Investigation of the Assembly Process of m03015 and a Brief Look at m0201 Components

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Abstract
Components are still shrinking in the SMT world and the next evolution of the passive components are the m03015 (009005) and m0201 (008004). Today it is seen that the 01005 component is still relatively unused in most of today's printed circuit board assemblies. Usage is mainly seen on module assemblies and smart products. It has been a slow adoption rate for other product technologies. For most assemblies 0402 components are still common but the 0201s are still rising in usage as there is a movement to use these in server, network, base station products.

The m03015 and the m0201 will see primary adoption in the products that require more miniaturization which would be system in packages (modules). These modules would then be assembled into products either through attachment to another assembly or via other interconnect methods.

This paper will explore the development of an assembly process (SMT only) for the m03015 component. Solder paste and stencil type will be discussed with results from the evaluations, as well as the placement and reflow of these components. Component to component spacing down to 0.100mm spacing will be discussed as well. AOI and the challenges around this area will be presented in a separate paper and rework will not be discussed at this time.

At the time of this writing, an investigation is being started on the m0201 and results at the time of the paper will be briefly touched on as well.

Introduction
Over the years components have continued to reduce in size. The latest components, m03015 and m0201, are starting to appear in the market. The m03015 is the metric designation for the EIA 009005 and m0201 is the metric designation for the EIA 008004. These types of components will be seen to be used in module assembly, which would include items for smart wearables where miniaturization is required for higher functional densities. System in Packages (SiP) is the latest term for these modules and these SiPs are already seen in wearables such as watches, wristbands, and other devices. These parts will not be "mainstream" for many years as the 01005 components have only been used for a small portion of products today. Below (Figure 1) is a graphic showing how the components have reduced in size over the years. Miniaturization and higher functional density is still the driving force. The smaller components, boards, and components use these to drive spacing between components lower and lower. Embedding components is still a growing market.

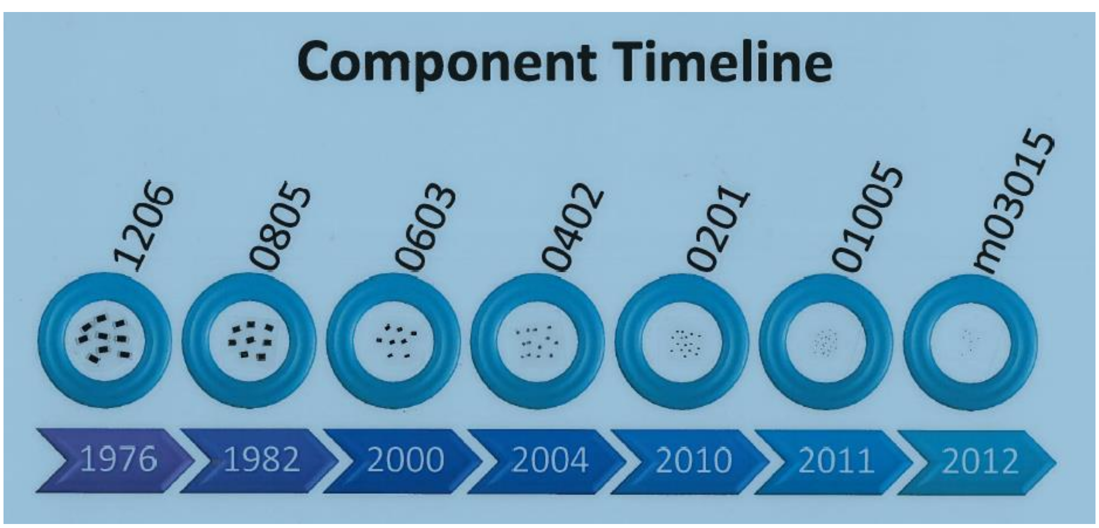


Figure 1: Component sizes through the years.

Test Vehicle
For this testing, our miniaturized test vehicle was used. This board has many uses which include PoP, 0.3mm pitch CSP, 01005, 0201, high density spacing, solder flip chip down to 180um pitch, and some other features. The bare board can be seen in Figure 2. The pads for m03015 were placed on these boards in anticipation of these parts about 5 years ago.

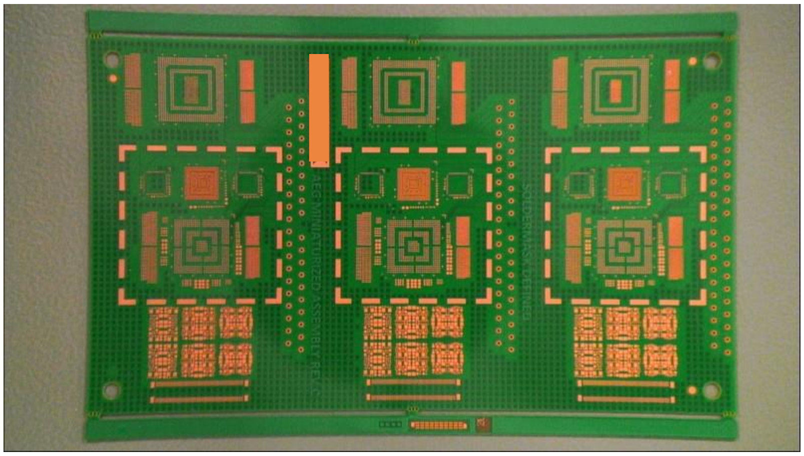


Figure 2: Miniaturized test vehicle.

The land pattern used has the following dimensions, 0.15x0.15mm copper pad with a gap of 0.076mm. This pad will have a toe of about 0.038mm based on the nominal component design. See Figure 3 for the schematic of the pad design. The pad design is slightly larger than other pad designs seen in other papers [1].

The spacing between the copper lands varies depending on the panel location. The pad spacing is 200µm, 150µm, and 100µm. The board is 130 x 77mm and 1mm thick with OSP surface finish. The m03015 components used in this test was bottom terminated style where the interconnect pad was only on the bottom side.

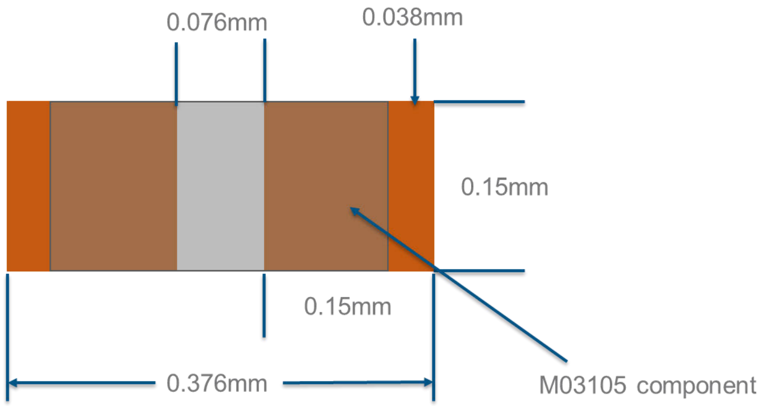


Figure 3: Pad design.

This pad was designed to help printability, but this pad design would not be the best for optimizing miniaturization. A new test board focused on miniaturization will be discussed briefly at the end of the paper. For a 76µm thick stencil the area ratio is about 0.49 and for a 50µm thick stencil the area ratio works out to be 0.75.

Process Materials and Parameters
For this testing it was decided to use a 50µm thick fine grain stainless steel stencil with 150x150µm apertures. The stencil was also nano-coated to help provide the best release possible. A dedicated support fixture was used for the print process The print parameters used in this experiment were as follows: Speed: 30mm/s, Pressure: 6kg, Separation Speed: 20mm/s. The equipment being used is what is typically used in a standard SMT manufacturing line. The pick and place machine had all necessary upgrades (camera, software, nozzles) required to pick and place these m03015 components. The equipment was verified prior to running the actual samples. For reflow we created a typical profile and ran in a nitrogen environment with 200-600ppm of O2 during the processing. See Figure 4 for the profile used.

