Effect of OSP Chemistry on the Hole Fill Performance During Pb-free Wave Soldering

Bala Nandagopal[1], Sue Teng[2] and Doug Watson[3]
[1, 2]Manufacturing Technology Group, Cisco Systems, Inc.,

Abstract
This paper analyzes the differences in plated through hole fill performance between the regular OSP and Pb-free OSP PCB surface finish chemistries in a Pb-free wave solder process. The variables studied include two board thicknesses - 93mil and 125mil, three hole sizes - pin plus 16, 24 and 40mils, internal Cu layer connections - single and three plane layer connections, two pin shapes - circular and rectangular and two reflow atmospheric preconditions - Nitrogen and Air. A SnPb control was included for the 93mil thick test board. The bare PCBs were initially subjected to 220^{o}C and 240^{o}C peak reflow process twice for the SnPb and Pb-free wave soldering samples, respectively. This was followed by a wash process before wave soldering.

The Pb-free wave soldering results indicated that the Pb-free OSP performed better than the regular OSP chemistry by 15% under air and 40% under nitrogen reflow preconditioning. In Pb-free wave soldering, the air preconditioning resulted in better hole fill than nitrogen. Board to board variation of hole fill was much lower in the Pb-free OSP chemistry compared to regular OSP. Plated through hole size of 40mils and 16mils, larger than the pin diameter proved to be best and worst designs for the 125mil PCB, respectively. The SnPb control almost had greater than 92% average hole fill for every design variable in this experiment.

Overall, the results indicated that the regular OSP chemistry in Pb-free wave soldering failed to meet the 50% hole fill required per IPC-A-610, for all the conditions studied. The 125mil thick PCB using Pb-free OSP chemistry also failed to meet the IPC requirements for all the conditions evaluated. However, the 93mil thick PCB using Pb-free OSP chemistry was able to meet this 50% hole fill requirement(although not meeting the general 75% minimum requirement), except when the hole diameter is 16mils larger than the pin.

Introduction
Since the advent of surface mount devices, its usage in the Printed Circuit Board Assembly (PCBA) has constantly risen. However, many board assemblies still incorporate some level of through hole design as well. Due to various reasons the through hole wave soldering technology is here to stay and cannot be eliminated completely. Wave solder process yields have been satisfactory on the thinner boards such as 62mil or lesser. IPC-A-610 describes the hole-fill requirements for the products of various classes. As product complexity increases within the telecommunications and networking industry, the PCB thickness continued to increase. This increase in thickness caused a drop in the wave soldering process yields. Meeting the IPC-A-610 requirements using SnPb solder alloy proved to be a significant challenge in process development, specifically, for thicker PCBs (>93mils) using OSP surface finish. PCB design and the wave solder process parameters were constantly optimized to improve yields.

In transitioning to Pb-free assembly process, one of the major hurdles is the hole-fill performance of wave soldered parts. SnPb has better wetting characteristics than the Pb-free alloys and that difference in wetting characteristics was expected to worsen the hole-fill yields. Although one may question if the same percentage hole fill criteria is appropriate for all PCB thicknesses, as specified by IPC-A-610. A recent study [1] on through hole reliability has suggested the use of absolute pin wetted length and then converted it to different percentage criteria based on PCB thickness. Converting the process to Pb-free, specifically for the thicker PCBs proves to be a much more complex process issue to be resolved due to inferior wettability of Pb-free solder compared to SnPb. Adding another dimension to this issue is the peak temperature rating of Pb-free components in IPC/JEDEC J-STD-020C, which constrains the delta between the wave solder pot temperature and melting point of solder. The Pb-free wave solder pot has to be maintained at a maximum of 265^{o}C. In SnPb wave process the typical solder pot temperatures are in the range of 260^{o}C to 265^{o}C. It is evident that 265^{o}C is 82^{o}C above the melting point of eutectic SnPb while it is only 44^{o}C for Pb-free. Any further increase in the Pb-free wave solder pot temperature may lead to violation of the IPC/JEDEC J-STD-020C specifications for maximum component temperature rating, if any Surface Mount Devices (SMDs) were exposed to wave solder pot.

In this study, the focus will be on the PCBs using Organic Surface Protectant (OSP) chemistry as its surface finish. OSP finish prevents oxidation of the copper pads. The present chemistry or the one that has been used in SnPb soldering shall be termed as 'Regular OSP chemistry'. Many improvements have been made to the existing chemistries in order to meet the soldering requirements of Pb-free reflow and this shall be termed as 'Pb-free OSP Chemistry'. The primary objective of this paper is to characterize the improvement in hole-fill performance between the regular OSP and that of the Pb-free OSP chemistry.

