Investigating the Metric 0201 Assembly Process

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Abstract

The advance in technology and its relentless development is delivering yet anothersurface mount assembly challenge. To meet the market demand for products with higher functionality whilst reducing the overall product size, the next generation of chip package isbeing readied upon the surface mount community. The Metric 0201 will have dimensions in the order of 0.25mm x 0.125mm, as a result the entire assembly process will be questioned as to its ability to deliver high volume/quality product.

This paper will look at the challenges of assembling the M0201 component in a high-volume manufacturing environment. The investigation will start with the printing process, with close attention to the impact of aperture and pad designs. The placement and reflow process will likewise be studied in detail.The resultant assemblies will be reviewed todeterminetheir suitability for a high-volume manufacturing environment. Discussion and conclusions will be directed at possible Metric 0201 assembly rules and the future challengers that exist.

Introduction

The impending introduction of the Metric 0201 component into the high-volume mobile communications sector is causing the Surface Mount Technology (SMT) community to ask questions of how this will affect the assembly process.The three main elements of the SMT process are, Printing, Placement and Reflow; within this paper each element will be investigated individually.

Within the printing process a stencil thickness of 60µm will be used. This foil thickness is the minimum that is compatible with the heterogeneous requirements for the mobile communications sector.To obtain a comprehensive understanding of the process window associated with the assembly process of Metric 0201, two solder paste materials will be evaluated along with three component interspaces and two pad designs. The solder paste materials will have two different grain sizes whilst the pad designs will include two different footprintsand three pad to pad interspacedimensions.

Experiment

The Supplier, Input, Process, Output and Customer (SIPOC)diagram in Figure 1 outlines the methodology used within the investigation.

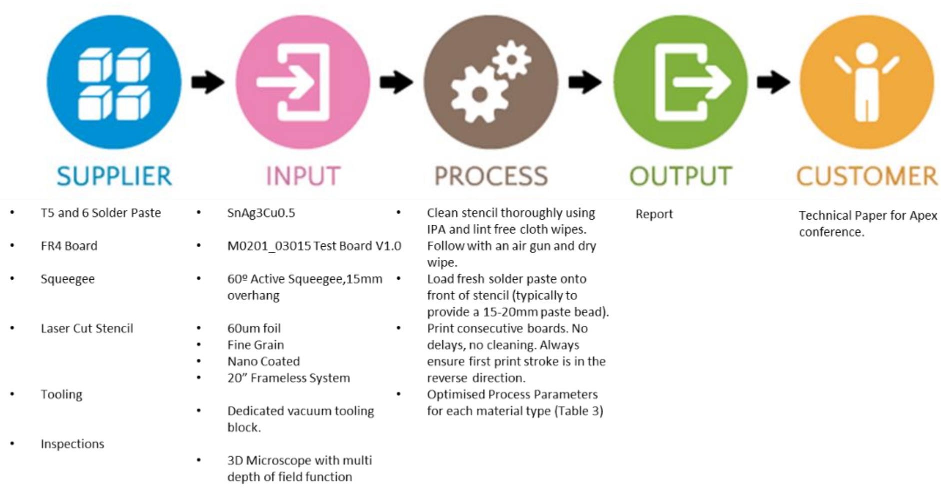

Figure 1 – SIPOC

Aperture Design and Area Ratio

The table below outlines the aperture design (Table 1), along with the associated area ratios. As can be seen to accommodate the required 60µm stencil foil the area ratio breaks the IPC guidelines (IPC.-7525).

Pad Design	X (um)	Y (um)	Area Ratio
P2	125	115	0.5
P4	100	115	0.45

Table 1 – Aperture Designs

Board Design

The printed circuit board (PCB) was manufactured from FR4 with a gold over nickel finish. The PCB dimensions were 200mm x 150mm with a board thickness of 1mm.Due to fabricationlimitations, solder mask is not present within the pad areas.The pad designs used throughout the investigation are shown in Figure 2.Both pad designs have an interspace of 50µm,75µm and 100µm,each design has 80 replicates.The P2 pad design includes a track of 60µm wide, this is not present on the P4 design.

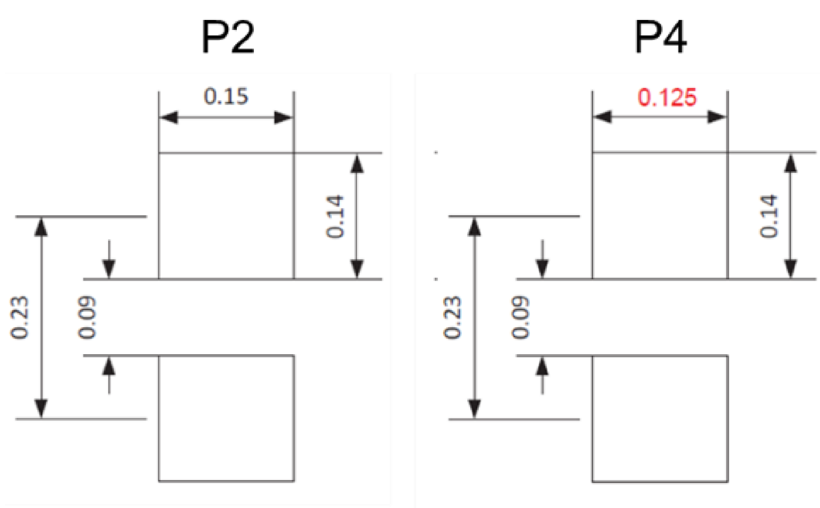

Figure 2 – Pad Dimensions (mm)

Material Set

The stencil technology used throughout the investigation was a fine grain stainless steel with a Nano coating applied to the board plane. The stencil foil was fabricated using a diode pulsed laser cutting machine and mounted into a frameless system.Type 5 and 6 solder paste materials were used within the investigation, all materials are commercially available. Each solder paste material was optimised for the printing process, these process parameters can be seen in Table 2.