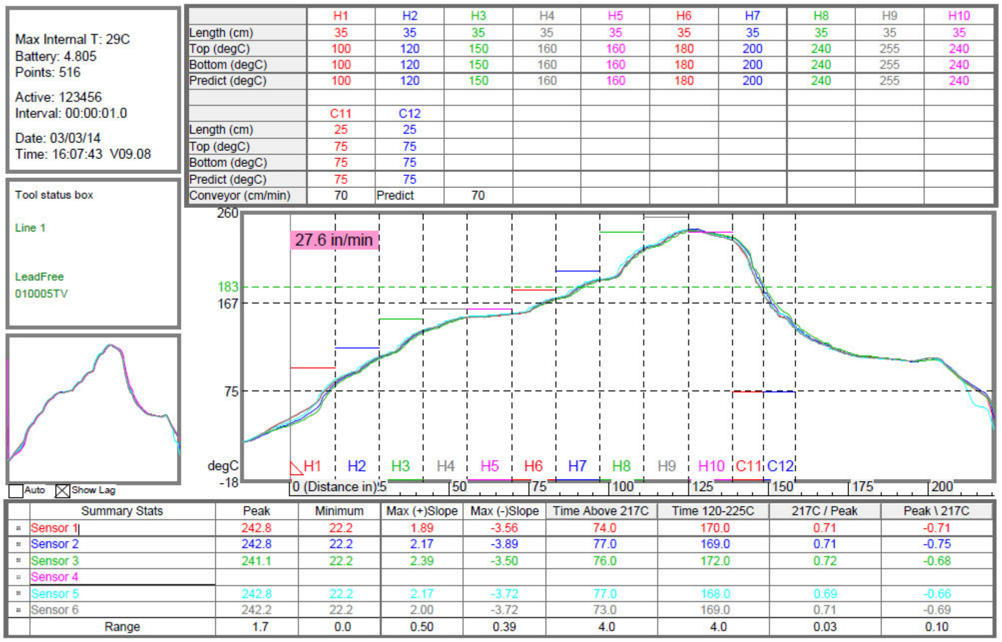


Figure 4: Reflow profile

The lead-free Sn3.0Ag0.5Cu solder paste material used was a material that has been used in volume production, the only difference being that a Type 5 particle size was evaluated. This was a low residue flux system, halogen free, ROL0 type material. A Type 4 material was trialed, but the decision was made to use the Type 5 for this study. See Figure 5 below for print comparisons.

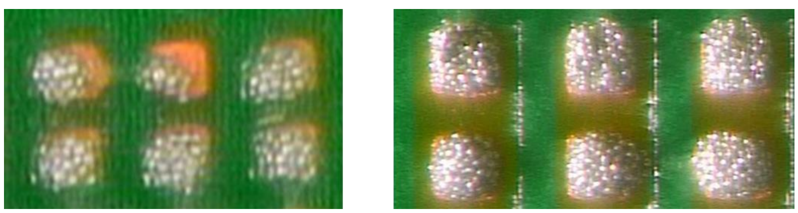


Figure 5: Left picture is Type 4 paste, right picture is Type 5 paste after printing.

Process Data Analysis

Printing Process Data: A solder paste inspection system was used to analyze the solder paste distribution from the printing process and an interesting observation was made during this analysis. Figure 6 shows the distribution of all the m03015 pads during this testing, and the data clearly shows that there are two distributions included in the data set.

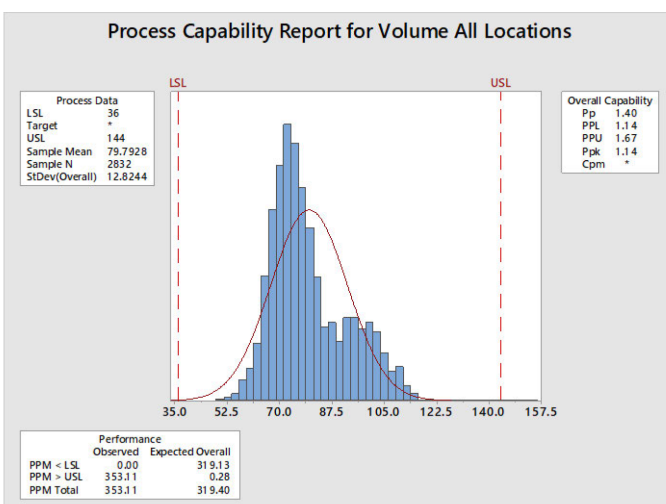


Figure 6: Solder paste data for all m03015 pads.

Looking at the data there are clearly 2 sets of distributions included. Further analysis was done and it was found that the pad designs on the test board were done differently. The 200 and 150µm pad designs were done with the solder mask throughout the array of pads while the 100µm pad area had solder mask completely cleared from the pad area. See Figure 7 for pictures of this.

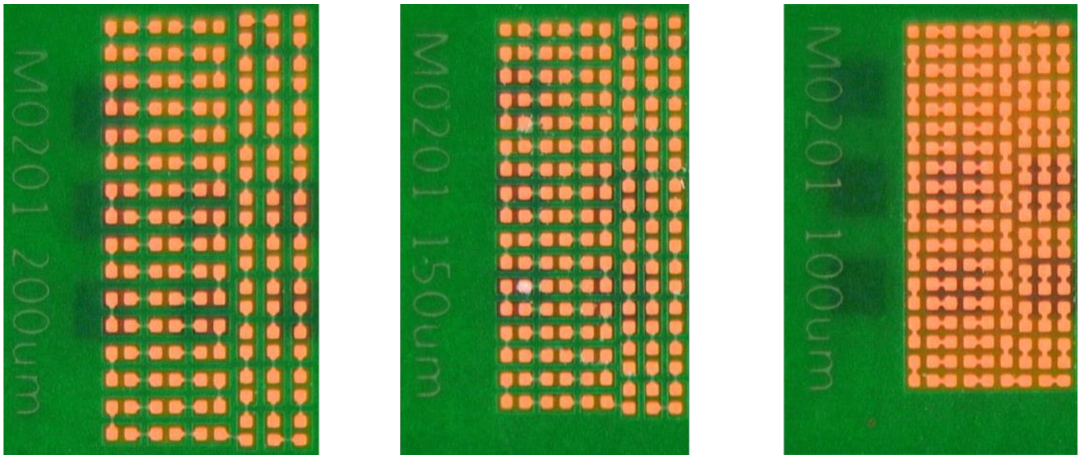


Figure 7: From left to right 200µm, 150µm, 100µm pad areas. See the solder mask differences.

The data was separated into the 2 types of pad designs and the distributions were redone. Figure 8 shows the new data.

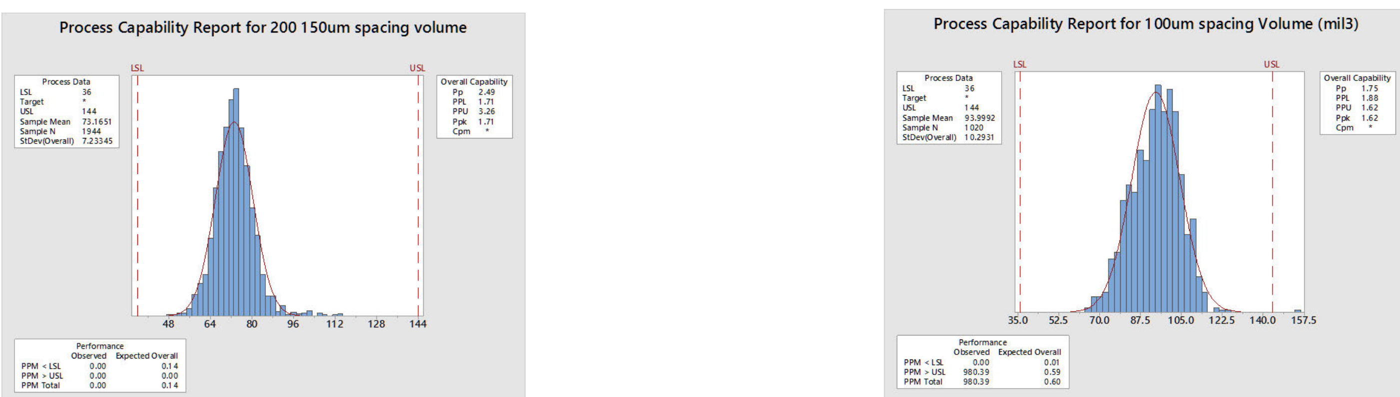


Figure 8: Cpk analysis for each set of pads (solder paste volume).

The Cpk data looks very good with 1.71 for the 200 and 150µm pads and 1.62 for the 100µm pad area. We then proceeded into the pick and place operations.

<u>Pick and Place:</u> Pick and place was performed and initial verification was done on double sided tape. An issue was found where some of the initial placements damaged the component. Figure 9 shows where the component impacted the board with too much force and shattered the component.

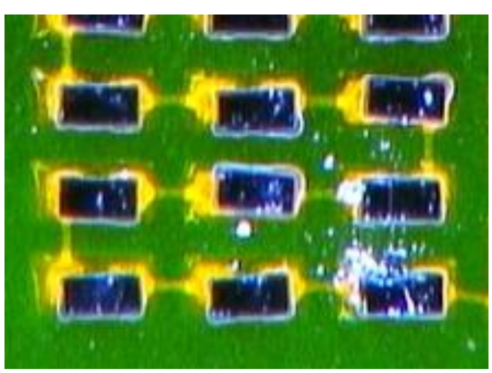


Figure 9: Damaged component during placement.

Everything was checked, the placement force was set at a minimum, and this was still seen. It turned out to be a software bug where the height at which the placement head starts its deceleration would not set properly. This only happened on the first placement of the board. This has been resolved since this time. Placements on solder paste were then done and 100% visual inspection was done to verify placements. No defects were found at any of the spacings, just the initial placement as seen above. Figure 10 shows a sample of the components placed onto the solder paste.

