 5-dot pattern, and a diagonal stripe pattern. The area of coverage of printed solder paste was 65% of the thermal pad. Two solder pastes with SAC305 alloy and two reflow profiles were tested. The voiding was lowest for 3 of the 4 stencil designs while the others showed similar voiding levels. Voiding was lowest for one solder paste coupled with one reflow profile.

Lentz, Chonis, and Byers [6] studied voiding in QFN thermal solder joints with a host of variables. Some of the variables included several different solder pastes made with SAC305 alloy in type 3, 4, and 5 solder powder sizes, and two different solder powder manufacturers. 4 stencil designs were tested including a standard 9-window pane, a diagonal window pane, a 5-dot pattern, and a diagonal stripe pattern. The area of coverage of printed solder paste was 64-65% of the thermal pad. Several reflow methods were tested including vapor phase with vacuum. Voiding was lower for some stencil designs, solder pastes, solder powder sizes, and some reflow methods. Vacuum reflow overcomes most of the other variables and resulted in very low voiding.

Lentz [7] analyzed voiding in QFN thermal pad solder joints with a large set of variables. Some of the variables were as follows:

- Solder alloy was varied including SAC305 alloy, SN100C® alloy, SN100CV® alloy and a mixture of SAC305/SN100C alloys.
- QFN68s and QFN48s were used, and the stencil designs were varied for each. The area of coverage was 65% and 50% on the QFN68s and QFN48s respectively.
- A second stencil design was used which varied the number of windows, window size and area of coverage. Web width was held constant at 8 mils.

Solder alloy influenced voiding, and the lowest voiding tended to be generated by the alloys with the widest melting ranges. Stencil design also had an impact on voiding, with higher area of coverage generating lower voiding levels.

Lentz and Smith [8] tested voiding for two sizes of QFN thermal pad solder joints with via hole in pad designs. The solder paste used was a no clean with SAC305 alloy. Two via hole plugging methods were used and compared to open via holes as well as flat thermal pads with no via holes. The stencil designs included a standard 9 window pane with 65% area of coverage and a 20-mil web width, and a modified design which printed solder paste around the via holes and allowed for via gasses to escape, with 65% area of coverage and an 8-mil web width. Voiding was lower for the larger QFN68 than for the smaller QFN48 regardless of stencil design. Inclusion of open vias or partially tented vias in the thermal pad reduced overall voiding regardless of stencil design. Printing solder paste around the vias reduced the amount of flow of solder to the bottom of the PCBs and had a slight effect on reduction of voiding.

Smith and Lentz [9] studied voiding in solder joints for a variety of BTCs and varied the stencil design to minimize voiding. A commercially available no-clean SAC305 solder paste was used. Printed solder paste area of coverage on the thermal pads was varied from 80 to 50%. The stencil designs included largest web, standard web, largest perimeter, and most window panes. The web width, perimeter gap, and number of window panes were varied to achieve these stencil designs. Lower voiding was observed with higher area of coverage. The largest perimeter and the narrower web designs gave lower voiding levels. It should be noted that a QFP144 with a "belly" pad generated high levels of voiding regardless of stencil design, while the QFN voiding levels could be minimized through stencil design.

Lentz and Smith [10] revisited voiding in solder joints for a variety of BTC components. Stencil designs were varied including: 4 and 5 mil thick stencils, 60 and 70% area of coverage, and the printed volume on QFN I/O perimeter pads. The web width was 20 mils, and the number of panes was kept at 4 for most of the components. Five different reflow profiles were used along with a no clean SAC305 solder paste. Voiding was lower for the 5-mil thick stencil, 70% area of coverage, and for the larger QFN sizes. As printed volume was increased on the QFN I/O perimeter pads, voiding decreased. In general, increasing the volume of solder paste on the thermal pads leads to less voiding.

