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Hand Printing using Nanocoated and other High End Stencil Materials

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Abstract:
There are times when a PCB prototype needs to be built quickly to test out a design. In such cases where it is known early on that there will be multiple iterations or that a “one and done” assembly will be made that there will be some SMT assemblers who choose to hand print solder paste onto the board using a “frameless” stencil. In such cases where hand printing is used, the consistency of the printing technique has typically been in question. Furthermore, the effectiveness of both the nanocoatings as well as the higher end stainless steel materials, which have been heretofore studied in controlled printing environments, will be evaluated for their impact on the hand printing process.

Purpose:
The purpose of the study was to determine the effectiveness of select nanocoating materials as well as certain high end stainless steel stencil materials as they relate to the manual SMT printing process. A variety of nanocoatings were applied to SMT metal stencils and solder paste volume measurements were taken to compare the effectiveness.

Experimental Method:

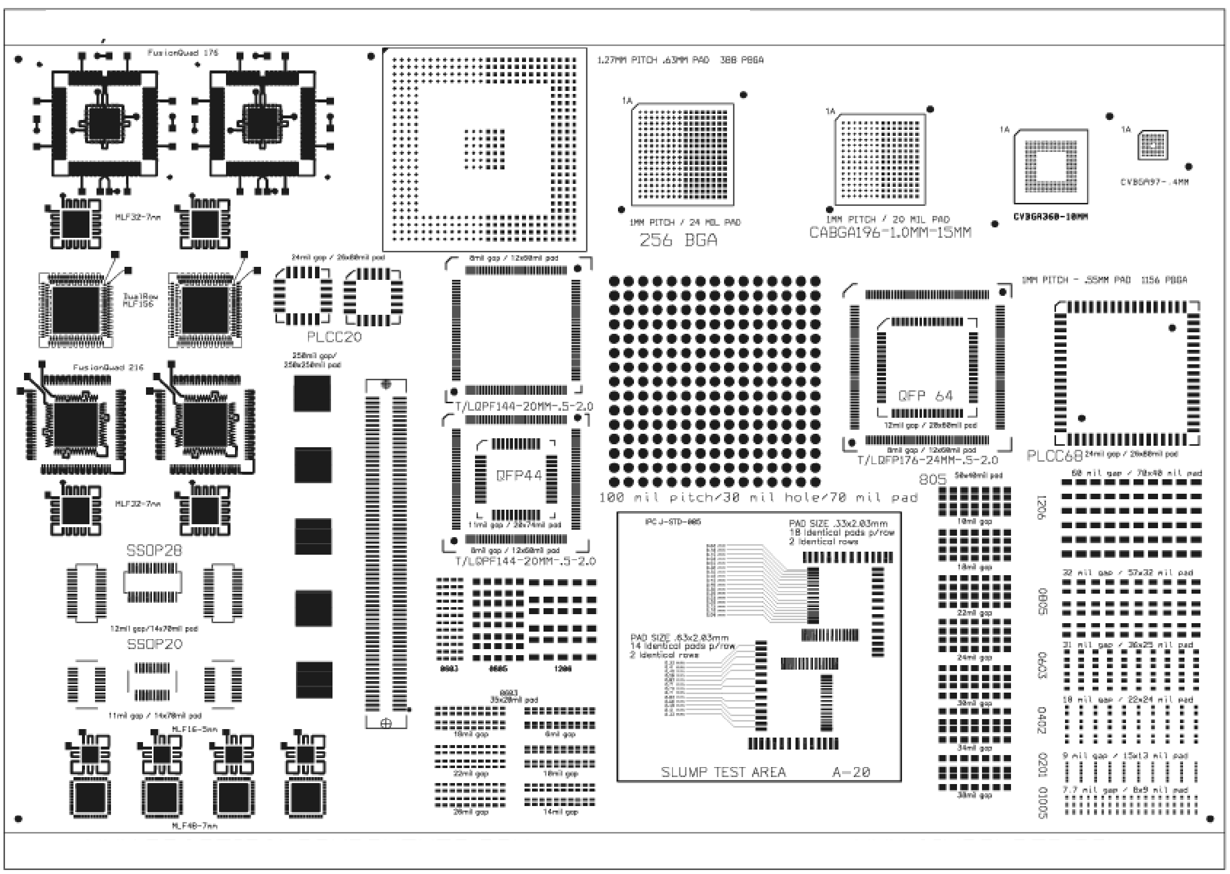

Figure 1: Solder paste Evaluation Board Layout

The test vehicle selected for the print study is shown in Figure 1 which is commercially available [1]. A picture (Figure 2) of one of the test boards is shown below.