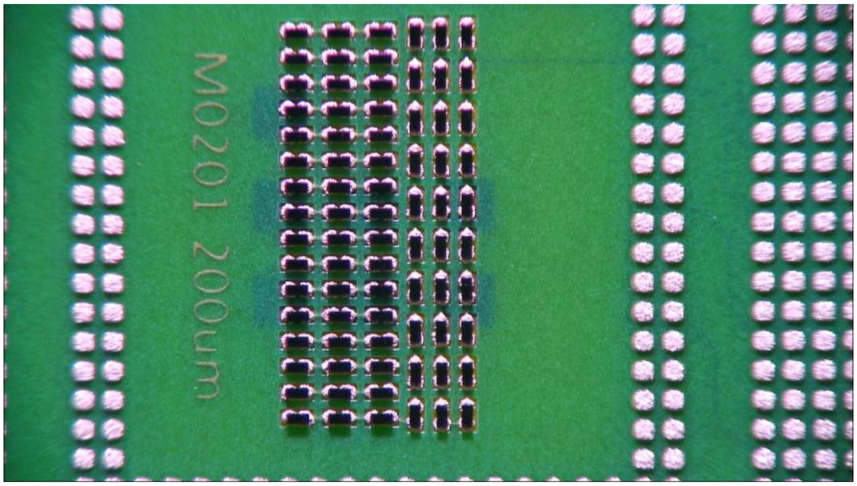


Figure 10: Component placement on solder paste.

The pickup and placement rates were recorded. For pickup rate, it was seen to be 98.9% and the placement rate was 100%. This is very encouraging that these pick and place rates are in the expected areas and that the equipment can tell if a part was present on the nozzle or not. Most of the latest equipment can do this well.

<u>Reflow Results:</u> After placing the components on the board, the assembly was sent through reflow. Overall the soldering with the Type 5 solder paste was acceptable. However, some issues were observed. On the larger pad containing mounted components with terminations on the bottom side only, the part tended to "float" on top of the solder. Figure 11 show the results after reflow.

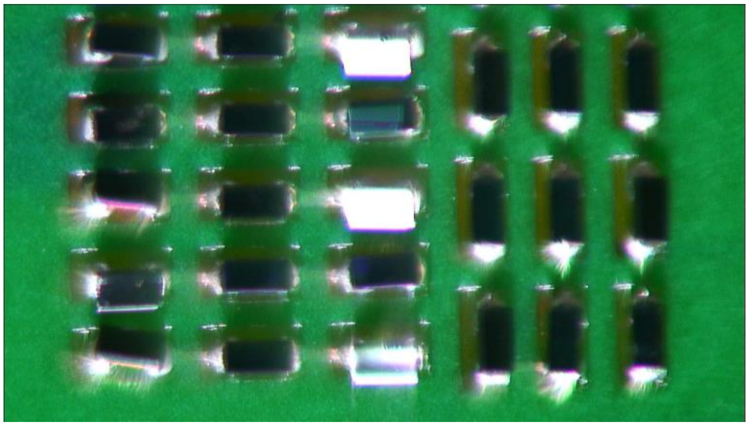


Figure 11: Components floating on the solder.

These results did not match results seen in other papers.[1] It has been found that the pad sizes can cause this as there is an excess of solder that forms a larger bump on the pad (semicircle). The component only having the bottom side termination can only solder in that area, so the solder bump raises the component. Depending on the location of the component it will be raised up and on the side of the solder bump. If there are three or more solderable terminations on the component instead of one surface, the part will flatten out better upon soldering to the pads. Further studies have also shown with a pad size closer to the terminal size that the part will not raise up as much and there will not be as rounded of a solder joint that would push the part to become tilted.

The only other defects seen was some shorting on the 100µm spacing due to the design of the traces connecting the pads together. The solder would wick down those traces since there was no solder mask covering these areas for the 100µm spacing area.

Due to the tilting of the component, this caused some issues with AOI and AXI not being able to detect the parts and determine defects. A separate paper in the future will cover more on those evaluations.

<u>Further Work:</u> Additional work is in progress and a new test vehicle has been designed to include m0201 components. Initial printing and placement has been done and additional trials are scheduled to be done. The pad designs on this SiP test vehicle are designed to the same size as the terminations on the m03015 and m0201 components. Also on this board the spacings have been decreased as well. The board contains component spacing of 100, 75 and 50µm which would be needed for the system in package type of products.

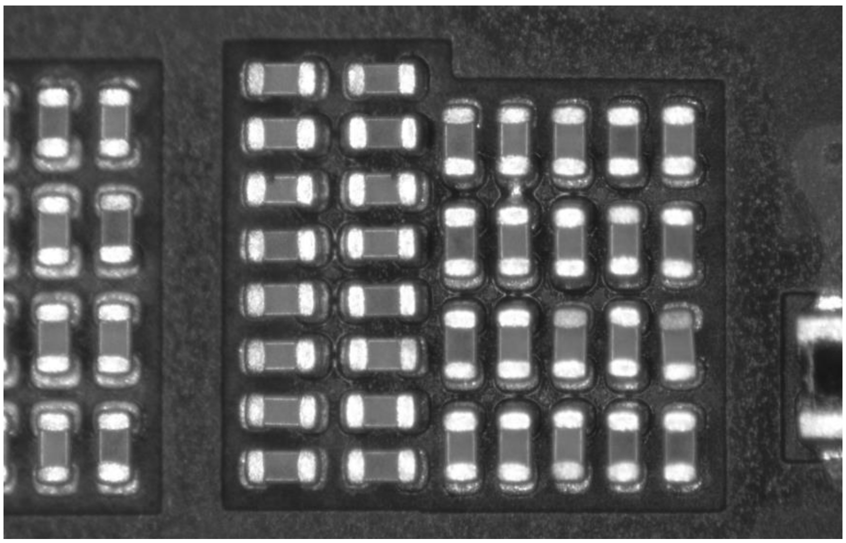


Figure 12: m0201 after reflow at 50µm spacing.

Figure 12 shows some of the initial results of m0201 assembly at 50µm spacing. The print process still needs to be dialed in further as the printing is inconsistent with many high-volume spikes (causing the bridging seen in Figure 12) and also insufficient to no solder was seen in the data. More trials are underway with different types of solder paste to enable better printability. More specifically, we are exploring Type 5 and Type 6 particle sizes using a 50um thick stencil. The placement equipment was capable to pick and place even these smaller components with little issues seen. New software and nozzles were required for the m0201 component on the equipment that was being used.

Conclusions

This paper demonstrated that these smaller components can be assembled in a SMT process with standard equipment (with the latest cameras, software, and nozzles) with high yield. Printing was shown to be possible with a high Cpk, pick and place rates were at a high level, and a minimum amount of defects were seen. The pad size in this study was slightly large so there is room to decrease further for enhanced miniaturization. This will be seen on the ongoing work with m0201 and m03015 for SiP products.

Acknowledgements

The authors would like to thank everyone involved on this project from inside and outside of the company.

References

[1] N. Heilmann, “03015 Information”, ASM Assembly Systems White Paper, Productronica, Munich, 2013.
[2] D. Geiger, A. Mohammed, M. Kurwa, “Overview Miniaturization on Large Form Factor PCBA”, Proceedings from IPC APEX 2016.

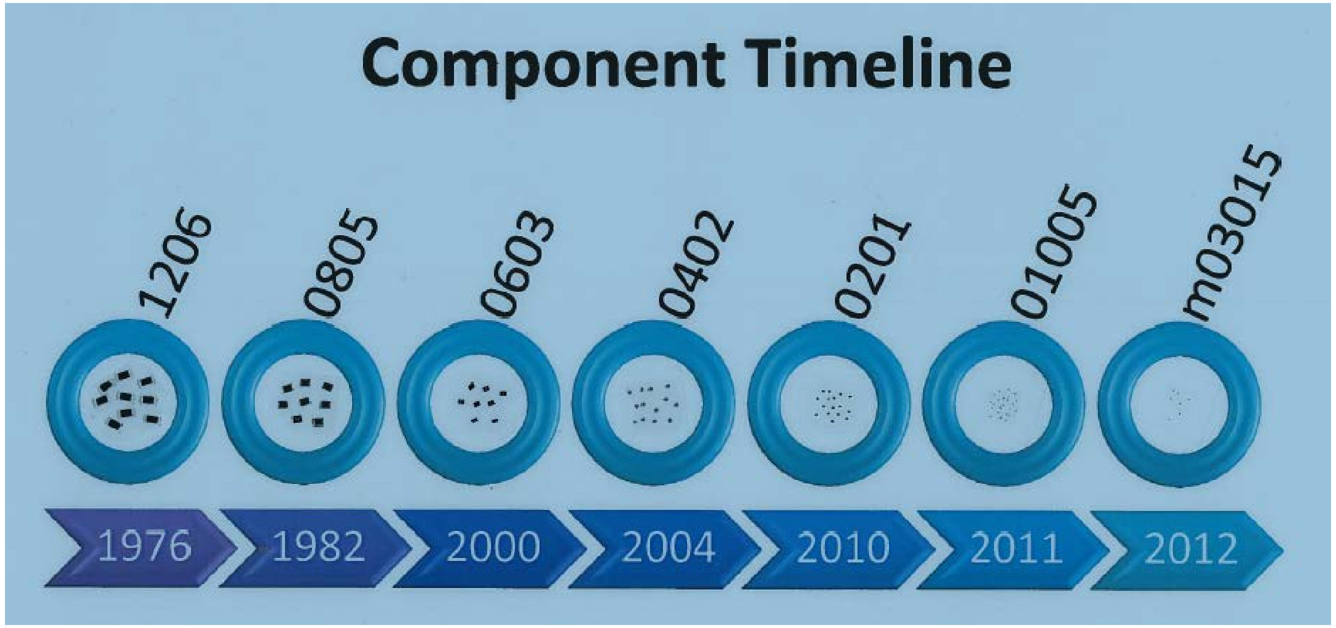
Investigation of the Assembly Process of m03015 and a Brief Look at m0201 Components