Paste	Print Pressure (Kg)	Print Speed (mm/s)	Separation Distance (mm)	Separation Speed (mm/s)
Type 5	6.4	50	3	3
Type 6	7.2	50	2	10

Table 2 – Solder Paste Printing Parameters

Print to Destruction

To understand the print capabilities of each material, a print to destruction test was carried out on both solder pastematerials.This test will aid in understanding the print capability and working window of each material. Each material was printed using a 14-board run with no under stencil cleaning. The 5th and last board was contrasted and compared against process stability.

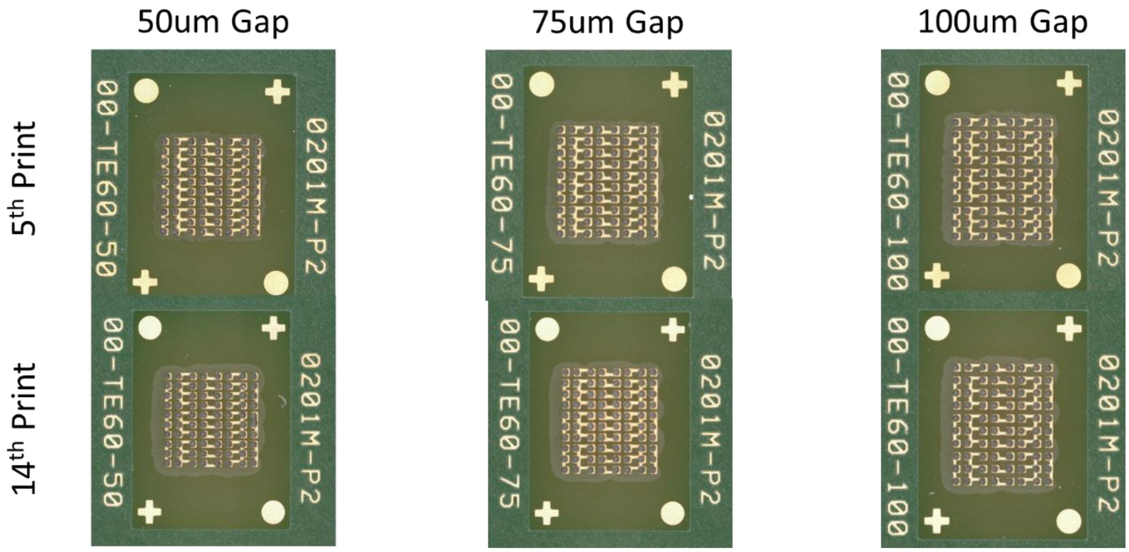

Figure 3 – Type 5 Solder Paste P2 Pad Design Print to Destruction

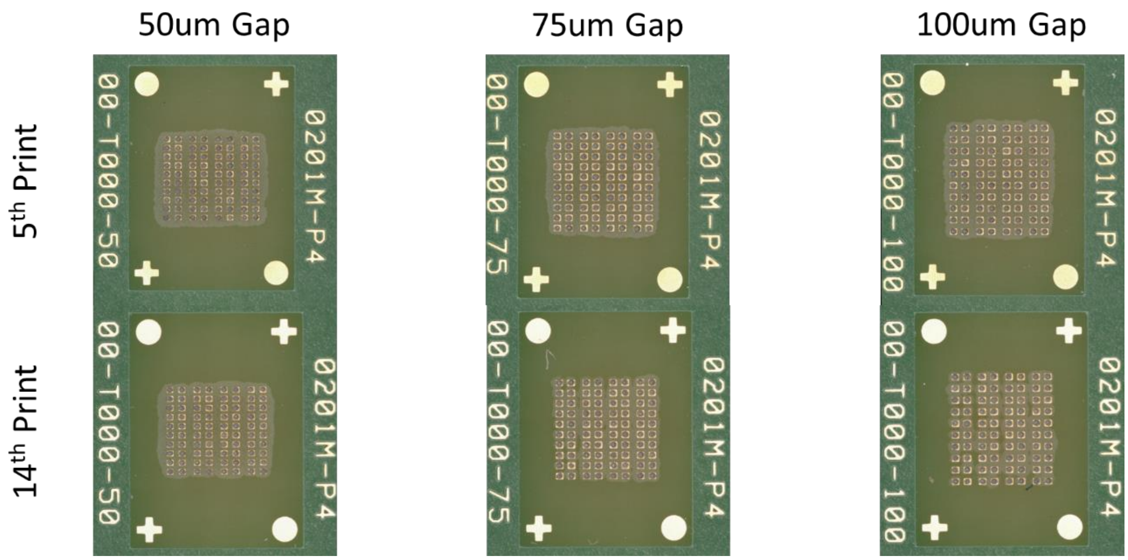

Figure 4 – Type 5 Solder Paste P4 Pad Design Print toDestruction

Figure 3 to 4 shows the print quality that was achieved for both solder paste material types, for simplicity only the 50µm P4 design is shown. Figure 3 to 4 shows the Type 5 material produced a fuller print deposit.This fuller print created a propensity to create solder paste bridging, this was observed from the 5th board onwards on both pad designs for the 50µm interspace. The Type 5 solder paste materialprinted with a higher definition,howeversolder paste bridging was also observed on the 14th board for the P2 design and 50µm interspace. Although both solder paste materials created bridge defects with the 50µm interspace, the Type 6 had a higher propensity to create process defects. Therefore, it can be concluded aType 5 solder paste material has a higher wet printing capability than the finer grain Type 6 material. The next step of the investigation is to assemble the Metric 0201.