Experiment Details

This study used two board thicknesses of 93mils and 125mils with 10 and 16 layers of copper, respectively. The board design variables included three hole sizes of 16, 24 and 40mils larger than the pin diameter, single and three internal copper layer and circular and rectangular pin shapes. These hole size variables were incorporated using three component types, namely, 4 pin oscillators, 2 pin electrolytic capacitors and 10 pin test headers. The oscillators and capacitors had circular pin of 18 and 24mils in diameter, respectively, while the test header had a 16x31mil rectangular pin. The rectangular test header had 38mil and 48mil finished hole sizes on the test board. The component pin lengths were trimmed to have 30mil lead protrusion through the bottom side of the board. Each board was populated with 4 oscillators and capacitors, and 3 test headers.

All the bare PCBs were preconditioned through two mass reflows of 220^{o}C and 240^{o}C peak to simulate SnPb and Pb-free process, respectively. The influence of Nitrogen and air during the reflow preconditioning was also studied. All PCBs were washed post reflow as part of the preconditioning. The wave solder experiment was conducted in less than 24hrs after the reflow preconditioning of the PCBs. A SnPb control was included for the 93mils thick PCB. Three boards were run for each variable in the Design Of Experiment (DOE).

The PCB samples associated with regular and Pb-free OSP chemistry is shown in Table 1. While the 93mils thick PCB had all the assembly variables incorporated, the 125mils PCB was run only through Pb-free wave with Nitrogen atmosphere reflow preconditioning.

Same flux chemistry (VOC free and low residue type) was used throughout the experiment to avoid any variation in performance due to flux chemistry. The solder pot temperature was maintained at 265^{o}C for both Pb-free and SnPb wave soldering. The dwell time for Pb-free and SnPb boards was 4.2 seconds and 4.5 seconds, respectively. A typical wave solder profile is shown in figure 1. Standard production equipment was used for reflow and wave soldering of the boards. Selective wave solder pallets were used during the wave process.

All the boards were inspected for hole-fill using high resolution X-ray. This data was then analyzed for statistical significance, which will be discussed in the subsequent sections. Further, two boards from Pb-free wave soldering were cross sectioned to validate the hole-fill percentage measured through X-ray.

Hole fill Results

SnPb and Pb-free process:

SnPb wave process resulted in >90% average hole fill for regular OSP, except for a few outliers (figure 2). Further, the change in surface finish to Pb-free OSP chemistry resulted in 100% hole fill without any exceptions.

The average hole fill of 93mil PCBs preconditioned in nitrogen atmosphere showed that Pb-free OSP outperformed regular chemistry by about 40%, with a mean hole fill of 74% and 31%, respectively (figure 3). On the other hand, this magnitude of increase in hole fill using Pb-free OSP dropped to 15% when the PCBs were preconditioned in air atmosphere (figure 4). The hole fill of air preconditioned regular OSP samples averaged 74%, while the nitrogen preconditioned samples averaged only 31%. Similarly, among the Pb-free OSP samples the air preconditioned PCBs averaged 88% while the nitrogen preconditioned samples where at 74%.

The average hole fill of 125mils PCB preconditioned in nitrogen atmosphere showed that Pb-free OSP outperformed regular chemistry by 40%, with a mean hole fill of 65% and 27%, respectively (figure 5). The 10 pin test header data points were removed since there wasn't sufficient lead protrusion when assembled on 125mils thick PCBs.

PCB Design Parameters:

Finished hole size of pin plus 0.016" performed the worst and pin plus 0.040" was the best for both the board thicknesses (Table 1). Although the finished hole of pin plus 0.040" on Pb-free OSP boards showed similar hole fill % (98-100%) for all variables of this experiment, the regular OSP boards exhibited poor hole fill % for nitrogen and 93mils (82% fill) thick PCB combination and even worse for the 125mils thick PCB (66% fill).

Among the 93mil thick PCBs, the increase in number of internal plane connections showed no more than 3% change in hole fill. On the other hand, the 125mil thick PCBs showed an 8% drop for the Pb-free OSP and a 25% drop for regular OSP.

Statistical Analysis:

One way analysis was performed to determine the statistical significance of average hole fill due to the OSP chemistry. For this analysis, each data point represents the average hole fill of all the leads within a component. The significance results are shown in figures 2-5. The mean hole fill (in fractions) are shown below the figure. In SnPb wave solder, the chemistry did not show a statistically significant difference in the average hole fill. On the other hand, in Pb-free wave solder, the chemistry did have a significance in the average hole fill. Interestingly, even for the Pb-free with air as preconditioning where the average hole fill improved only by 15% due to Pb-free OSP, the data showed statistically significant difference in average hole fill. Further, the wide variation in the average hole fill due to the design parameters studied in the regular OSP PCBs was significantly narrowed by using the Pb-free chemistry.