David Geiger, Robert Pennings, Anwar Mohammed

Flex

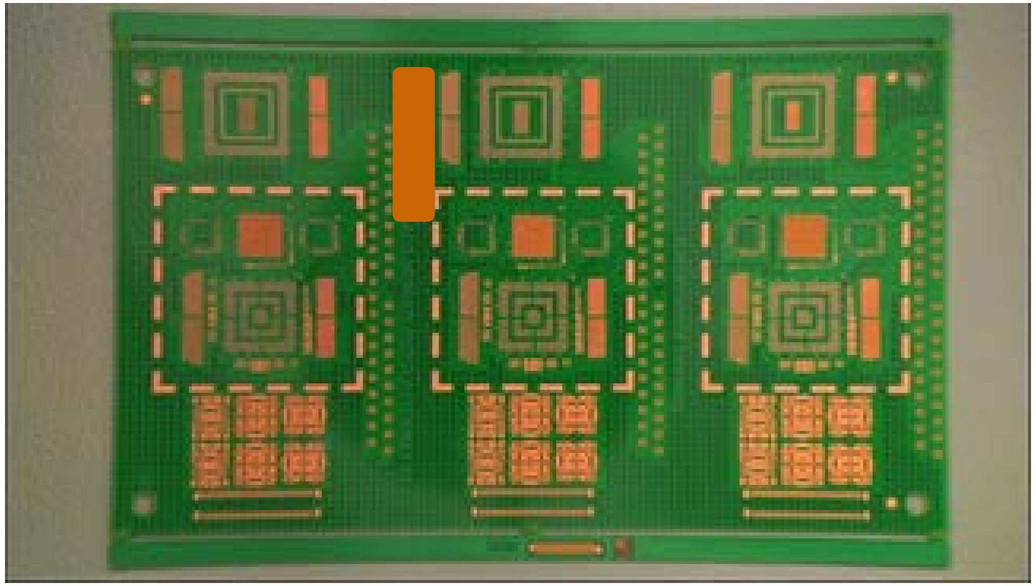
Background

- Miniaturization continues
- SIP packaging is increasing requiring finer density
- Components are becoming smaller



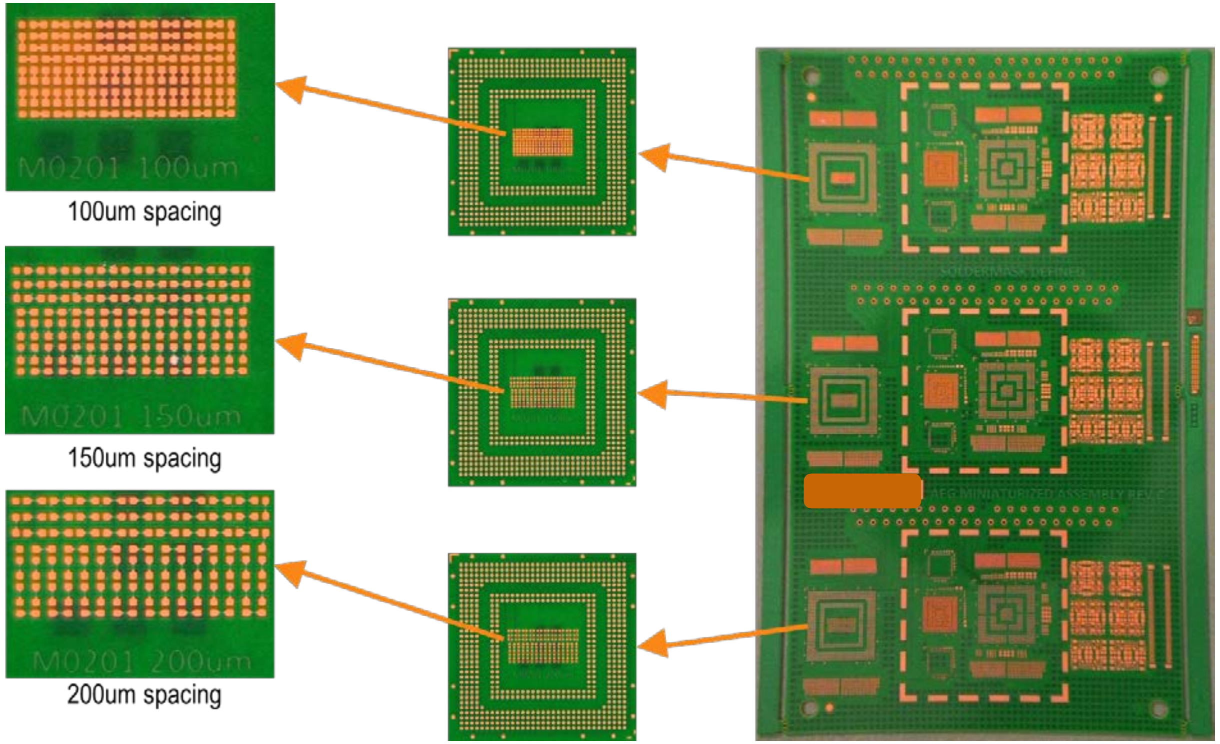
Materials

- Type 4 no clean halogen free SAC305 solder
- Type 5 no clean halogen free SAC305 solder
- Miniaturized Test Vehicle
  - *130 x 77mm and 1mm thick with OSP surface finish*



Test Vehicle

- Miniaturized Test Vehicle
  - *130 x 77mm and 1mm thick with OSP surface finish*



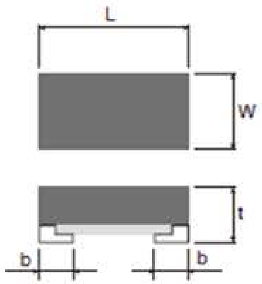
M03015 Component

<009005>								
Part No.	Size code mm (inch)	Rated power (70℃)	Limiting element voltage (V)	Tolerance	Temperature coefficient (ppm /℃)	Resistance range	Operating temperature range (℃)	Automotive Grade Available
New	03015 (009005)	0.020W	10	J (±5%) F (±1%)	±200	10 to 1MΩ	−55 to +125	—

Jumper type					
Part No.	Size code mm (inch)	Rated current	Resistance	Temperature range (℃)	Automotive Grade Available
	03015 (009005)	0.5A	50mΩ Max.	−55 to +125	—

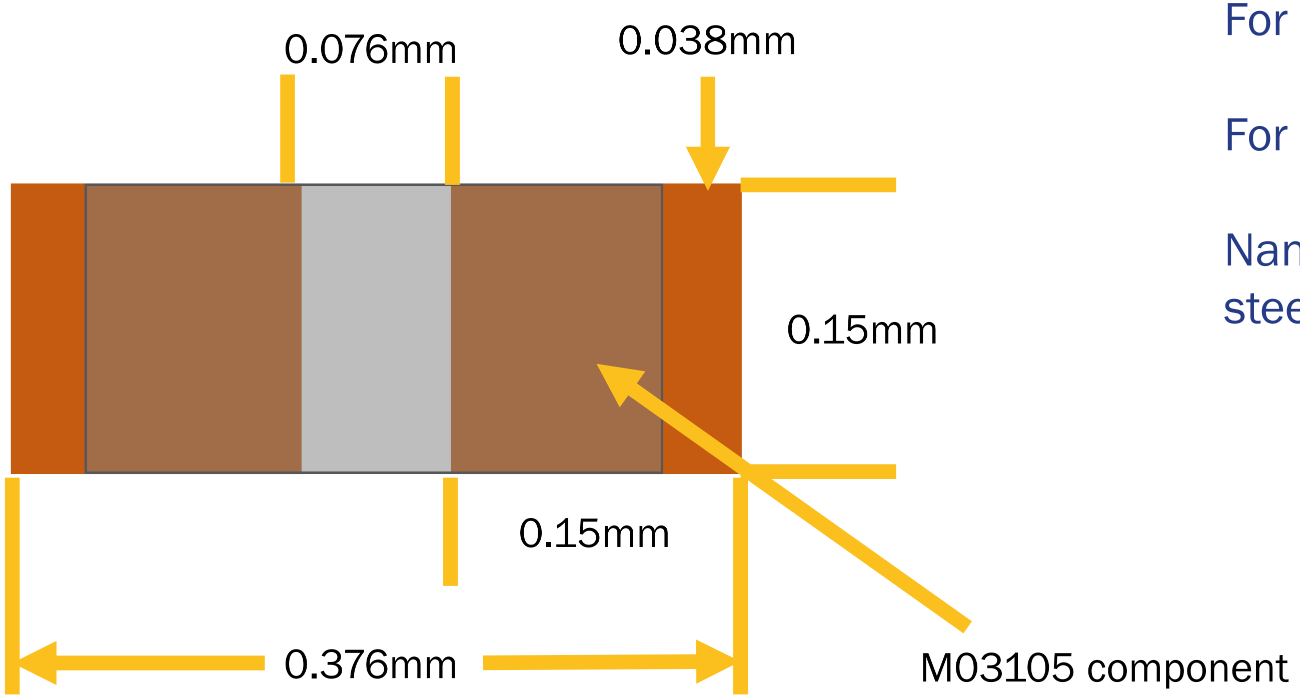
■Dimensions (Unit : mm)