Metric 0201 Assembly

For the assembly trials the following equipment was used: a fully automated stencil printing machine capable of 12.5µm alignments at 2 Cpk. An automated placement machine which incorporated a multi-stationed highspeed placement head with a high-resolution vision system. A multi-programmable zoned reflow with nitrogen capability.For all the assembly runs the optimised print parameters (Table 2)were used.To ensure the printing process had stabilised, four test boards were processed before running two production boards; the second production board was used for the analysis.

Results/Analysis

The results below show the findings from the assembly trials, both solder paste materials and pad designs P2 and P4 are shown. To maintain a certeris paribus methodology the same location of the PCB will be displayed for each process step, thus allowing the process to be chronologically recorded.

P4 Pad Design – Type 5

50µm Interspace

Print

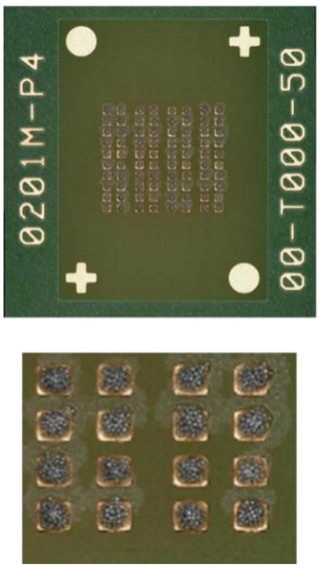

Figure 5a – Print P4 Type5

Placement

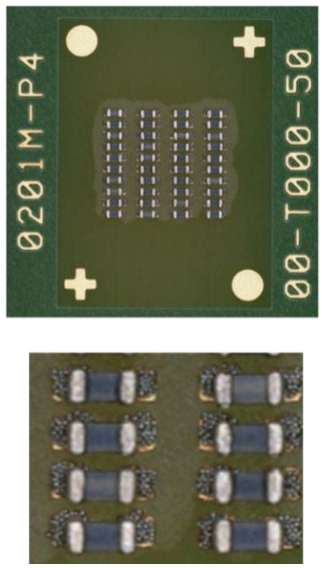

Figure 5b – Placement P4 Type5

Reflow

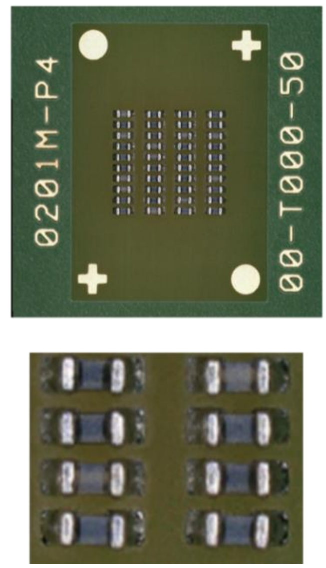

Figure 5c – Reflow P4 Type 5

75µm Interspace

Print

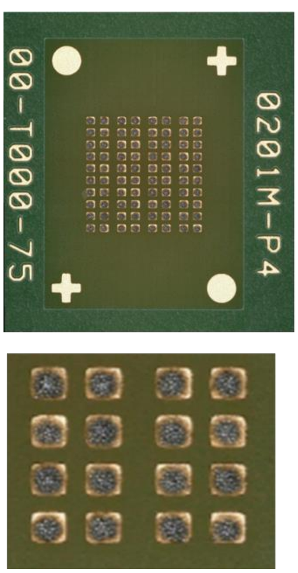