Discussions

In SnPb wave soldering, both the OSP chemistries resulted in close to 100% hole fill. Therefore, the percentage improvement in hole fill due to chemistry or design variables could not be quantified. We may say that acceptable hole-fill (per IPC-A-610) in SnPb wave process can be achieved using Pb-free OSP boards with optimal design and process considerations. In Pb-free wave soldering with nitrogen preconditioning, the Pb-free OSP chemistry can improve average hole fill by 40% compared to regular chemistry. However, under air preconditioning this difference in average hole fill dropped to 15%. Furthermore, comparing the preconditioning within a given chemistry, air outperformed the nitrogen samples by 43% (regular OSP) and 14% (Pb-free OSP), which was contrary to our expectations. These results indicated that the air reflow preconditioning was a critical factor in improving the hole fill performance of regular OSP samples but not in Pb-free OSP samples.

The 125mil thick PCBs showed only a slight reduction of 4% in hole-fill performance compared to its 93mil PCBs. Interestingly, the performance difference between the two chemistries (figure 5) still remained at 40% proving a strong significance to the use of Pb-free OSP chemistry.

A clear trend of increasing hole fill with increase in finished hole size was evident from the results (Table 1). Finished hole size of pin plus 40mils proved to be the best design, outperforming the pin plus 16mil and 24mil designs. For a given chemistry, moving from a one to three internal plane connection showed no more than 3% difference in the average hole fill for the 93mil PCBs, whilst the 125mil thick PCBs had 8% to 28% drop. Interestingly, the use of Pb-free OSP chemistry did improve the hole fill for a given plane connection design. Another significant observation was that the variability in hole fill among the designs was wide for regular OSP boards while the Pb-free OSP boards had a much narrower band. This leads to the conclusion that in Pb-free wave solder the use of Pb-free OSP chemistry not only improves the hole fill but also its repeatability.

Finally, despite significant improvement to hole fill performance by using Pb-free OSP chemistry, the hole fill % for many pins failed to meet the IPC-A-610 criteria of 75%. This creates the need to initiate future studies with wider scope involving variables such as wave solder flux, process parameters and PCB surface finish. Also, this study should be extended to evaluate the reliability of absolute height of hole fill for 93mil and thicker PCBs instead of using the percentage requirements specified by IPC-A-610.

Conclusions

The use of Pb-free OSP chemistry in Pb-free wave soldering improves hole fill by about 40% and the process repeatability. The pin plus 40mils proved to be the best design for the finished hole size of thick PCBs. SMT reflow under air was found to be the best condition to maximize hole fill performance. In spite of these improvements many of the design parameters studied, especially the 125mil thick PCB with three plane connections, failed to meet IPC-A-610 requirements.

Acknowledgements

The authors would like to thank the management at Cisco Systems, Inc. and Dave Mendez of Solectron Corporation for their support of this project.

Reference:

[1] Reliability of Partially Filled SAC305 Solder Joints, Helen Holder, Hewlett Packard Company, IPC / APEX Feb 2006, Anaheim, CA. S29-02-1 – S29-02-11
[2] IPC/JEDEC J-STD-020C, “Moisture/Reflow Sensitivity Classification Nonhermetic Solid State Surface Mount Devices”, July 2004, www.jedec.org
[3] IPC-A-610, “Acceptability of Electronic Assemblies”, Feb, 2005, www.ipc.org

Table 1 - The average hole fill % for the variables studied in this DOE

OSP Chemistry	SMT Precon	Wave Solder Alloy	PCB Thkns	FHS+16	FHS+24	FHS+40	1 Plane	3 Plane
Regular	Nitrogen	SnPb	93	92%	95%	100%	100%	100%
Regular	Nitrogen	Pb-free	93	26%	44%	82%	55%	58%
Regular	Air	Pb-free	93	38%	79%	98%	83%	81%
Regular	Nitrogen	Pb-free	125	17%	24%	66%	53%	25%
Pb-free	Nitrogen	SnPb	93	100%	100%	100%	100%	100%
Pb-free	Nitrogen	Pb-free	93	50%	81%	98%	84%	81%
Pb-free	Air	Pb-free	93	61%	91%	100%	92%	90%
Pb-free	Nitrogen	Pb-free	125	40%	71%	98%	77%	69%