Part No.	Size code mm (inch)	L	W	t	a	b
	03015 (009005)	0.30 ± 0.01	0.15 ± 0.01	0.11 ± 0.01	—	0.07 ± 0.01



M03015 Land Pattern on Test Vehicle

Company Test Vehicle



Area Ratio:

For 0.076mm thick stencil area ratio: 0.493

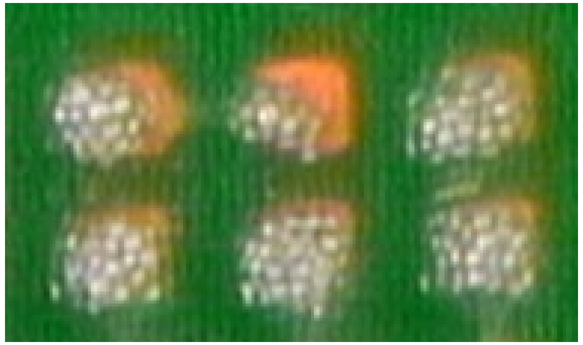
For 0.050mm thick stencil area ratio: 0.750

Nano coated laser cut stencil with fine grain stainless steel recommended.

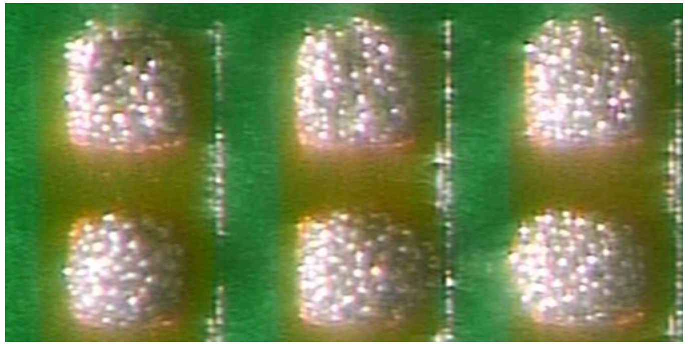
Solder Paste Type 5 Particle Size

Type designation [JEDEC]	Mesh size in lines-per-inch	Max. size (no larger than)	Max. size (less than 1% larger than)	Particle size in um (80% min. between)	Avg. size in um	Avg. size in um (10% max. less than)
Type 1			150	150-75		20
Type 2	-200/+325		75	75–45	60	20
Type 3	-325/+500		45	45–25	36	20
Type 4	-400/+635		38	38–20	31	20
Type 5	-500	30	25	25–10		10
Type 6	-635	20	15	15–5		5
Type 7		15	11	11–2		
Type 8		11	10	8–2		

Type 4 Solder Particle



Type 5 Solder Particle



Equipment

- Standard solder paste printer (with dedicated fixturing)
- Automated Solder Paste Inspection
- Placement machine
  - *Upgrades for camera and nozzles*
- Reflow Oven with Nitrogen capability (200-600ppm O_2)

Reflow Profile

Max Internal T: 29C
Battery: 4.805
Points: 516

Active: 123456
Interval: 00:00:01.0

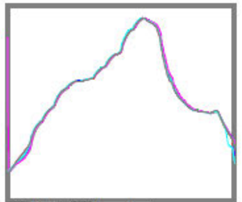
Date: 03/03/14
Time: 16:07:43 V09.08

	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
Length (cm)	35	35	35	35	35	35	35	35	35	35
Top (degC)	100	120	150	160	160	180	200	240	255	240
Bottom (degC)	100	120	150	160	160	180	200	240	255	240
Predict (degC)	100	120	150	160	160	180	200	240	255	240
	C11	C12								
Length (cm)	25	25								
Top (degC)	75	75								
Bottom (degC)	75	75								
Predict (degC)	75	75								
Conveyor (cm/min)	70	Predict	70							

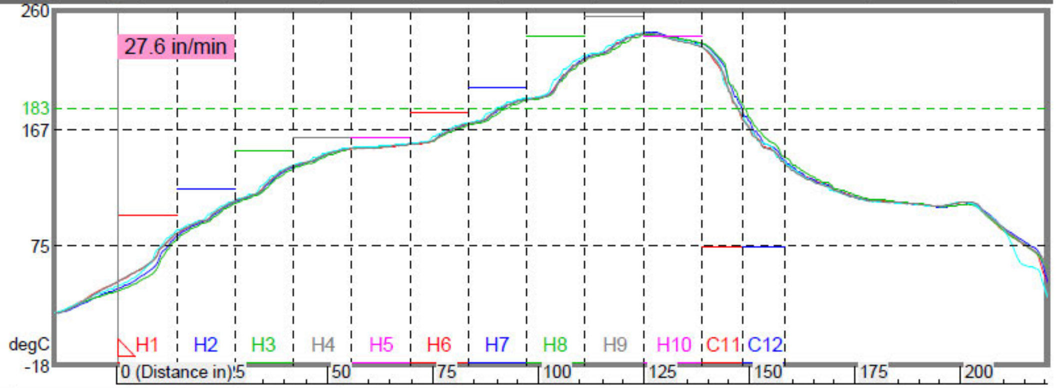
Tool status box

Line 1

LeadFree
010005TV



Auto ☒ Show Lag

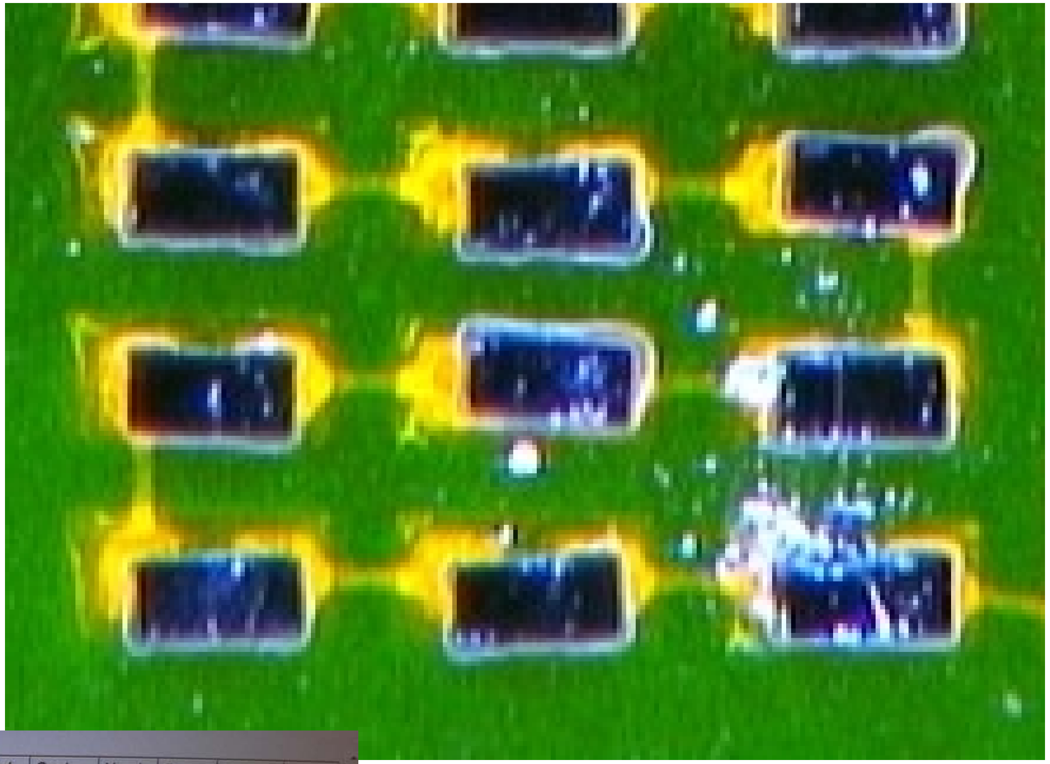


	Summary Stats	Peak	Minimum	Max (+)Slope	Max (-)Slope	Time Above 217C	Time 120-225C	217C / Peak	Peak \ 217C
¤	Sensor 1	242.8	22.2	1.89	-3.56	74.0	170.0	0.71	-0.71
¤	Sensor 2	242.8	22.2	2.17	-3.89	77.0	169.0	0.71	-0.75
¤	Sensor 3	241.1	22.2	2.39	-3.50	76.0	172.0	0.72	-0.68
¤	Sensor 4								
¤	Sensor 5	242.8	22.2	2.17	-3.72	77.0	168.0	0.69	-0.66
¤	Sensor 6	242.2	22.2	2.00	-3.72	73.0	169.0	0.71	-0.69
	Range	1.7	0.0	0.50	0.39	4.0	4.0	0.03	0.10