Figure 6a – Print P4 Type5

Placement

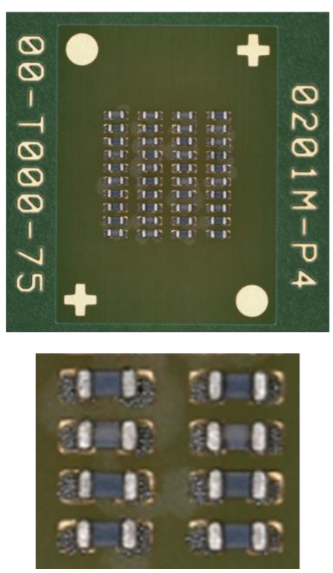

Figure 6b – Placement P4 Type5

Reflow

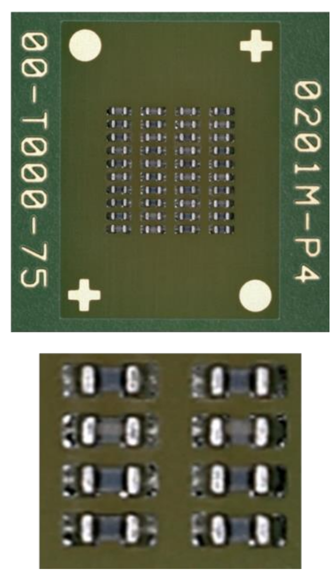

Figure 6c – Reflow P4 Type 5

100µm Interspace

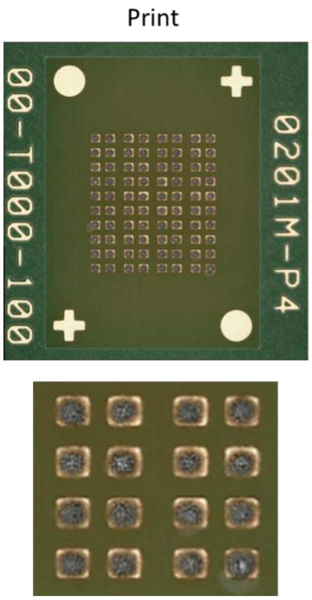

Figure 7a – Print P4 Type 5

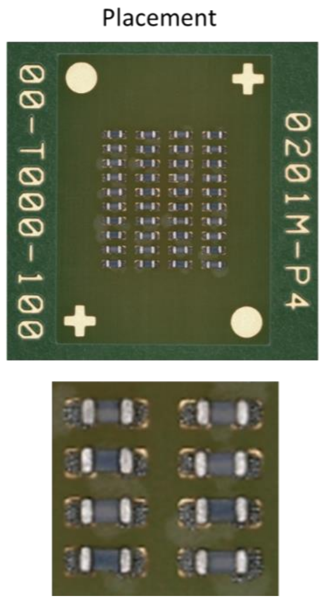

Figure 7b – Placement P4 Type 5

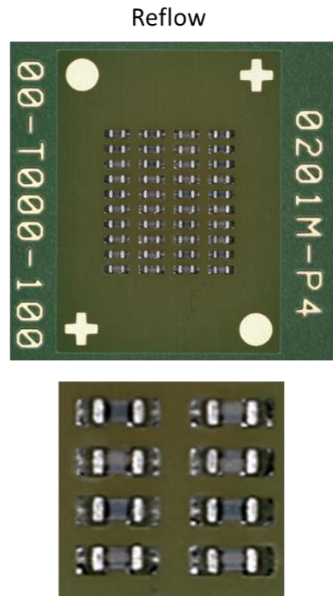

Figure 7c – Reflow P4 Type 5

Figures 5a to 7adisplaysthe printing results from the Type 5 solder paste material and three interspace P4 pad designs. Visually the paste printing process shows some variation, however, the printing process generally meets all inspection standards. The observed variation isa result of the apertures associated to area ratio of 0.45. This value falls outside the IPC minimum recommendation of 0.5 or greater (IPC - 7525).Figures5b to 7b shows the Metric 0201 after placement, visually the placement of the Metric 0201 componentslook acceptable with no missing or skewed parts.Also, worth notice is the placement process has not compressed/bridged the solder paste material.Finally, Figures5cto 7c shows the P4 pad designs after reflow, the solder joint integrity visually looks acceptable with no dry or bridged joints.