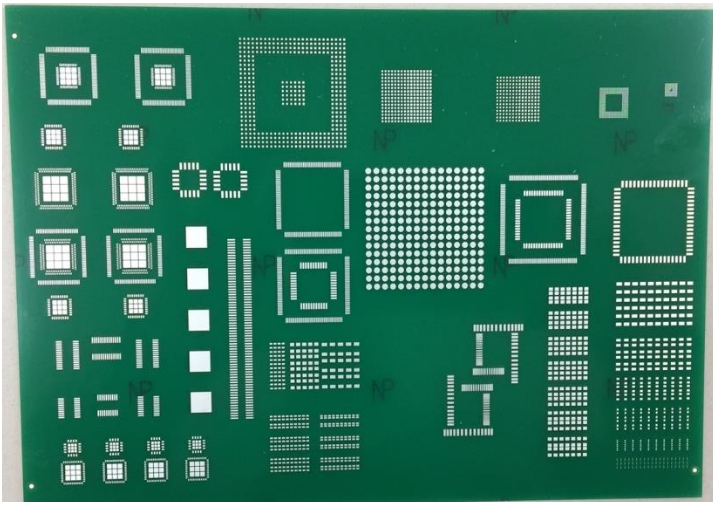

Figure 2: Test Vehicle for Solder Paste Printing Study

The feature sizes measured in this study ranged from a 15 x 13 mil (0201 component) up to the 70 x 40 mil pad (1206 component) pattern. The pad sizes and areas are given in Figure 3. The measured pad sizes and stencil thicknesses were measured using a digital metrology system. These values corresponded closely to the Gerber file as well as the board pad sizes.

Pad Size (microns)	Stencil Thickness (microns)	Measured Average Area (mils ^{2}) of Control Stencil
70 x40 mil -1206	4mils (101.6)	9318.0
(1778x1016)	3 mil (76.2)	6924.7
57 x 32 mil -0805	4mils (101.6)	6913.5
(1447.8x812.8)	3 mil (76.2)	5136.15
36 x 25 mil -0603	4mils (101.6)	2897.4
(914.4x635)	3 mil (76.2)	2146.74
22 x 24mil -0402	4mils (101.6)	2112.3
(558.8x609.6)	3 mil (76.2)	1182.48
15 x 13 mil -0201	4mils (101.6)	487.2
(381 x 330.2)	3 mil (76.2)	355.26

Figure 3 – Pad Sizes and Stencil Thicknesses Used in the Study

Stencils

The majority of the stencils including the "control" stencils, were fabricated from a high nickel content, small grain structure stainless steel. The stencil labeled "High Tension" was fabricated using a higher end stainless steel material known for its ability to more readily release solder paste from apertures when the area ratios are less than 0.66. They were all cut on a modern laser by a US based stencil supplier. The stencil supplier provided (4) separate stencils with (2) different nanocoating materials. These nanocoating materials were applied per the nanocoating suppliers' recommendations. The SPI results from each stencil were compared to the "control" which was the uncoated high nickel content, small grain structure stainless steel. All apertures were reduced to coincide with industry best practices.

Equipment and Printing Parameters

The test and processing equipment consisted of several elements. The manual printing station (Figure 4) consisted of "L" brackets to align the board in the same location from print to print. Board holding brackets were placed at opposite corners of the board. The manual squeegee used was a 25 degree polymer infused metal squeegee blade. Blue painter's tape held the top of the stencil in position relative to the board. All stencils were cut on the same laser by the same operator using the same control settings on the laser. Any systematic error was applied to all stencils.

Figure 4 – Typical manual stencil printing set- up

Solder Paste

The solder paste used in this particular test was a Type 4 SnAgCu no clean solder paste. It was taken out of the jar from the refrigerator at 3°C and mixed with a metal stirrer 15 minutes before the beginning of the printing study.

Environment

The parameters in the printing and measuring area were recorded at 24.7 degrees Celsius and 55% RH.