Ran with 200-600ppm O2 during testing

Pick and Place

- Placement speed 100%
- Issues seen with 1st placement in sequence
  - *Bug in software*
- Pick up rates were 98.9%
- Placement rates were 100%



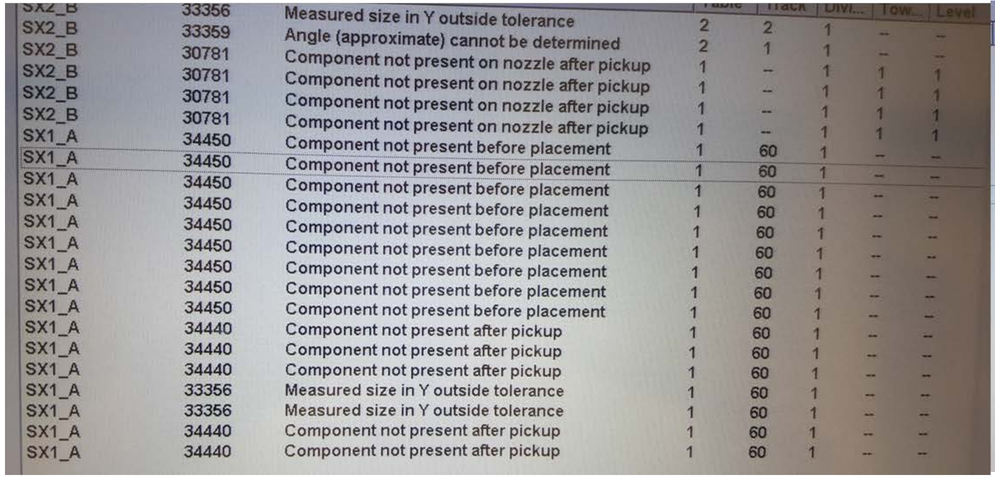
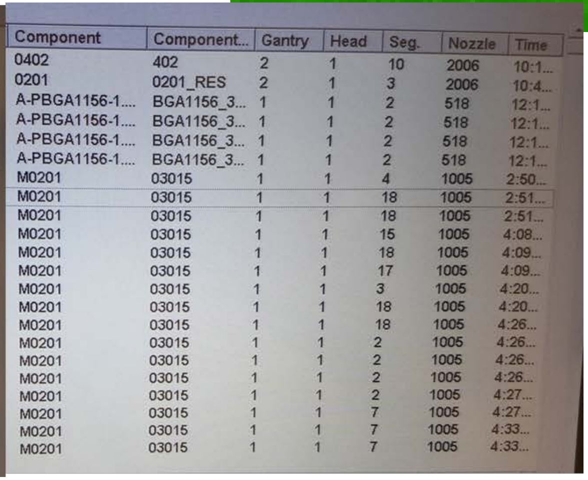


			Table	Track	Divi...	Tow...	Level
SX2_B	33356	Measured size in Y outside tolerance	2	2	1	--	--
SX2_B	33359	Angle (approximate) cannot be determined	2	1	1	--	--
SX2_B	30781	Component not present on nozzle after pickup	1	--	1	1	1
SX2_B	30781	Component not present on nozzle after pickup	1	--	1	1	1
SX2_B	30781	Component not present on nozzle after pickup	1	--	1	1	1
SX2_B	30781	Component not present on nozzle after pickup	1	--	1	1	1
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34450	Component not present before placement	1	60	1	--	--
SX1_A	34440	Component not present after pickup	1	60	1	--	--
SX1_A	34440	Component not present after pickup	1	60	1	--	--
SX1_A	34440	Component not present after pickup	1	60	1	--	--
SX1_A	33356	Measured size in Y outside tolerance	1	60	1	--	--
SX1_A	33356	Measured size in Y outside tolerance	1	60	1	--	--
SX1_A	34440	Component not present after pickup	1	60	1	--	--
SX1_A	34440	Component not present after pickup	1	60	1	--	--

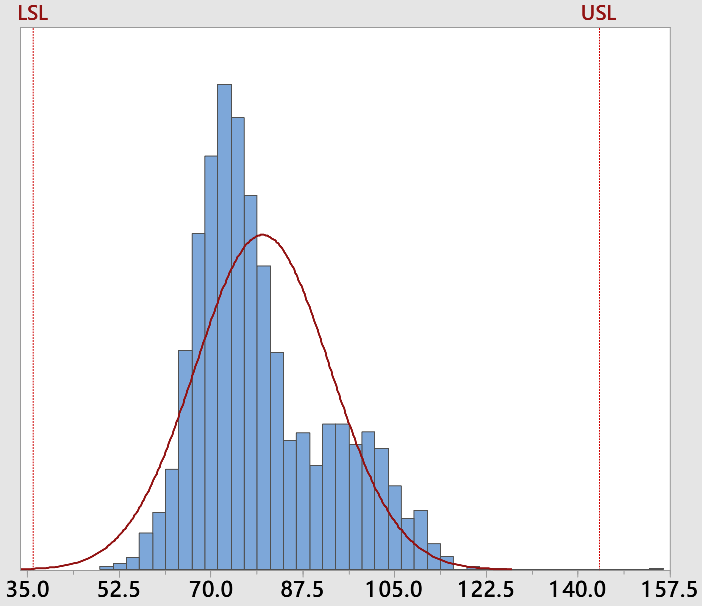


Component	Component...	Gantry	Head	Seg.	Nozzle	Time
0402	402	2	1	10	2006	10:1...
0201	0201_RES	2	1	3	2006	10:4...
A-PBGA1156-1....	BGA1156_3...	1	1	2	518	12:1...
A-PBGA1156-1....	BGA1156_3...	1	1	2	518	12:1...
A-PBGA1156-1....	BGA1156_3...	1	1	2	518	12:1...
A-PBGA1156-1....	BGA1156_3...	1	1	2	518	12:1...
M0201	03015	1	1	4	1005	2:50...
M0201	03015	1	1	18	1005	2:51...
M0201	03015	1	1	18	1005	2:51...
M0201	03015	1	1	15	1005	4:08...
M0201	03015	1	1	18	1005	4:09...
M0201	03015	1	1	17	1005	4:09...
M0201	03015	1	1	3	1005	4:20...
M0201	03015	1	1	18	1005	4:20...
M0201	03015	1	1	18	1005	4:26...
M0201	03015	1	1	2	1005	4:26...
M0201	03015	1	1	2	1005	4:26...
M0201	03015	1	1	2	1005	4:26...
M0201	03015	1	1	2	1005	4:27...
M0201	03015	1	1	7	1005	4:27...
M0201	03015	1	1	7	1005	4:33...
M0201	03015	1	1	7	1005	4:33...

Solder Paste Printing

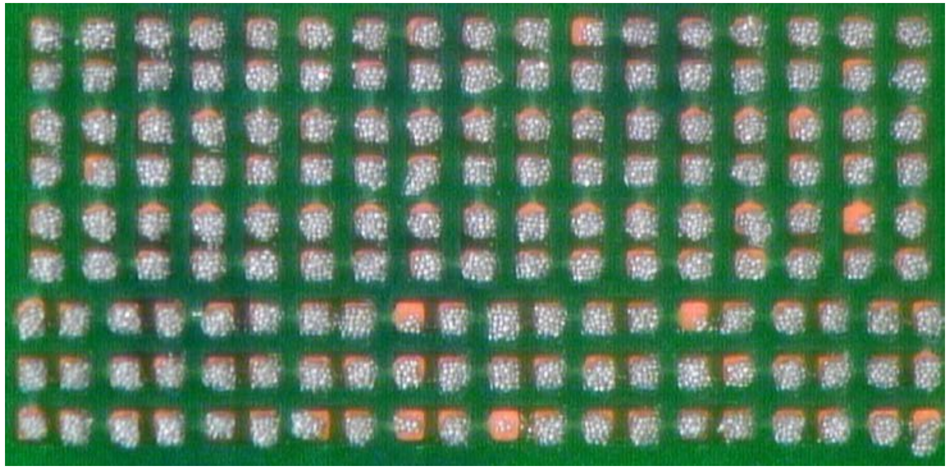
Process Capability Report for Volume All Locations

Process Data	
LSL	36
Target	*
USL	144
Sample Mean	79.7928
Sample N	2832
StDev(Overall)	12.8244