P2 Pad Design – Type 5

50µm Interspace

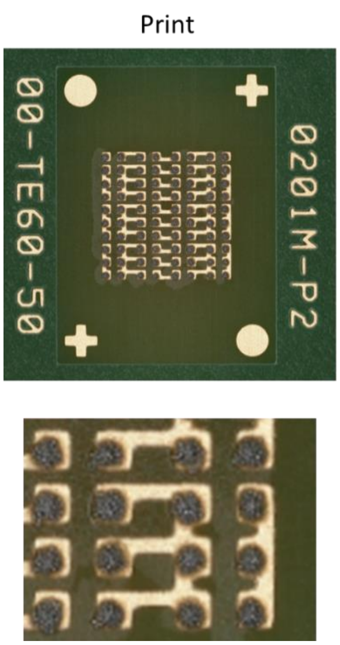

Figure 8a – Print P2 Type5

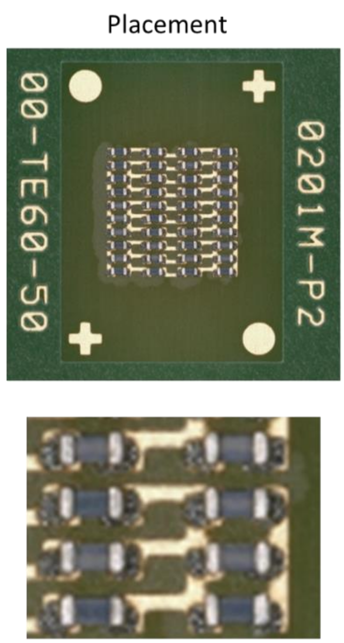

Figure 8b – Placement P2 Type5

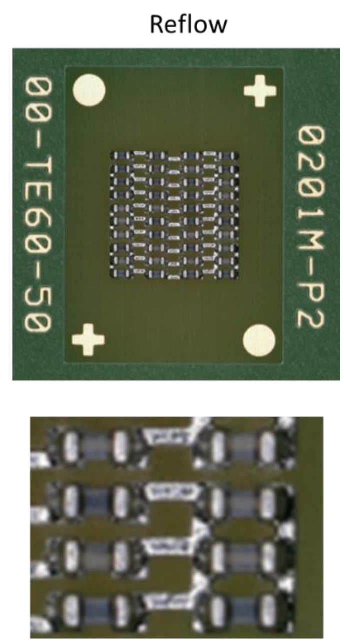

Figure 8c – Reflow P2 Type 5

75µm Interspace

Print

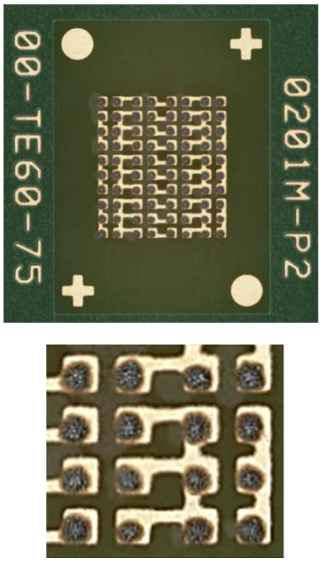

Figure 9a – Print P2 Type 5

Placement

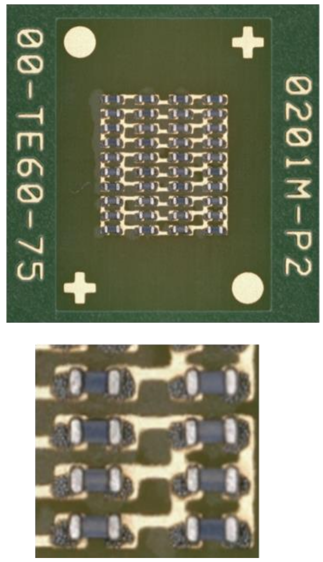

Figure 9b – Placement P2 Type 5

Reflow

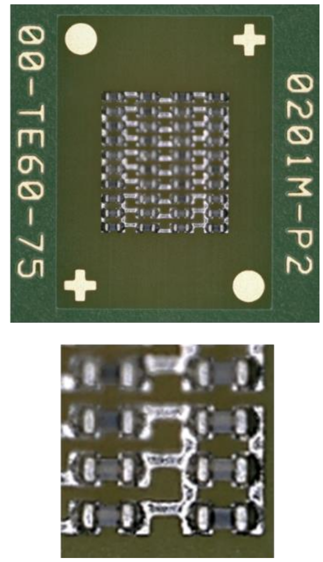

Figure 9c – Reflow P2 Type 5

100um Interspace

Print

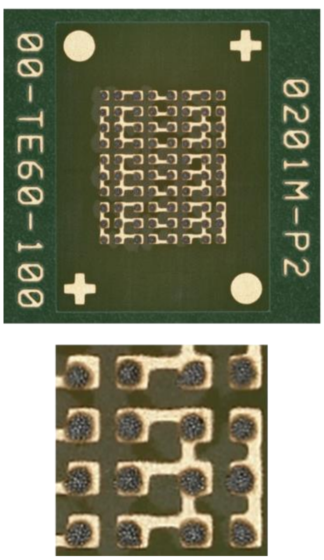

Figure 10a – Print P2 Type 5

Placement

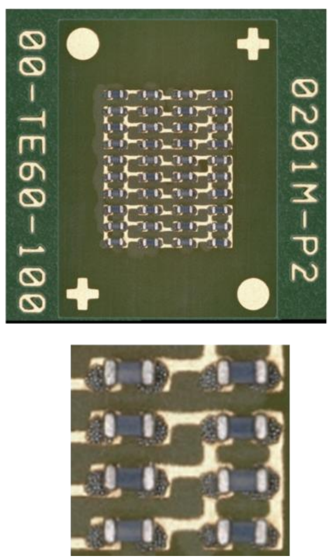

Figure 10b – Placement P2 Type 5

Reflow

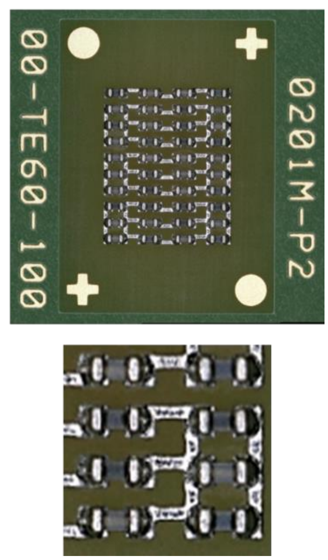

Figure 10c – Reflow P2 Type 5

Figures8a to 10a shows the printing results from the Type 5 solder paste material and three interspace P2 pad designs; the P2 pad design has an end track of 60µm. Visually the paste printing process meets the visual requirements of repeatable/present deposits. The area ratio associated with the P2 design is 0.5. This value is at the extremities of the allowable value as prescribed by IPC -7525. Figures8b to 10b shows the Metric 0201 after placement. Visually the placement of the devices looks acceptable with no missing or skewed parts. As this pad design has an end track it is worth noticing that the solder paste material has not been compressed by the placement process, such that the fluid elements of the material have bled across the track elements. Finally, Figures 8c to 10c shows the P2 pad designs after reflow. The solder joint integrity visually looks acceptable with no dry or bridging joints. The solder paste has flowed across the conjoinedtracks, but the wetting forces have not modified the original placement positionof the Metric 0201 devices.