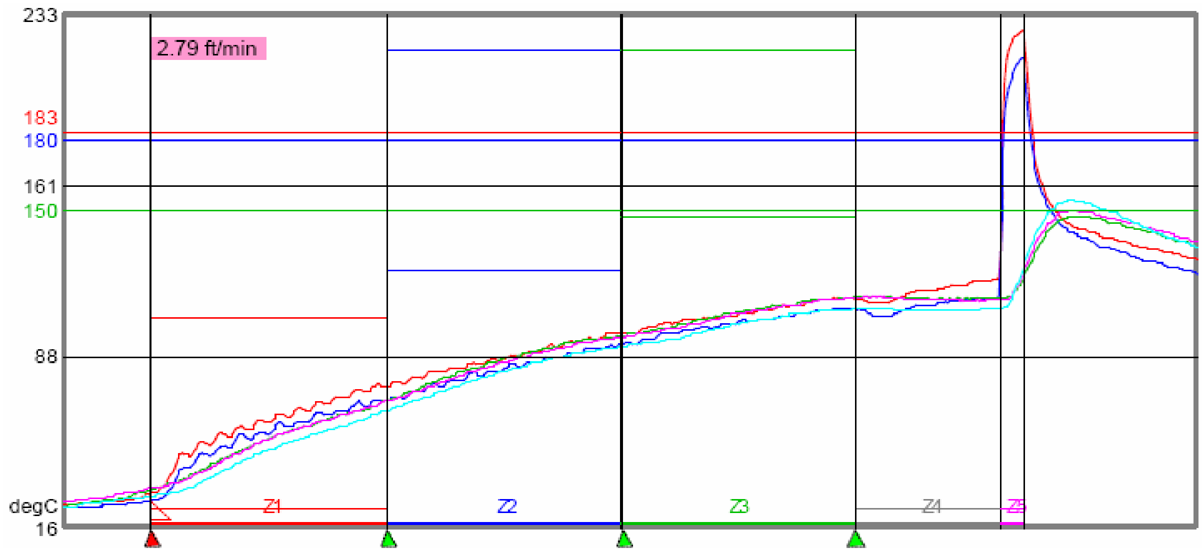
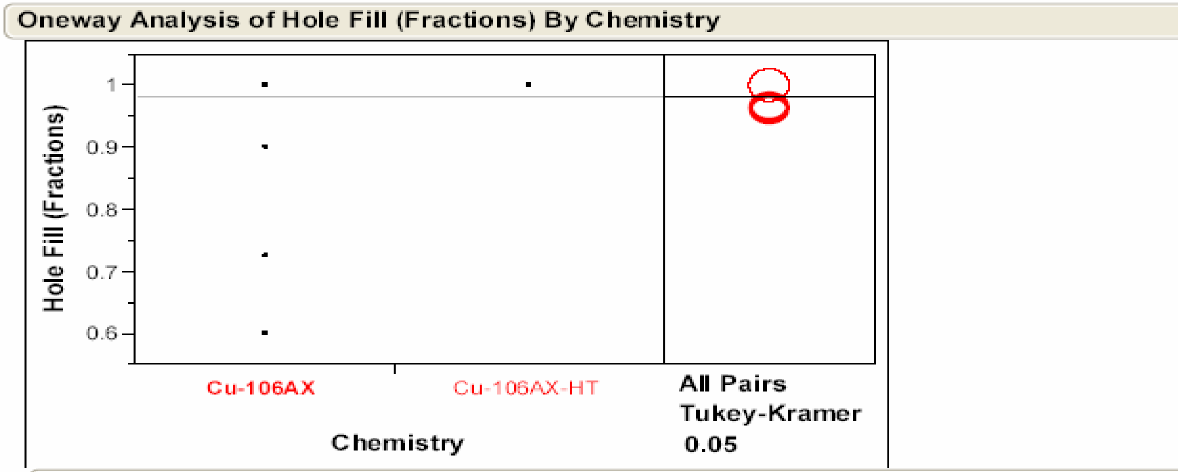