Hillman, et. al., [11] studied how BTC voiding related to component reliability. 4 solder alloys were tested including Sn63/Pb37, SAC305, and two high-reliability Pb-free alloys. Four different QFN's were daisy chained on a 10-layer test PCB which mimicked a real PCB. Thermal cycling was done from -55 to +125 °C for 3000 cycles. Failure rates were correlated to void area percentage (%). Sn63/Pb37 gave the lowest overall voiding levels, but this did not correlate to higher reliability. The Pb-free alloys had higher overall voiding levels, but again this did not indicate lower reliability. Overall, the correlation between voiding and reliability was very weak. A proposed voiding limit for thermal pads was given as established between the user and manufacturer. When a limit is not established, then the soldered connection shall be larger than 50% of the thermal pad area, and this is a process indicator for Class 2 and 3 PCBs.

## EXPERIMENTAL METHODOLOGY

The goal of this work was to determine the effects of solder alloy coupled with stencil design on voiding in solder joints. The theory is that the leading causes of voiding are gas entrapment and poor wetting or spread of the solder alloy. There are many other factors that can influence voiding, so the experiment was designed to isolate solder alloy and stencil design as the only variables.

A commercially available no-clean Pb-free flux medium was chosen, and a SAC305 reflow profile was run for comparison of all alloys. The solder alloys evaluated include: Sn63/Pb37, SAC305, SN100CV (Sn1.5Bi0.7CuNi), LF-C2 (Sn3.5Ag3Bi1Cu) and TempSave B37 (Sn37BiX). SN100CV is a silver-free alternative for SAC305, and both use the same reflow profile. LF-C2 is a high reliability alloy designed for automotive applications and typically reflows in a profile similar to SAC305. TempSave B37 is a low temperature, Pb-free alloy designed to reflow in a profile like Sn63/Pb37.

Solder paste reflow performance was evaluated using the PR test board V3 (Figure 3).

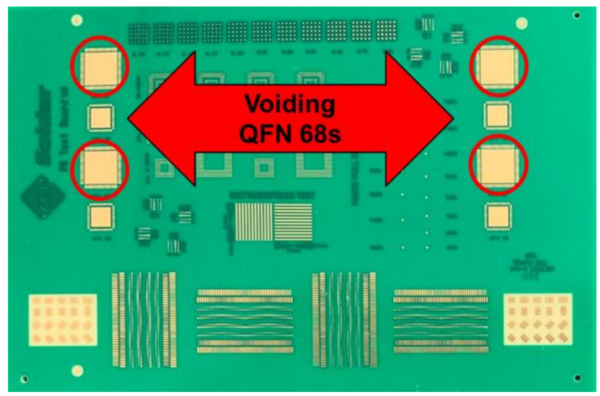



**Figure 3**. PR test board V3 from FCT Solder.

The PR test board V3 is made from 1.57 mm (0.062 in) thick FR-4 laminate with an ENIG surface finish. This PCB was used to quantitatively measure wetting, solder balling, graping, and voiding in QFN68 thermal pads [12]. The QFN68 "dummy" components have a square 10 mm body size and an 8.3 mm square thermal pad.

Wetting was measured as a spread test down a long circuit line, with increasing gap size between the printed solder paste bricks. As the solder spreads down the lines, the gaps between solder paste bricks close indicating good wetting. Solder balling is measured by evaluating random microscopic solder balling that occurs when solder paste pulls back from solder mask. Fewer solder balls indicate good performance. Graping is measured using a range of very small solder paste deposits on varying pad sizes and designs. Fewer solder deposits showing graping indicate good performance.

The normally used web width for the QFN68 thermal pad is 508-microns (20 mils) and the printed solder paste bricks are 2286-microns (90 mils) square. The web width was varied to narrower and wider gaps from the norm. The stencil designs evaluated included 4 different web widths:

254, 381, 508, and 635 µm (10, 15, 20, and 25 mils respectively). Each stencil design had the same area of coverage of solder paste on the thermal pad at 65%. The QFN68 thermal pad stencil designs are shown below (Figure 4).