P4 Pad Design Type 6

Interspace 50µm

Print

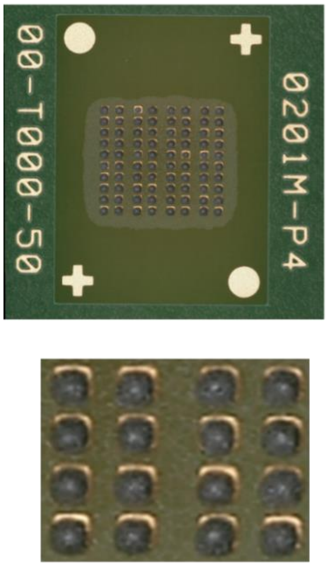

Figure 11a – Print P2 Type6

Placement

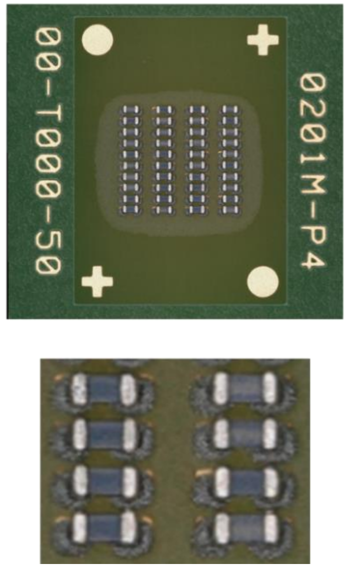

Figure 11b – Placement P2 Type6

Reflow

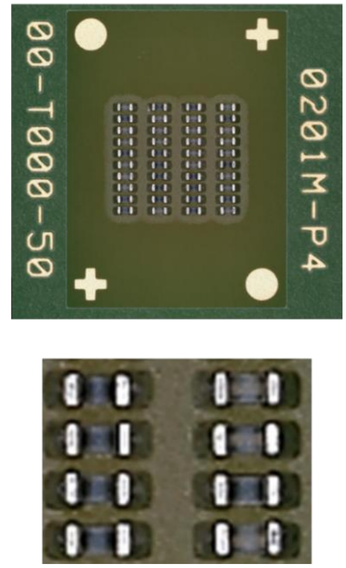

Figure 11c – Reflow P2 Type 6

Interspace 75µm

Print

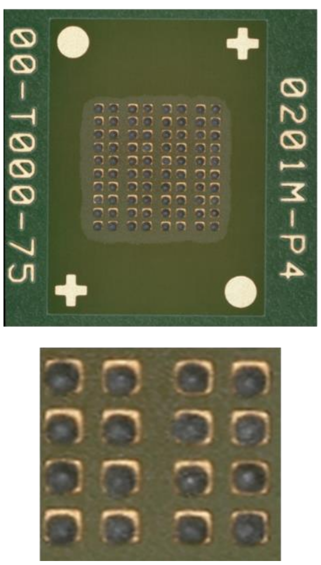

Figure 12a – Print P2 Type 6

Placement

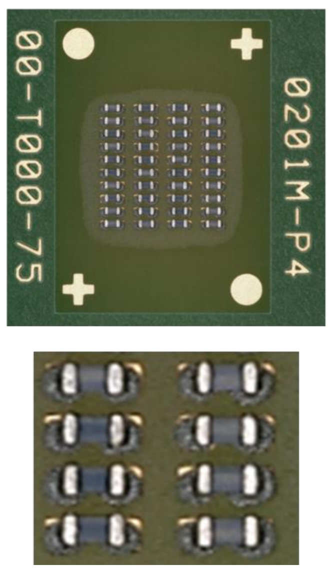

Figure 12b – Placement P2 Type 6

Reflow

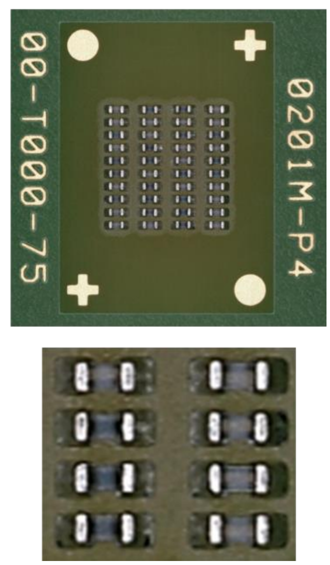

Figure 12c – Reflow P2 Type 6

Interspace 100µm

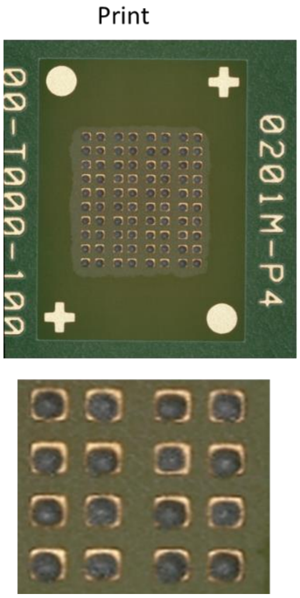

Figure 13a – Print P2 Type 6

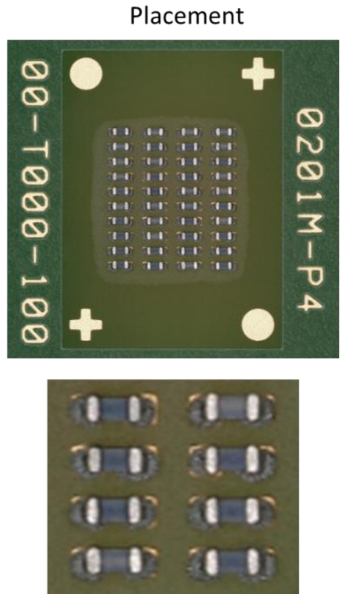

Figure 13b – Placement P2 Type 6

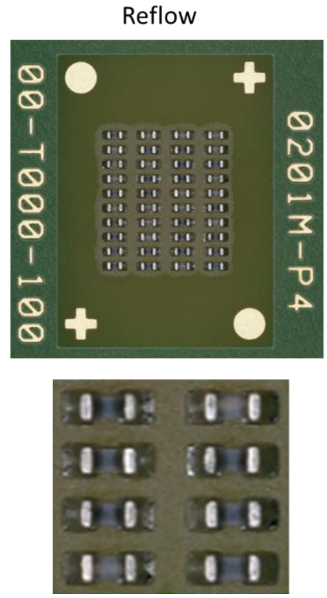

Figure 13c – Reflow P2 Type 6

Figures11a to 13a shows the printing results from the Type 6 solder paste material with the P4 designs and associated interspaces. The Type 6 solder paste material produces a fuller print. This is caused by the Type 6 material having a finer particle size. Although the print is fuller than the Type 5 solder paste material, the variation of deposit to deposithas not significantly improved.Figures11b to 13b shows the Metric 0201 component after placement. The 50µm interspace examples have been compressed to a point where the solder paste material has abutted to an adjacent pad.The 75µm and 100µm interspace examples also exhibits the same observation, but due to the increased distance from pad to pad the propensity to bridge has diminished.Figures11c to 13c shows the P4 examples after the reflow process, with worth noticing is that the 50µm interspace examples have not culminated in bridged interconnects.