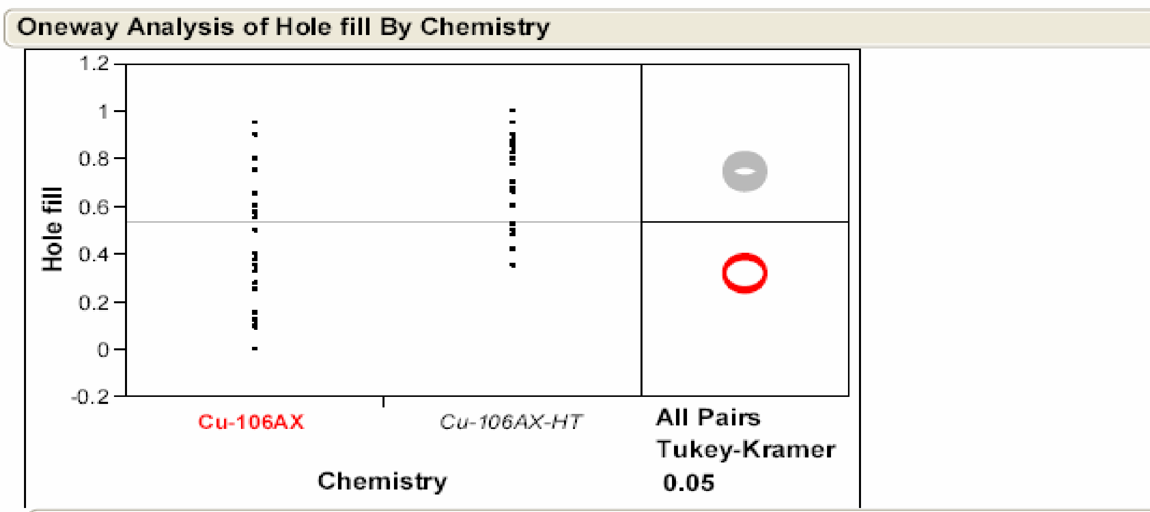
Figure 1 - Typical wave solder profile



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Cu-106AX	32	0.96328	0.108134	0.01912	0.9243	1.0023
Cu-106AX-HT	33	1.00000	0.000000	0.00000	1.0000	1.0000

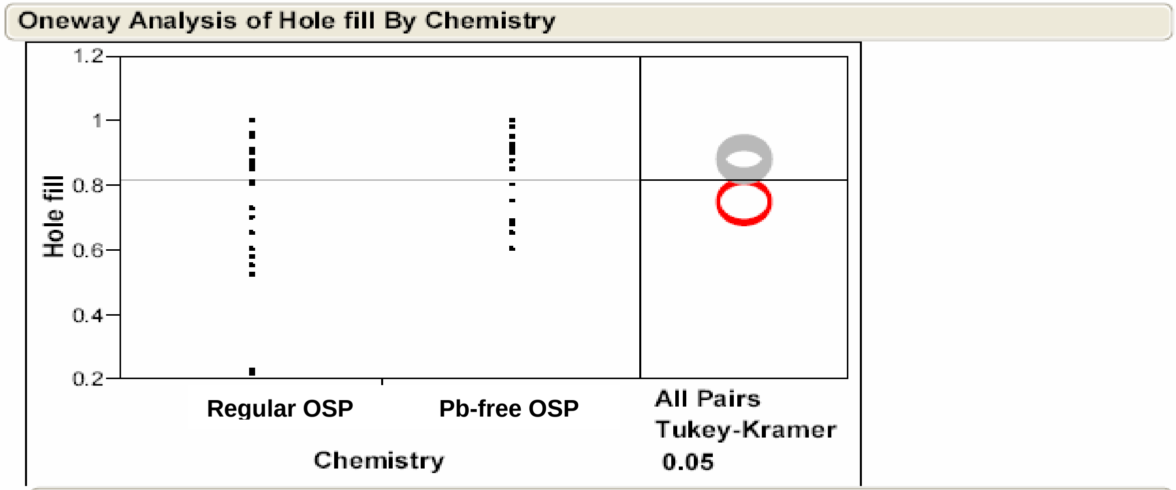
Figure 2 - Statistical analysis comparing regular and Pb-free OSP (93mils thick PCB; Nitrogen preconditioning; SnPb wave process)



Means and Std Deviations

	Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
R	Cu-106AX	33	0.318939	0.298676	0.05199	0.21303	0.42485
P	Cu-106AX-HT	33	0.747727	0.180395	0.03140	0.68376	0.81169