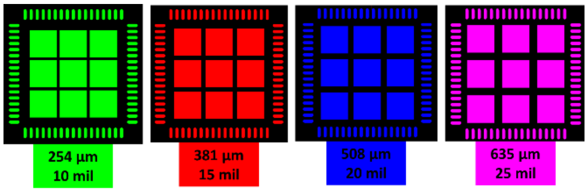



**Figure 4**. QFN68 Stencil Designs in the Thermal pads.

Printing was performed on a DEK Horizon 02 printer. The printing process parameters are listed in Table 2 below.

**Table 2**. Printing process parameters.

| | |
|---|---|
| Print speed (mm/sec) | 30 mm/sec |
| Blade length (mm) | 300 mm |
| Print pressure (kg) | 5.0 kg |
| Separation speed (mm/sec) | 3 mm/sec |
| Separation distance (mm) | 1 mm |
| Stencil thickness (µm) | 127 microns |
| Stencil material | Fine grain stainless steel |

Reflow was performed in a 7-zone Heller 1707EXL convection oven with an air atmosphere. The reflow profiles used were linear ramp to spike (RTS) type profiles and the measured data is in Table 3 below.

**Table 3**. Reflow profile parameters.

| **Parameter** | **SAC305 RTS** | **Sn63/Pb37 RTS** | **TempSave B37 RTS** |
|---|---|---|---|
| Time above Liquidus | 57-59 sec > 220 °C | 67-70 sec > 183 °C | 75-77 sec > 174 °C |
| Peak temperature | 241-244 °C | 208-210 °C | 200-203 °C |
| Time from 25 °C to peak | 4.4-4.6 min | 3.6-3.7 min | 4.8-5.0 min |

The SAC305 profile was used for the bulk of the testing. The Sn63/Pb37 reflow profile was run with the Sn63/Pb37 solder paste only on 1 test iteration for a comparison with the SAC305 profile. The TempSave B37 profile was run with the TempSave B37 solder paste only on 1 test iteration for a comparison with the SAC305 profile. The SAC305 profile was run for all other solder paste and stencil combinations and the reflow profile graph is in Figure 5.

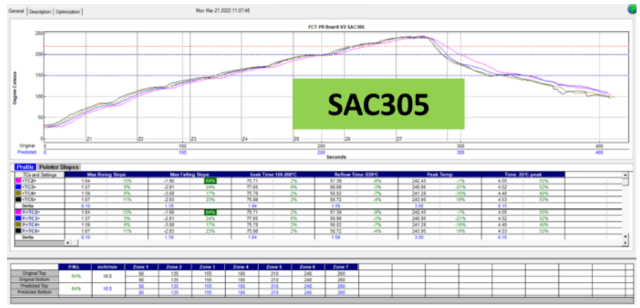



**Figure 5**. Linear RTS Reflow profile for SAC305.

5 solder pastes, each with a different alloy, were run with 4 stencil designs which gave a total of 20 combinations. 5 test boards were run for each solder paste and stencil combination, and 4 dummy QFN68 components were placed on each board. There were a total of 20 void measurements for each combination, which gave statistically significant results.

Voiding area % was evaluated using a 2D X-ray on the QFN68 thermal pad solder joints for each combination of solder paste and stencil design. Void area % levels were compared using statistical analysis software. Tukey-Kramer means comparison was done to determine significance of the differences in voiding.

A simple reflow test was conducted to measure the time between initial heating and the last gas bubble to escape the molten solder (Figure 6).