Automatic Solder Paste Inspection

A semiautomatic solder paste inspection system was used to measure the paste print height as well as print volume. Board samples were prepared, printed and then measured within 5 minutes of printing using the same measuring parameters.

Experimental Design

There were a variety of both input and output variables as part of this study. The input variables included the type of stencil material whether low grain structure or high tension, the type of nanocoating material and the stencil aperture size. Output variables consisted of solder paste deposit volume, solder paste deposit height as well as measured aperture sizes and stencil thickness.

Statistics calculated from the output readings included: standard deviation, mean and coefficient of variation of the print height and volume.

The testing was completed using the following steps: align board into holders, place first PCB into holders, align the stencil number 1 to the PCB, stir solder paste, align the board into the manual holders, manually print the board, inspect the print and measure. No wiping of the stencils was made between each print. SPI readings were automatically written to the hard drive for later extraction. Select pads from select device types scattered over the board were measured by the SPI system.

Results and Discussion

The mean value of the measured population, the standard deviation as well as the Coefficient of Variation (CVs) for the differing device pad types measured from 1206 (120 x 60 mils) to 0201 sizes (20 x 10 mils). Each data point on the table (Figure 4) represents the average of 248 deposit readings for the 1206, 254 for the 0805, 150 for the 0603, 153 for the 0402 and 150 for the 0201 component sizes (imperial). Five boards per stencil variation were measured.

Figure 5- Results of Statistical Analysis of Printing Volumes

Device Size		**4 mil**	**4 mil**	**4 mil**	**4 mil**	3 mil	3 mil	3 mil	3 mil
Pad Size		Control	High Tension	NC #1	NC #2	Control	High Tension	NC #1	NC #2
1206	Mean-mils^3	11,679.7	12,306.4	11,791.8	11,194.4	8,709.8	10,555.0	9,992.3	9,593.2
70 x 40 mil	Std Dev	1,458.9	909.1	527.8	656.4	824.1	862.8	1,813.6	1,291.3
	CV	0.12	0.07	0.04	0.06	0.09	0.08	0.18	0.13
0805	Mean-mils^3	7,715.3	8,203.0	7,892.9	7,522.9	6,083.2	7,054.6	6,514.3	6,569.3
57 x 32 mil	Std Dev	887.1	783.5	599.0	973.6	782.3	934.5	1,720.0	1,079.0
	CV	0.11	0.10	0.08	0.13	0.13	0.13	0.26	0.16
0603	Mean-mils^3	3,354.0	3,260.6	3,203.5	2,941.8	2,371.5	2,697.4	2,728.5	2,513.1
36 x 25 mil	Std Dev	353.5	232.4	173.9	164.0	262.3	229.6	511.4	364.4
	CV	0.11	0.07	0.05	0.06	0.11	0.09	0.19	0.15
0402	Mean-mils^3	1,624.1	1,661.1	1,570.6	1,490.2	1,301.6	1,406.3	1,387.6	1,301.4
22 x 24 mil	Std Dev	295.8	110.5	80.0	87.8	203.6	131.5	212.6	197.6
	CV	0.18	0.07	0.05	0.06	0.16	0.09	0.15	0.15
0201	Mean-mils^3	409.2	425.7	357.5	306.3	269.8	298.6	321.8	307.8
15 x 13 mil	Std Dev	31.9	31.0	33.7	44.6	40.9	41.4	56.0	63.4
	CV	0.08	0.07	0.09	0.15	0.15	0.14	0.17	0.21

The paste stencil volumes measured as a function of stencil thickness performed as expected with the 4 mil material having a greater deposit volume over the 3 mil materials. However, the 3 mil material had larger coefficients of variation.

In terms of the nanocoatings they had different overall printing volume performance outcomes with coating material #1 outperforming coating material #2. On average nanocoating # 1 performed by about 5% better in terms of print volume than coating #2 within a band of 1-14% across the range of different pads and stencil thicknesses. Coating #2 had a higher standard deviation than coating #1 for the 4 mil stencil and the opposite was true for the 3 mil stencil.

In terms of the nanocoated #1 stencil performance overs its uncoated counterpart, the results were mixed. In the case of the thicker 4 mil stencil the nanocoated #1 results versus the control there were mixed results. However, for the 3 mil material the nanocoated #1 material outperformed the control for every pad size.