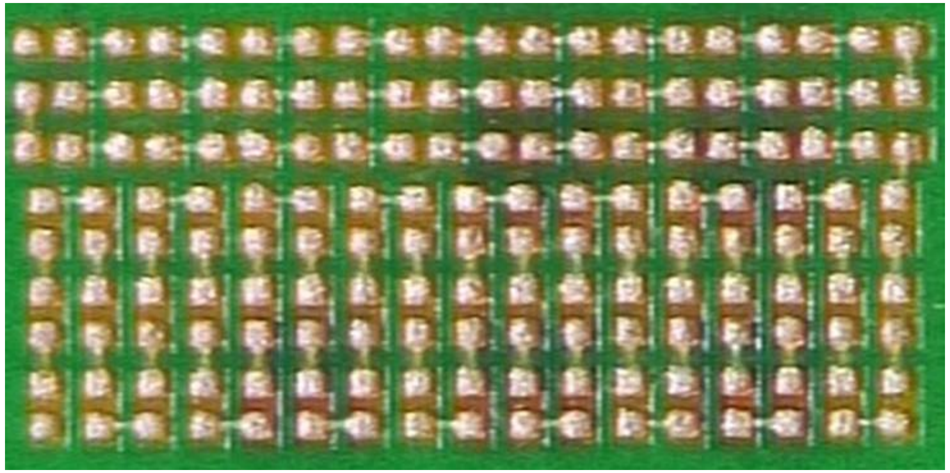


Overall Capability	
Pp	1.40
PPL	1.14
PPU	1.67
Ppk	1.14
Cpm	*

Performance	Observed	Expected Overall
PPM < LSL	0.00	319.13
PPM > USL	353.11	0.28
PPM Total	353.11	319.40



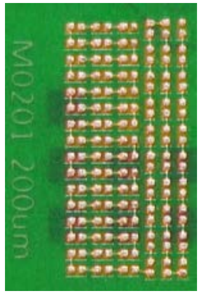
Type 4 solder paste with 0.076mm thick stencil



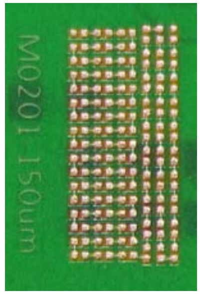
Type 5 solder paste with 0.050mm thick stencil

Solder Paste Printing

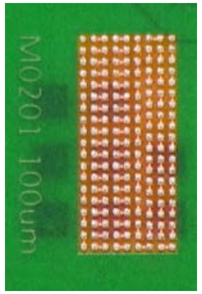
200um pitch

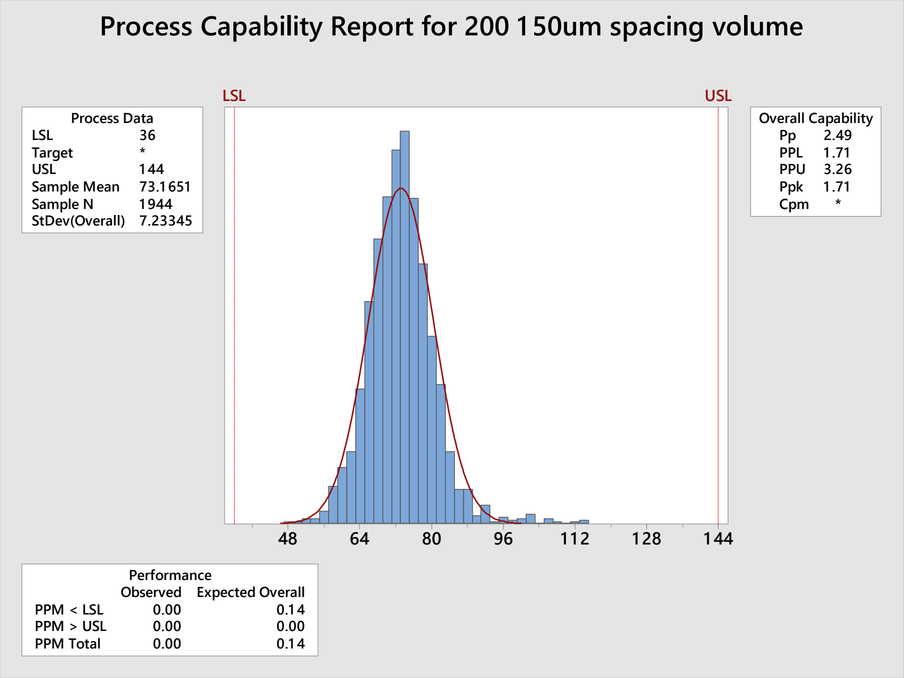


150um pitch



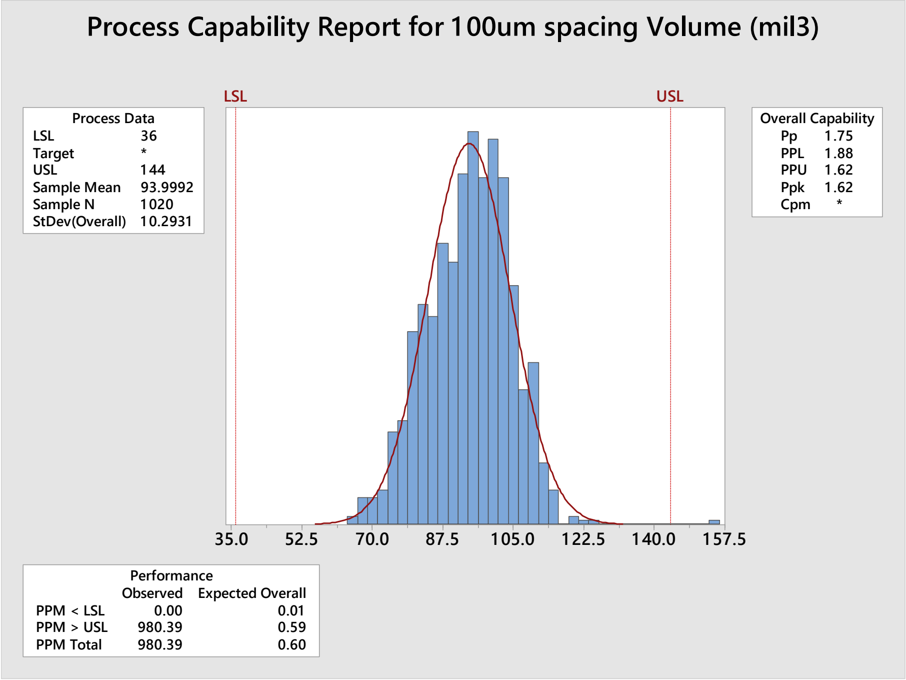
100um pitch





The pads of the 200 and 150um spacing show a better Cpk than the pads that have a large gang relief around all pads of the 100um spacing.

Since there is less stencil support from the solder mask, the 100um spacing sees a larger variation of data