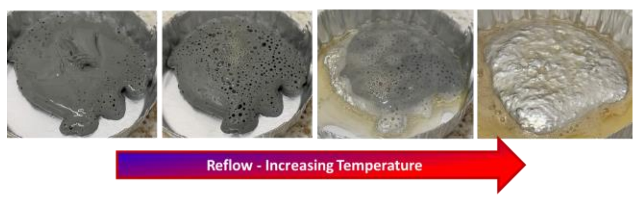



**Figure 6**. Solder Paste Melting and Gas Entrapment

20 +/- 0.2 grams of solder paste was placed in an aluminum weigh dish. The solder paste was heated on a hot plate at a temperature roughly 60-70 °C above the melting point of the alloy. The hot plate temperature used for Sn63/Pb37 and TempSave B37 alloys was 250 °C. The hot plate temperature used for all other alloys was 280 °C. The time was measured between placement of the aluminum weigh dish on the hot plate and the last gas bubble escaping from the molten solder. The time for gas escape was correlated to the voiding levels from each solder alloy.

## RESULTS AND DISCUSSION

### Solder Paste Reflow Performance

Wetting, solder balling, and graping performance were measured for each solder paste using the patterns on the PR test board run in the SAC305 reflow profile. These metrics were averaged from patterns on 2 test boards from each set of test boards. The results are reported as performance (%)

for each solder alloy in Figure 7 below. Ideal performance is 100% in each category.

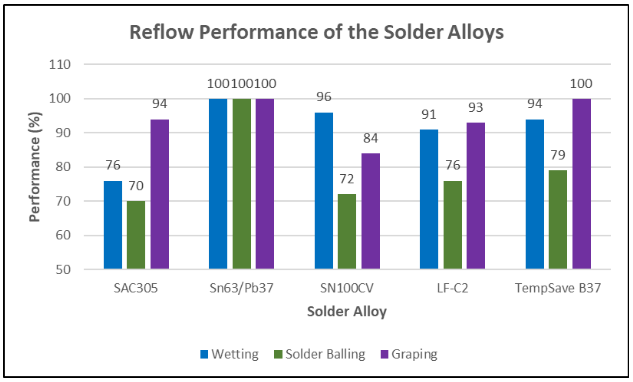



**Figure 7**. Wetting, solder balling, and graping performance for each solder alloy using the SAC305 reflow profile.

Sn63/Pb37 gave optimal reflow performance in all three categories of wetting, solder balling, and graping, and was better overall than the Pb-free alloys. Amongst the Pb-free alloys, SN100CV showed the best wetting, and TempSave B37 showed the best solder balling and graping performance. SAC305 had good graping performance, and LF-C2 did well in both wetting and graping.

A bare board without QFN components was run for each solder paste and stencil combination in the SAC305 profile. Pictures of the QFN thermal pads were taken to compare solder spread behavior with respect to the gap sizes in the stencil design. The pictures are shown below (Figure 8).

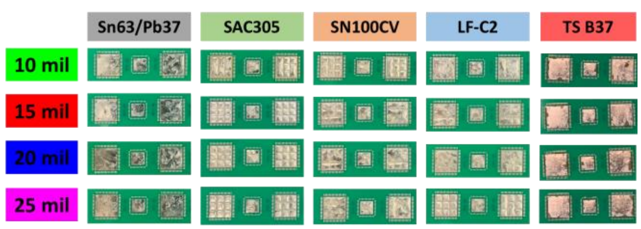



**Figure 8**. Solder spread in the QFN thermal pads for each solder alloy and gap size.

Sn63/Pb37 and TempSave B37 spread fully and leveled the solder deposits for all gap sizes. SAC305 shows distinct brick shapes which did not level out. As gap size increased, the SAC305 brick shapes became more distinct indicating less spread. SN100CV showed the best leveling of the remaining Pb-free solder alloys. The brick shapes in the SN100CV thermal pads are faintly visible and show areas of leveling for each gap size. LF-C2 also showed good spread and leveling behavior for the 10, 15, and 20 mil gaps, but there are faint brick shapes visible in the 25-mil gap pattern.

The wetting performance measured on the PR test board for each alloy matched the observed spread in the QFN thermal pads. Here is the order of wet and spread behavior ranked from best to worst: Sn63/Pb37, TempSave B37, SN100CV, LF-C2, and SAC305.