In every case the high tension material printed a greater average paste volume compared with the control material. The results indicated that the deposits seen on the high tension material were 2-6% higher for the 4 mil material and 8-21% for the 3 mil thick material. The high tension material also had a small standard of deviation and coefficient of variation across the board (Figure 8).

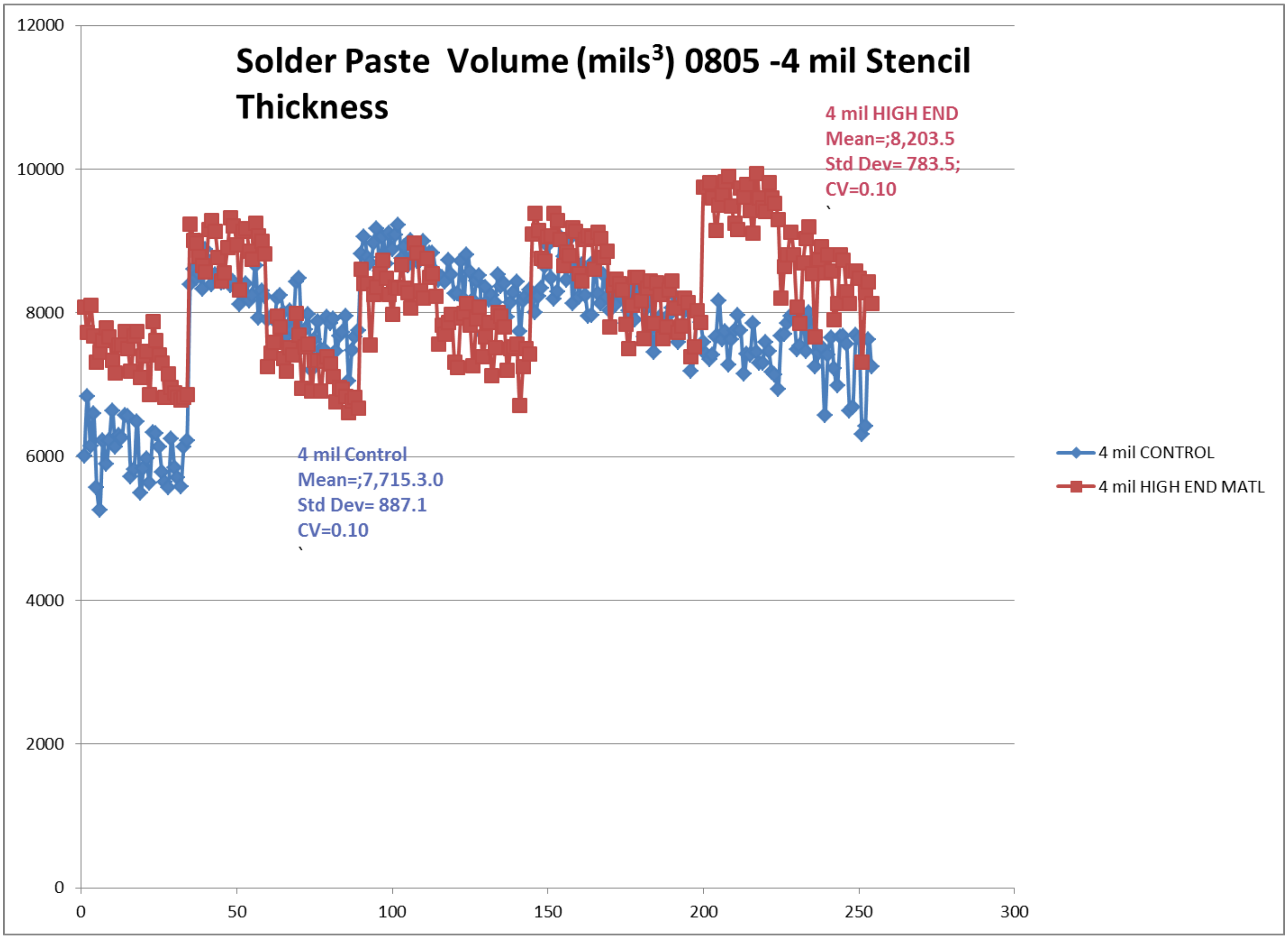

Figure 6- Print performance , 4 mil stencils, Various stencils 0805-46.6 X 37.0 mil measured aperture size