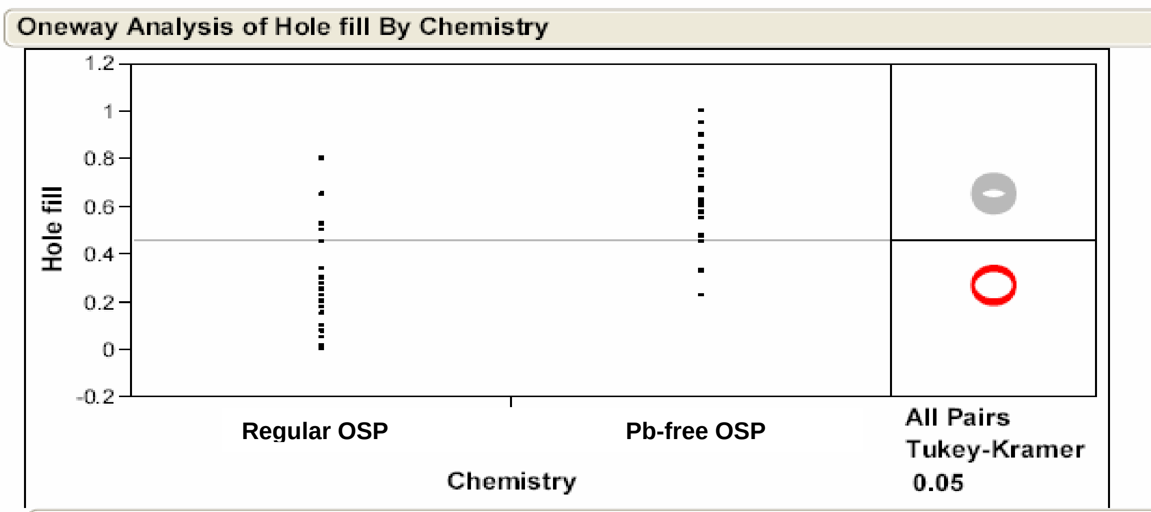
Figure 3 - Statistical analysis comparing regular and Pb-free OSP (93mils thick PCB; Nitrogen preconditioning; Pb-free wave process)



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Regular OSP	33	0.748864	0.251207	0.04373	0.65979	0.83794
Pb-free OSP	32	0.880938	0.175305	0.03099	0.81773	0.94414

Figure 4 - Statistical analysis comparing regular and Pb-free OSP (93mils thick PCB; Air preconditioning; Pb-free wave process)

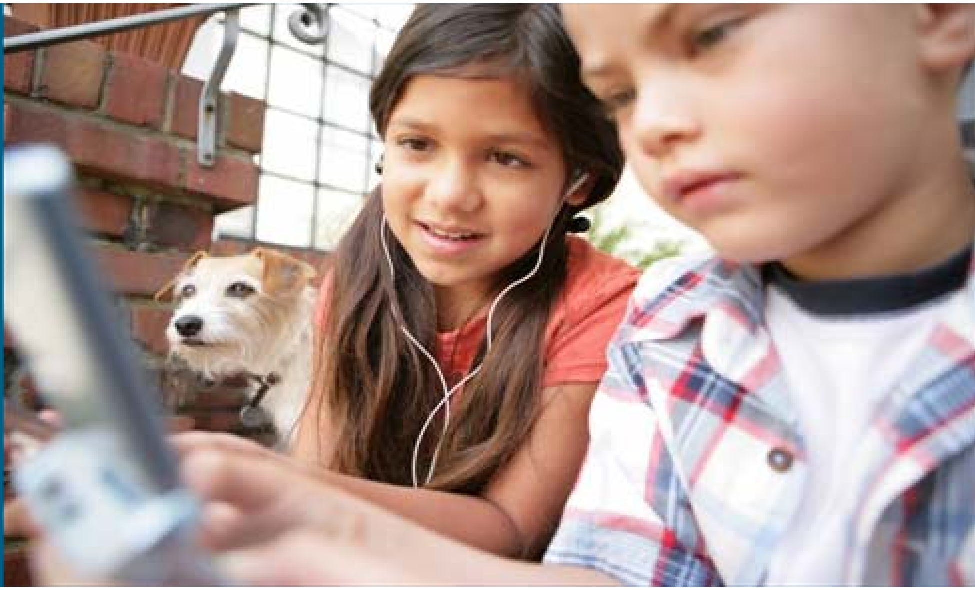


Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Regular OSP	24	0.268750	0.209878	0.04284	0.18013	0.35737
Pb-free OSP	24	0.653646	0.216239	0.04414	0.56234	0.74496

Figure 5 - Statistical analysis comparing regular and Pb-free OSP (125mils thick PCB; Nitrogen preconditioning; Pb-free wave process) ***Note*****:** ***test header data points are not included*****.**

Effect of OSP Chemistry on the Hole Fill Performance During Pb-free Wave Soldering



Bala Nandagopal[1], Sue Teng[1] and Doug Watson[2]

[1]Manufacturing Technology Group, Cisco Systems, Inc., San Jose, CA

[2]Solectron Texas, Austin, TX

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Overview

- Introduction
- Objective
- Experiment Details
- Results
- Conclusions
- Q & A

Introduction

- Hole fill issues in SnPb for thicker PCBs with OSP finish
- IPC A 610 requires std hole fill % for all PCB thickness
- A recent study by HP suggests reducing the % for thicker boards
- SnPb to Pb-free transition further complicates the wave soldering process
  - – JEDEC rating for component peak temperature
  - – SnPb Vs. Pb-free wetting characteristics
- New OSP chemistries have been developed for Pb-free wave soldering

Objective

Determine if there is a significant difference in Pb-free wave solder hole-fill performance using regular and Pb-free OSP chemistry.