**Voiding Performance**

Voiding data separated by solder alloy is shown below (Figure 9) Each box plot includes all stencil gap widths. Ideal performance is 0% void area.

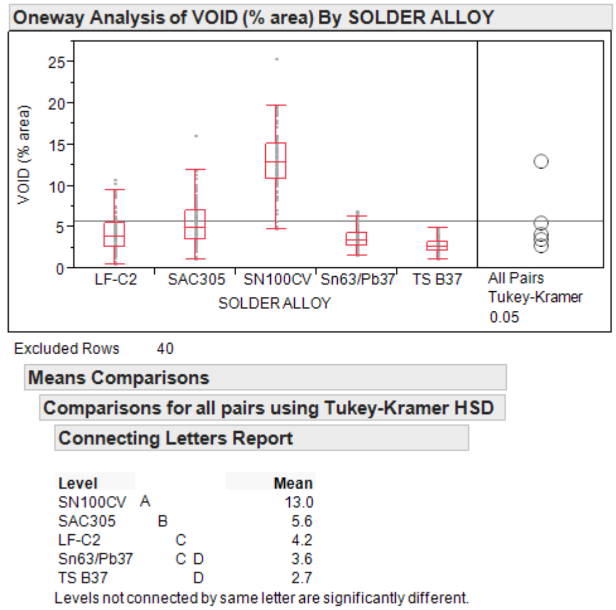



**Figure 9**. Voiding by solder alloy including all stencil gaps.

Voiding was highest for SN100CV, which was statistically higher than all the other alloys. SAC305 had the 2nd highest voiding and was statistically higher than LF-C2, Sn63/Pb37, and TempSave B37 alloys. LF-C2 and Sn63/Pb37 had statistically similar voiding levels. TempSave B37 had the lowest overall voiding.

It is apparent from this ranking of void behavior by solder alloy that wet and spread of an alloy is not necessarily a good predictor of voiding potential. SN100CV showed good wet and spread behavior, but the worst overall voiding. Poor wetting is only one possible cause for voiding in solder joints. Gas generation and entrapment is another major cause of voiding. The flux used in the solder paste has a large influence on both wetting and gas generation and can overshadow the voiding potential of the solder alloy.

In the simple reflow test on a hot plate, the time from initial heating of the solder paste to the last gas bubble to escape the molten solder is in table 4 below.

**Table 4**. Time from initial heating to the last gas bubble to escape the molten solder.

| Solder Alloy | Time for Gas Bubble Escape (sec) |
|---|---|
| LF-C2 | 300 |
| SAC305 | 270 |
| SN100CV | 450 |
| Sn63/Pb37 | 160 |
| TempSave B37 | 100 |

The time for gases to escape the molten alloy correspond to the voiding levels for each alloy, except for LF-C2. LF-C2 was ranked lower in wetting ability than most of the other alloys and has the 2nd longest time for gas bubbles to escape but gives low voiding. SN100CV alloy has a greater potential to trap gases than the other alloys, which correlates to the high voiding levels for this alloy. This potential to trap gasses overcomes the effects of good wetting with respect to voiding. Sn63/Pb37 and TempSave B37 have a lower potential to trap gasses than the other alloys, and better wetting than the other alloys, and consequently voiding was low for these alloys.

A graph was made (Figure 10) to correlate gas escape time to voiding area %. The mean void areas from Figure 9 were plotted against the gas escape time from Table 4.