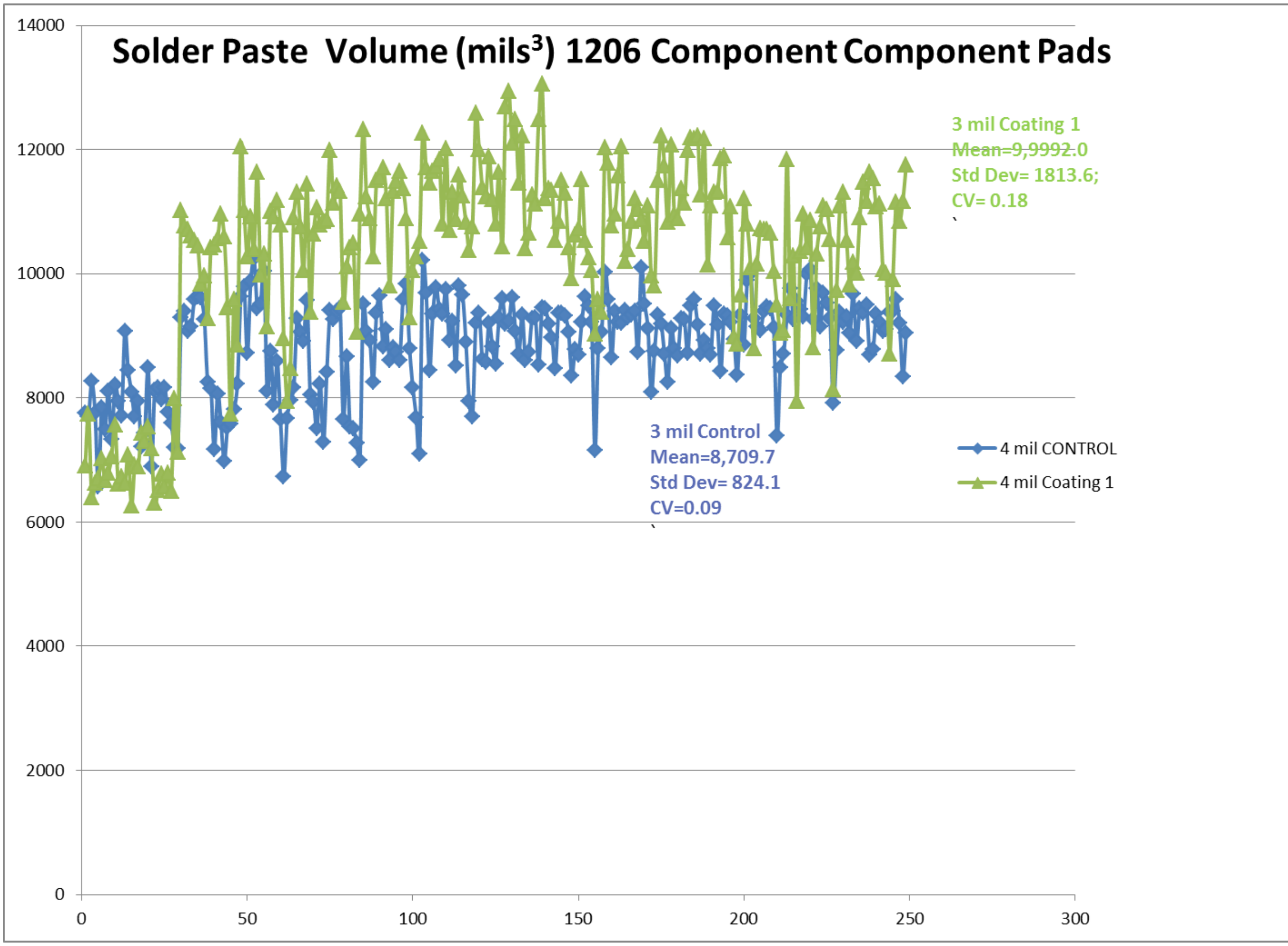

Figure 7- Print performance, 4 mil stencils, Various stencils 1206- 62.8 X 37.0 mil pad size

The consistency of the high tension stencil performance was better than the best performing nanocoated stencil (Figures 7,8). The 4 mil thick high tension stencil outperformed the nanocoated #1 stencil with the standard deviation and CV being better. The performance between the two types of 3 mil stencils had a mixed result with some of the pad sizes being better and some worse. However the consistency of the 3 mil printed high tension stencil was superior to the nanocoated stencils as both the standard deviation and CV were more favorable on the high tension stencils.