Process Pictures

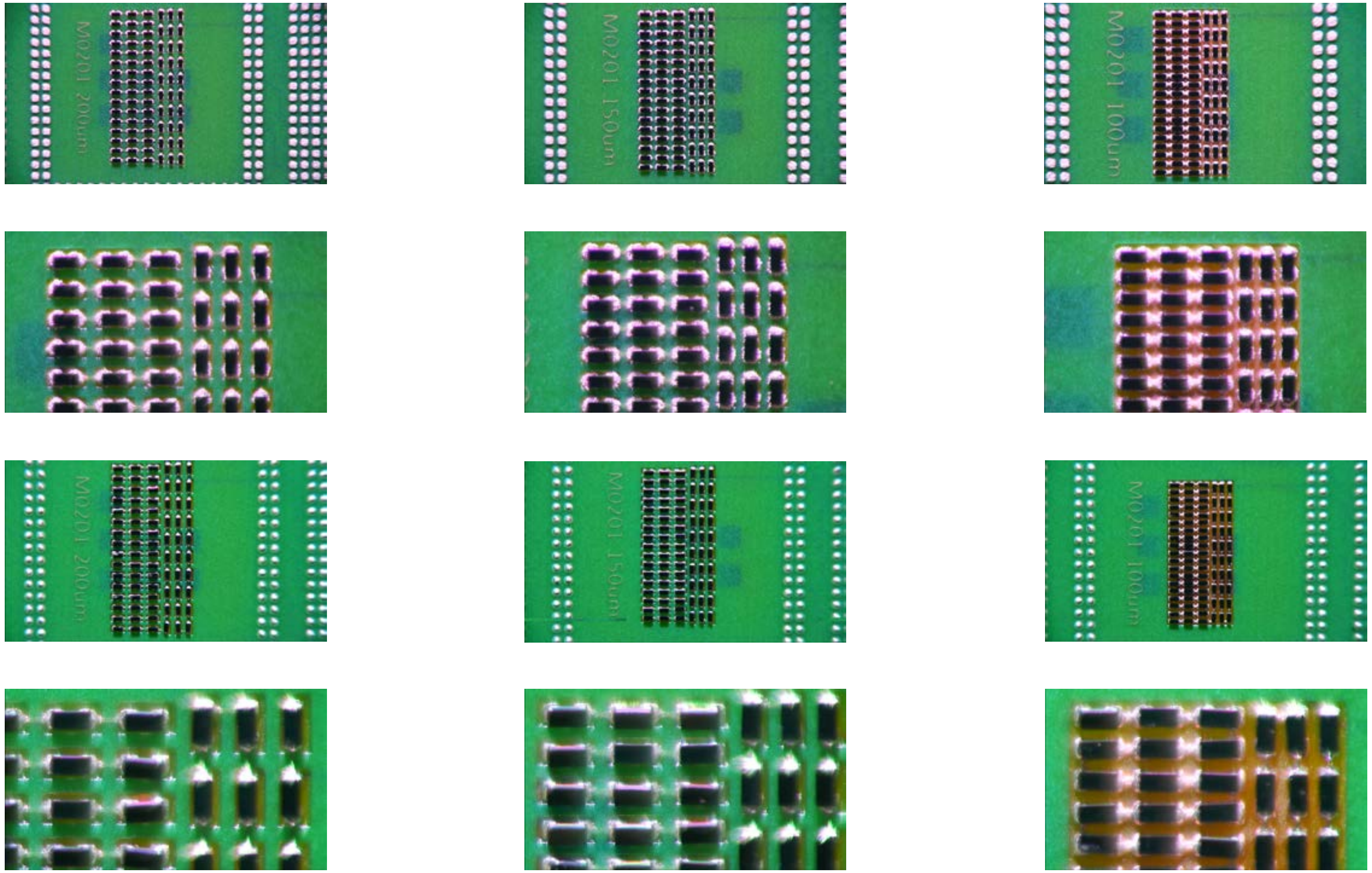
200um pitch | 150um pitch | 100um pitch

Before Reflow

Close-up

After Reflow

Close-up

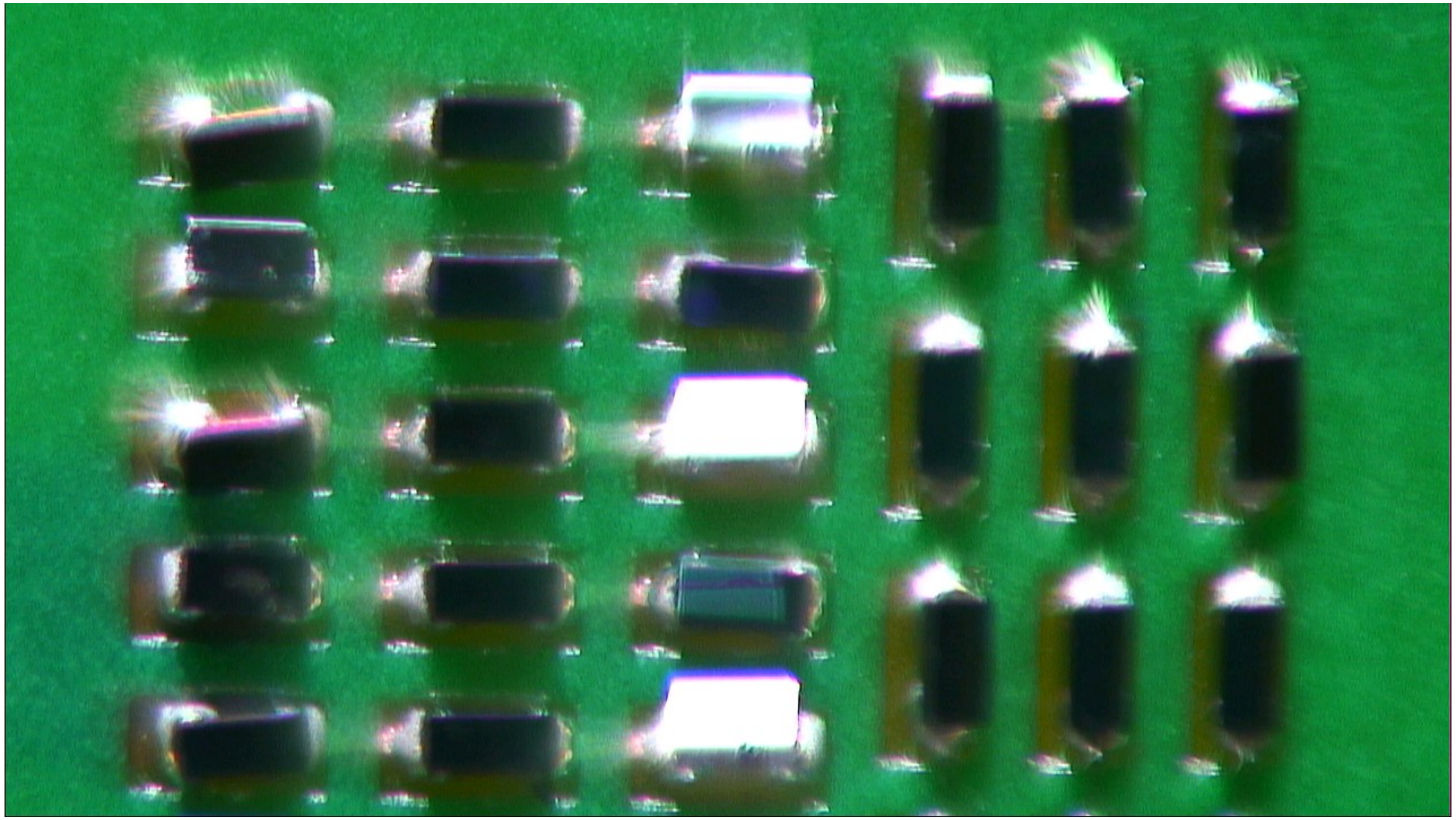


Tilting of components was observed.

No other defects were observed.

The shorting on the 100um spacing is along the traces that connected the pads together. Components would shift toward the trace locations.

Tilting of Components after Reflow



Tilting of components was observed.

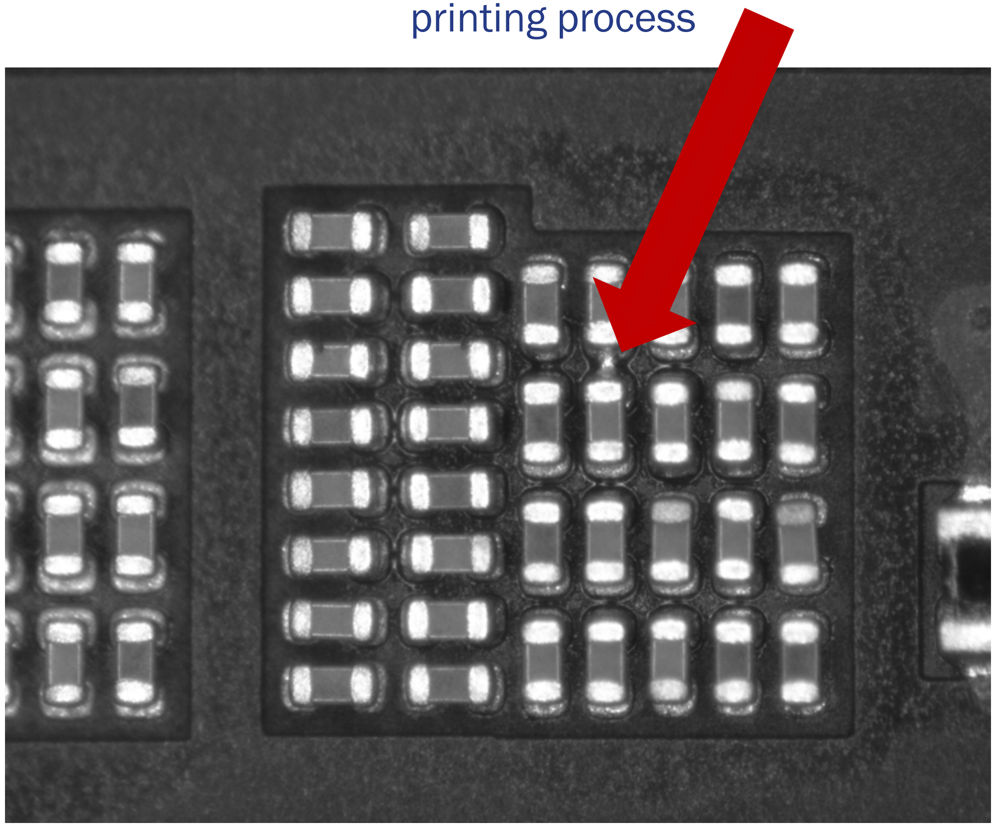
Parts “float” on the solder

Makes it hard for AOI and AXI to effectively inspect component and solder joints

Brief Look at m0201

- New test board designed for SiP wirebonding
  - *Included m03015 & m0201 components*
  - *Smaller pad sizes (pads approximately same size as terminations on components)*
  - *Tighter component to component spacings (100, 75, & 50um)*
  - *Optimizing solder paste printing process*
  - *Tilting not observed to the same amount on m03015 components due to smaller pad size and less solder on the pads*

Solder shorts were seen, caused by inconsistent printing process



M0201 Capacitors with 50um spacing

Conclusions

- M03015 component placements can be successfully done with a high yield process.
- Recommend using type 5 solder paste particle sizes. Chosen solder paste works well for this application
- Recommend using a 0.050mm thick stencil for best solder paste printing performance.
- Pick and place can be accomplished with the proper camera, feeder, nozzles.
- Reflow can be done in air, however more graping of the solder joint will occur.
- PCBs will be harder to route if fine pitch spacing is desired. The pad sizes are becoming very small and may not enable the use of uVia in pad for these applications from the normal pcb supplier. Will need to use high technology pcb supplier (substrate) for the use of miniaturized technologies.
- M0201s can also be processed, work ongoing with smaller pad sizes and finer spacings (100, 75, & 50um component spacings)

Thank You