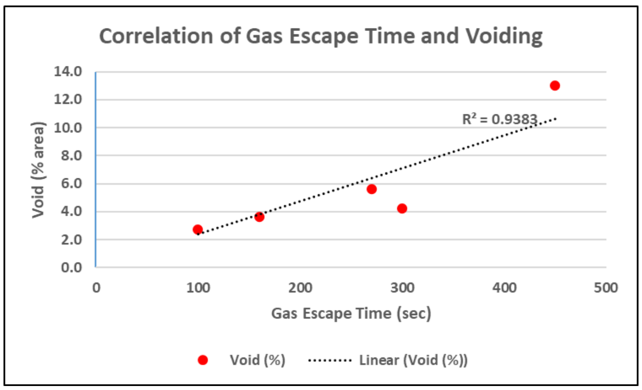
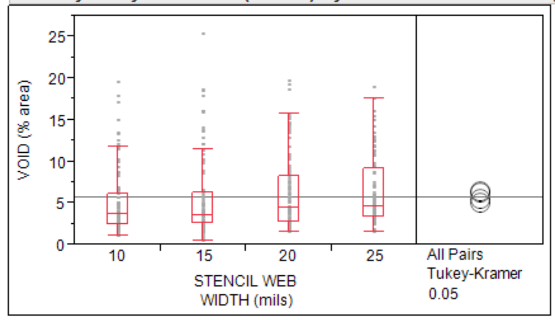



**Figure 10**. Correlation of gas escape time to voiding.

This correlation of void area to gas escape time is close to linear with an $R^2$ value of 0.94. This simple test of measuring gas escape time by reflowing solder paste on a hot plate will have to be investigated further to determine if it is a reliable predictor of voiding behavior.

Voiding data analysis broken out by stencil gap (web) width is shown below (Figure 11). Each box plot includes all solder alloys.

Oneway Analysis of VOID (% area) By STENCIL WEB WIDTH (mils)




Excluded Rows 40

Means Comparisons

Comparisons for all pairs using Tukey-Kramer HSD

Connecting Letters Report

| Level | | Mean |
|---|---|---|
| 25 | A | 6.4 |
| 20 | A | 6.2 |
| 15 | A | 5.5 |
| 10 | A | 5.1 |

Levels not connected by same letter are significantly different.

**Figure 11**. Voiding by stencil web width including all solder alloys.

This overall look at voiding by stencil gap width shows no difference in voiding, when averaging the data for all the alloys. A closer look at voiding by solder alloy broken out by web width gives a better understanding of the data.

Voiding by solder alloy broken out by web width is shown below (Figure 12).

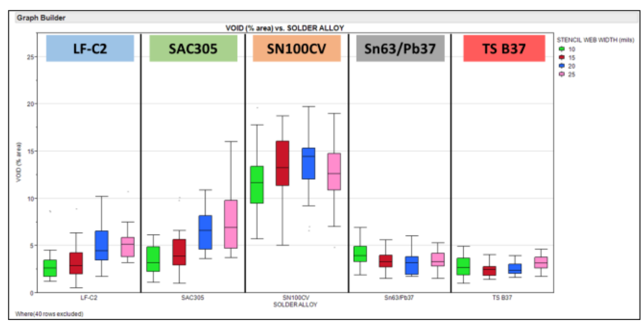



**Figure 12**. Voiding by solder alloy broken out by web width. Green = 10 mil, Red = 15 mil, Blue = 20 mil, and Pink = 25 mil.

LF-C2 and SAC305 show increasing voiding with increasing web width. SN100CV gave the highest overall voiding and shows a slight trend of increasing voiding with increasing web width. Sn63/Pb37 and TempSave B37 show very little difference in voiding by web width.

Statistical analysis of voiding for each solder alloy broken out by web width is shown below (Figure 13).