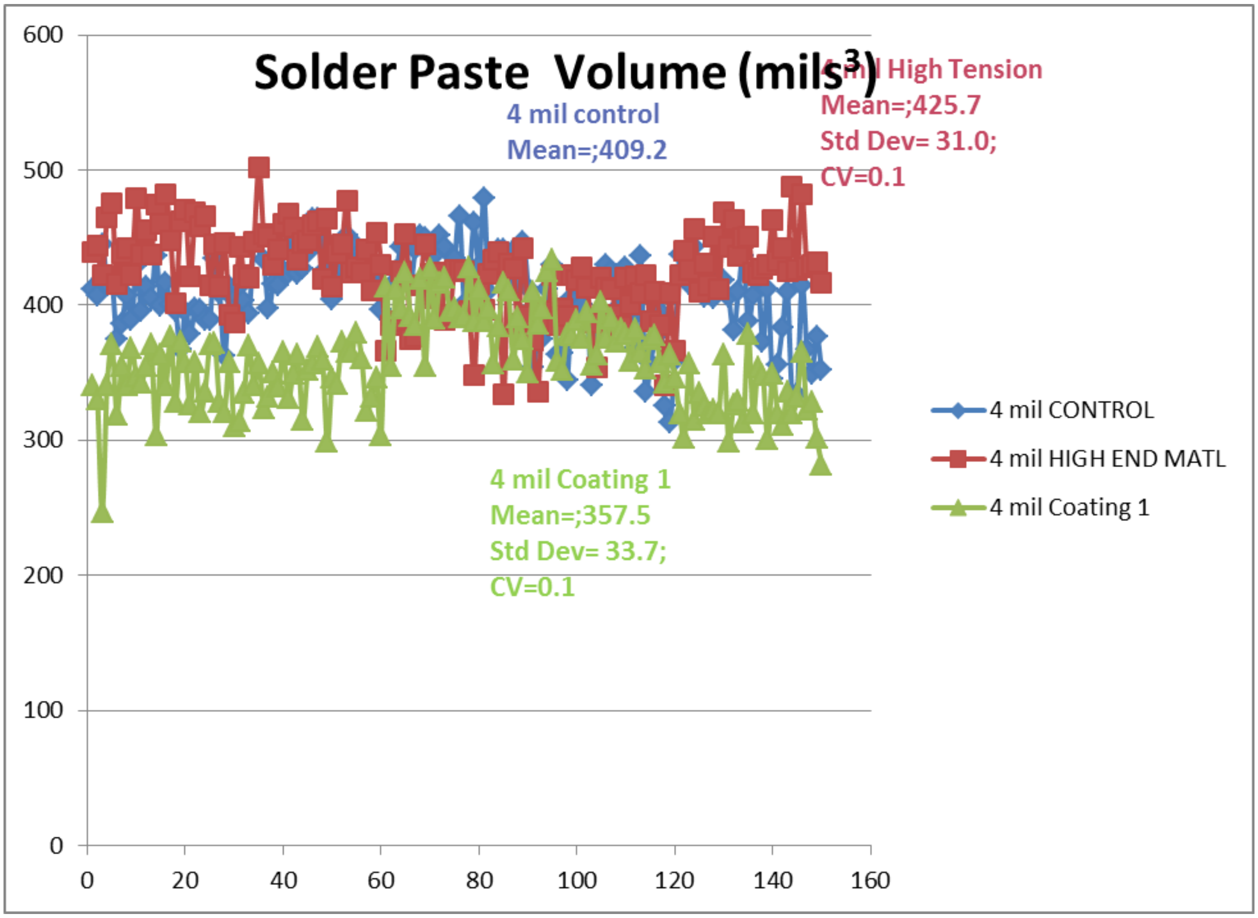

Figure 8- Print performance, 4 mil stencils, Various stencils 0201-12.0x10.1 mil pad size