P2 Pad Design – Type 6

Interspace 50µm

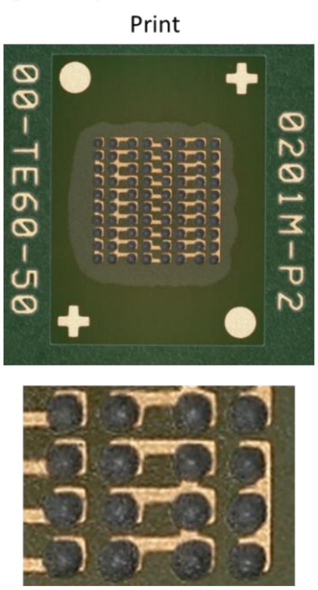

Figure 14a – Print P2 Type6

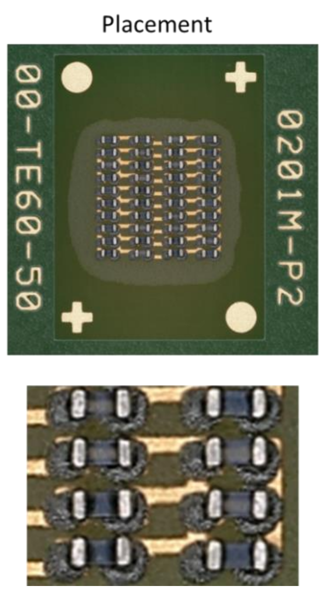

Figure 14b – Placement P2 Type6

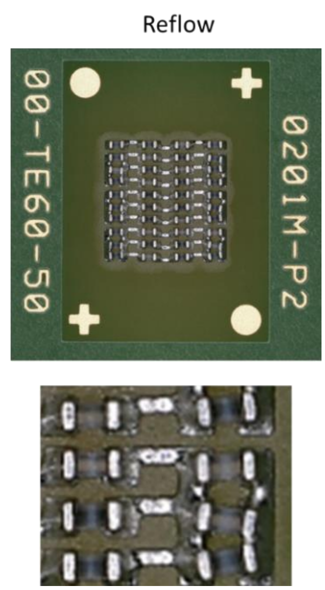

Figure 14c – Reflow P2 Type 6

Interspace 75µm

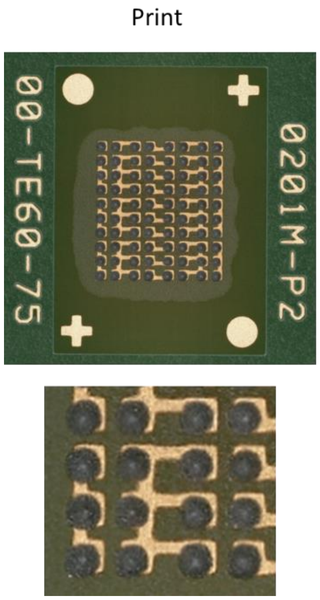

Figure 15a – Print P2 Type 6

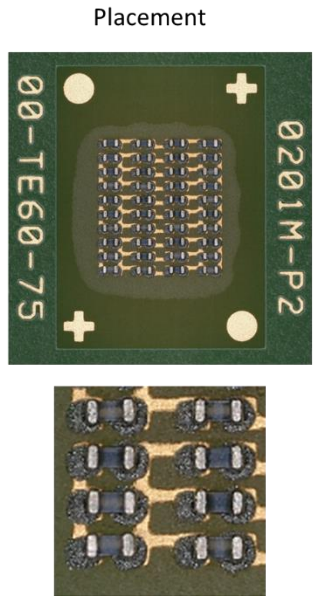

Figure 15b – Placement P2 Type 6

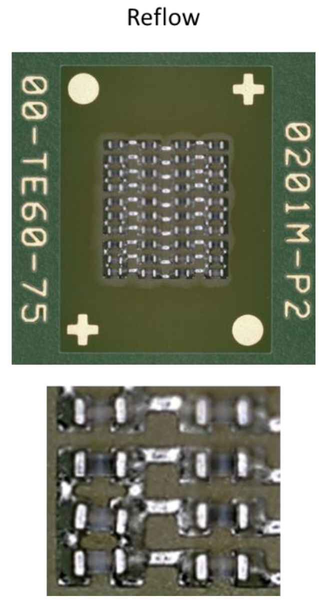

Figure 15c – Reflow P2 Type 6

Interspace 100µm

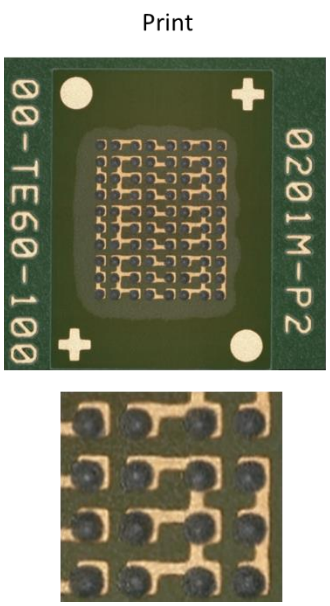

Figure 16a – Print P2 Type 6

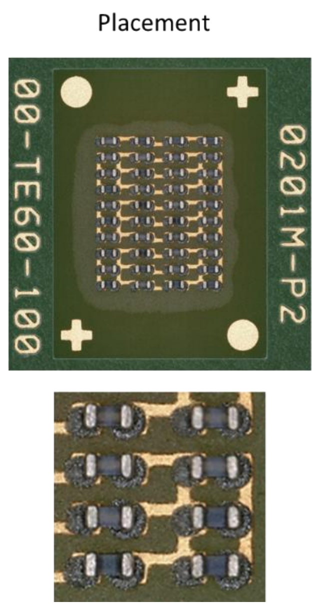

Figure 16b – Placement P2 Type 6

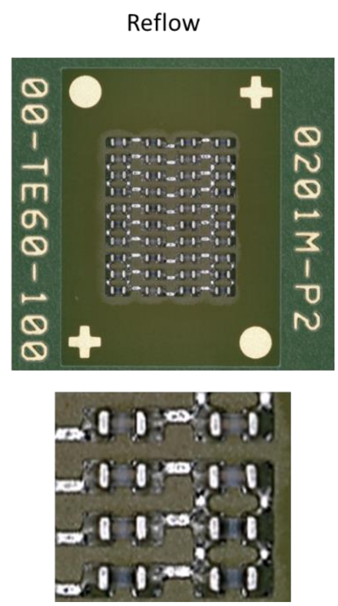

Figure 16c – Reflow P2 Type 6

Figures 14a to 16a shows the print quality from the P2 pad design using the Type 6 solder paste material. As with the P4 examples, the Type 6 material has produced a fuller print than the Type 5 material. Again, the fuller deposits are increasing the propensity to bridge.Figures14b to 16b shows the Metric 0201 component after the placement process. The 50µm interspace examples have been compressed to a point where the solder paste material has abutted to an adjacent pad. The 75µm and 100µm interspace examples also exhibits the same observation, but due to the increased distance from pad to pad the propensity to bridge has diminished.Figures14c to 16c shows the P2 designs after reflow. The 50µm and 75µm interspaced examples have numerous instances of conjoined interconnects. The solder joints that have bridged are all associated with tracks that adjoin neighbouring pads, therefore electrically the interconnect meets the design requirements.However, from a manufacturing standardsperspective, the conjoined devices do not meet quality standards and therefore would not be fit for purpose.

Conclusions

From this investigation several findings have been gained. Industry guidelines and general rules of thumb claim that a finer particle paste will produce an enhanced print quality. However, it has been observed through this investigation that although a finer grainType 6 solder paste material has produced a fuller print deposit for both pad designs, the resultant process capability has not followed this prediction. Both the printing and placement process have been negatively affected by the inclusion of excessive solder paste volume.