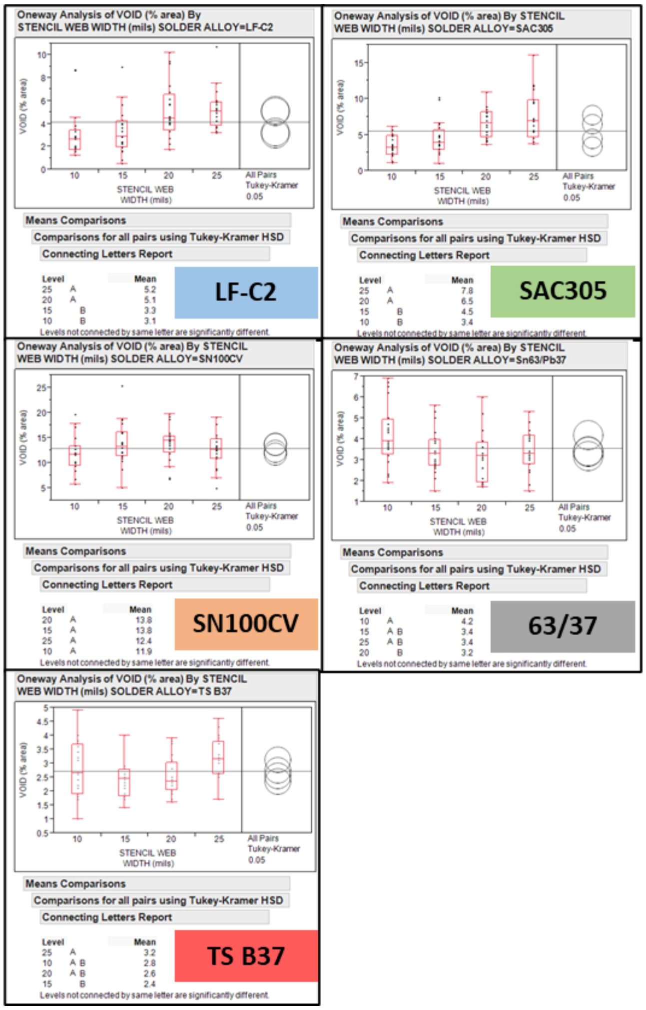



**Figure 13**. Statistical analysis of voiding by solder alloy broken out by web width.

LF-C2 and SAC305 showed similar voiding response to changes in web width. The 25 and 20-mil gaps gave statistically higher voiding than the 15 and 10-mil gaps. The alloys were able to close the smaller gaps better than the larger gaps during reflow.

SN100CV showed statistically similar voiding levels for each stencil gap width and the voiding levels were the highest of the alloys tested. Gap width did not affect voiding for SN100CV alloy which indicates that the voiding is related to a root cause that overcomes the effects of wetting.

Sn63/Pb37 shows slightly higher voiding for the 10-mil gap than the 20-mil gap. The other gap sizes gave statistically similar voiding. The voiding data for Sn63/Pb37 is very low overall and these differences by web width are minor.

TempSave B37 shows slightly higher voiding for the 25-mil gap than the 15-mil gap. The other gap sizes gave statistically similar voiding. The voiding data for TempSave B37 is very low overall and these differences by web width are minor.

A comparison was made of voiding for Sn63/Pb37 solder alloy in the Pb-free SAC305 profile to a standard Sn63/Pb37 reflow profile. The stencil with the 20-mil web width was used for this comparison, and the void data analysis is shown below (Figure 14).

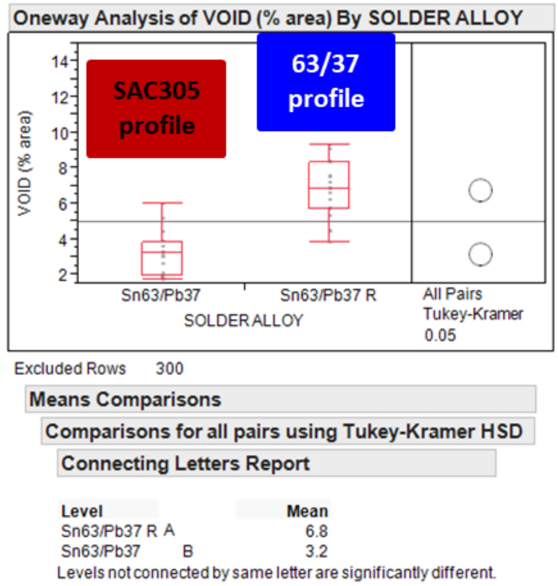



**Figure 14**. Voiding for the Sn63/Pb37 solder paste and the 20-mil stencil web, comparing the SAC305 profile and Sn63/Pb37 profile. The Sn63/Pb37 profile is denoted by an "R" after the alloy.