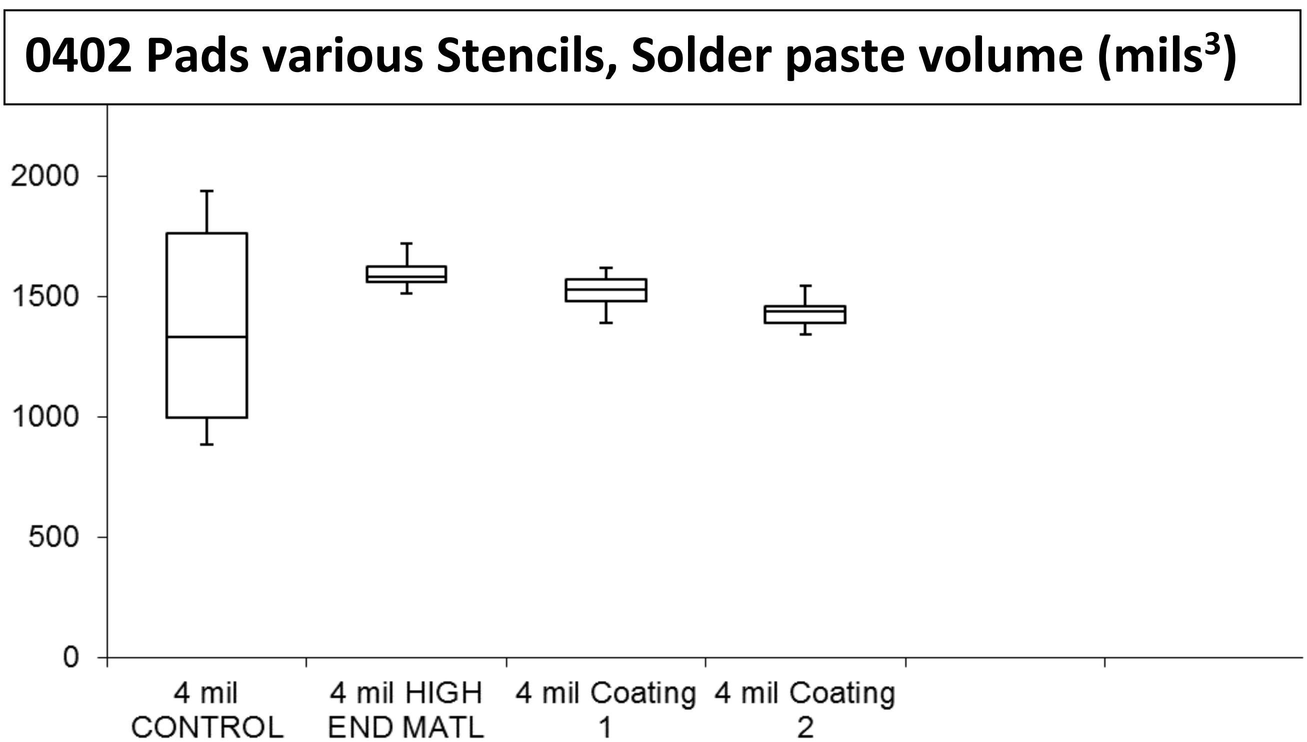

Figure 9- Box plot of print performance , 4 mil stencils, 0402-22 x 24 mil pad size

Conclusions

The solder paste printing process is the area of the SMT assembly process where the greatest strides in improvement can be made with respect to yield. This is especially true in the case where several inputs to the manual printing process, are not controlled as in a machine-controlled printing process.

The high tension advanced stainless steel material provided the best release characteristics across all aperture sizes compared to the standard nickel-content small grain structure stainless steel. In addition, the printing volume was more consistent using this higher grade material. All the high tension material results were better than the high nickel content stainless steel stencils.

The addition of a nanocoating to the high nickel content stainless steel stencil did generally bring about higher print volume compared to an uncoated stencil. This was especially true of the thinner 3 mil stencil. However the consistency of the printing was lessened by the addition of a nanocoating for the thinner stencil.

Finally, it was demonstrated that each type of nanocoating material needs to be evaluated and confirmed for the manual printing process. In this study the nanocoating 1 material outperformed the nanocoating 2 material.

The higher grade high tension material had the best overall printing performance using a manual SMT printing process.

Acknowledgements

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References

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