Within the printing process the excessive volume has caused the solder paste to saturate its designed area, thus causing the solder paste to merge into a neighbouringregion. Within the placement process an excessive volume of solder paste caused the pressure of the placement processto squeeze out the solder paste beneath the component's termination. In the interspace examples of 50µm and 75µm this deformation of solder paste caused enough movement to form a solder paste bridge.

The Type 5 solder paste was not exempt from process issues andthe variation between deposits was still observed.However, the volume of solder paste was compatible with the application of Metric 0201 assembly.The main observation was a reduction of bridging errors on the finer interspaces.The inclusion of a conjoined track (P2 design) also added an additional challenge to the investigation. The track provides a path for the liquid elements of the printed solder paste andreflowed molten solder to migrate. The increased volume produced by the finer grain Type 6 solder paste material resulted in an increased propensity of bridging along the tracks from both the printing and reflow process. The additional issue with reflowed generated bridging is the tendency for the molten solder to alter the position of the components. This is due to the surface tension of molten solder overcoming the mass of the Metric 0201 component. The lower volume delivered by the Type 5 solder paste material produced lesssolder paste and reflowed bridging.

Within this investigation the assembly of Metric 0201 components have been accomplished with area ratios as low as 0.45, interspaces down to 50µm, a 60µm conjoined track and pad dimensions of 100µm x 115µm.The material selection for successful Metric 0201 assembly is as follows: 60µm fine grain stainless steel foil with a polymer coating and Type 5 grain sized solder paste.