Sn63/Pb37 solder run with the SAC305 reflow profile gave statistically lower voiding than with the Sn63/Pb37 reflow profile. This may be due to the use of a Pb-free solder paste flux medium for this testing. Pb-free fluxes are designed to be used in higher temperature and longer reflow profiles than Sn/Pb fluxes. Pb-free fluxes run in a Sn63/Pb37 reflow profile could release gaseous materials later in the reflow cycle leading to a greater possibility of gas entrapment.

A similar comparison of reflow profiles was done with TempSave B37 solder alloy. This low temperature Pb-free alloy was run in a SAC305 profile and compared to a standard low temperature Pb-free reflow profile and voiding was determined. The stencil with the 20-mil web width was used for this comparison, and the void data analysis is shown below (Figure 15).

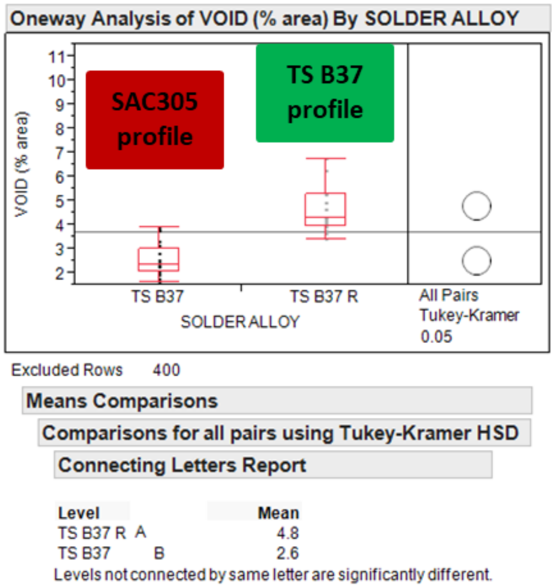



**Figure 15**. Voiding for the TempSave B37 solder paste and the 20-mil stencil web, comparing the SAC305 profile and TempSave B37 profile which is marked with an "R".

TempSave B37 solder paste run with the SAC305 reflow profile gave statistically lower voiding than with the lower temperature TempSave B37 reflow profile. The lower temperature and shorter reflow profile could release gaseous materials later in the reflow cycle leading to a greater possibility of gas entrapment resulting in higher voiding.

## CONCLUSIONS

Voiding in solder joints is a complex issue that has been studied for many years. There are multiple causes for void formation in solder joints. Two of the most likely causes of voiding are entrapment of gaseous materials, and poor spread or wetting of the solder paste.

This study confirmed that voiding differs by solder alloy. Some Pb-free alloys, like LF-C2 and TempSave B37, approach the low voiding potential of Sn63/Pb37 alloy in QFN thermal pad solder joints. Increasing web width tends to increase voiding potential for some solder alloys. SAC305 gave low voiding results with narrower gaps, but the voiding levels increased for the higher gaps likely due to the limited wetting ability of SAC305. Changing web width had no effect on the voiding of alloys with very low voiding potential, like Sn63/Pb37 or TempSave B37. Alloys with higher voiding potential, like SN100CV, also overcame the influence of stencil web width on voiding. Voiding was influenced through changing reflow profiles for the same solder paste and alloy.

Based upon this work, here are recommendations to "Fill the Void". Choosing solder alloys with lower voiding potential may be helpful at reducing voids in solder joints. Changing solder alloys may not be possible if certain alloy properties are of greater importance, e.g., customer requirements, thermal cycling reliability, etc. Changing stencil designs is a more common method of affecting voiding. Use of smaller stencil web widths in thermal pads can have a big impact on voiding. Modification of the reflow profile can reduce voiding potential for a specific solder paste and alloy. Hopefully this data is useful in helping the "Fill the Void."

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