PCB Design Variables

- 2 PCB thickness - 93/10L and 125mil/16L
- 3 Hole Sizes - Pin + 16, 24 and 40mils
- 2 PCB inner plane connections - One and Three plane
- 2 OSP chemistries - Regular and Pb-free

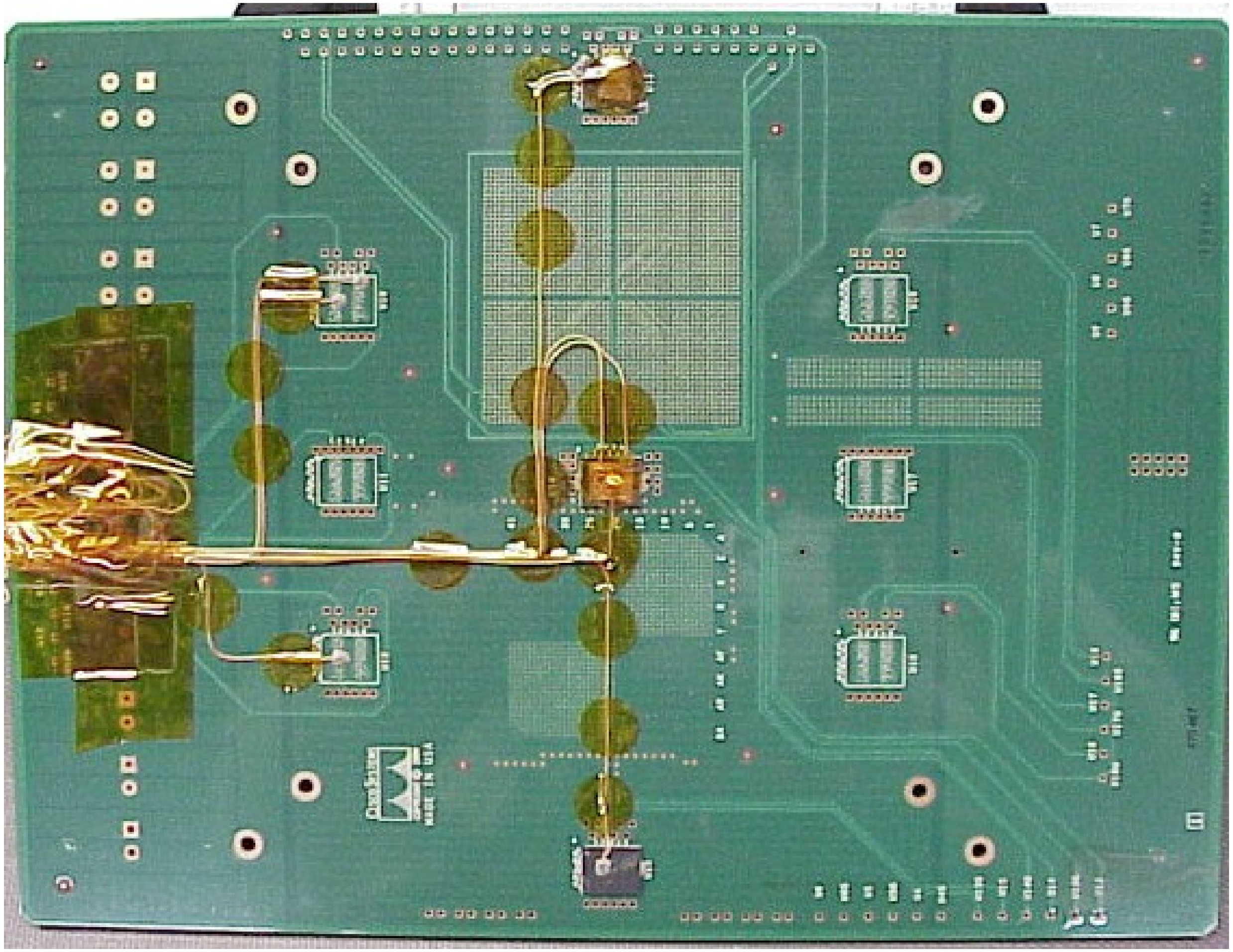
Component Details

- 4 pin Oscillators
  - 18mil pin diameter
  - 4 pins / component
  - 4 components / PCB
- 2 pin Electrolytic capacitors
  - 24mil pin diameter
  - 2 pins / component
  - 4 components / PCB
- 10 pin Test headers
  - 16x31mil rectangular pin
  - 10 pins / component
  - 3 components / PCB

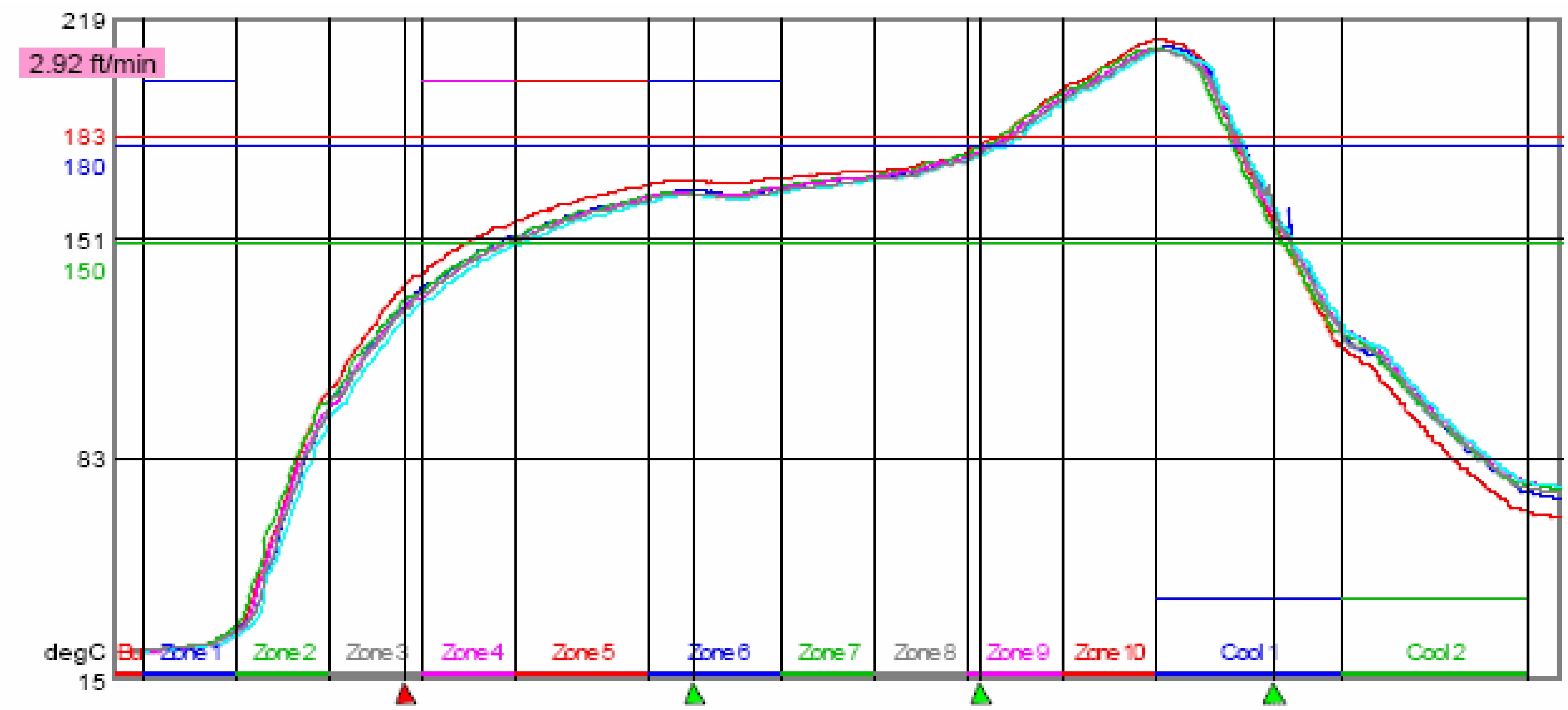
Assembly Process

- Nitrogen and Air preconditioning was also included
- SnPb Control was also included in the 93mil PCB
- Preconditioned twice through mass reflow with a peak temperature of 220C and 240C to simulate SnPb and Pb-free respectively
- All boards were washed post reflow
- Reflow and Wave was completed within 24hrs
- Common flux, profile, etc., were used
- Dwell time ~4.5secs and pot temperature 265C
- Standard Production Equipment
- Dage X-Ray was performed to study the hole fill performance

Reflow Profile Board



SnPb Reflow Profile – 93mil PCB



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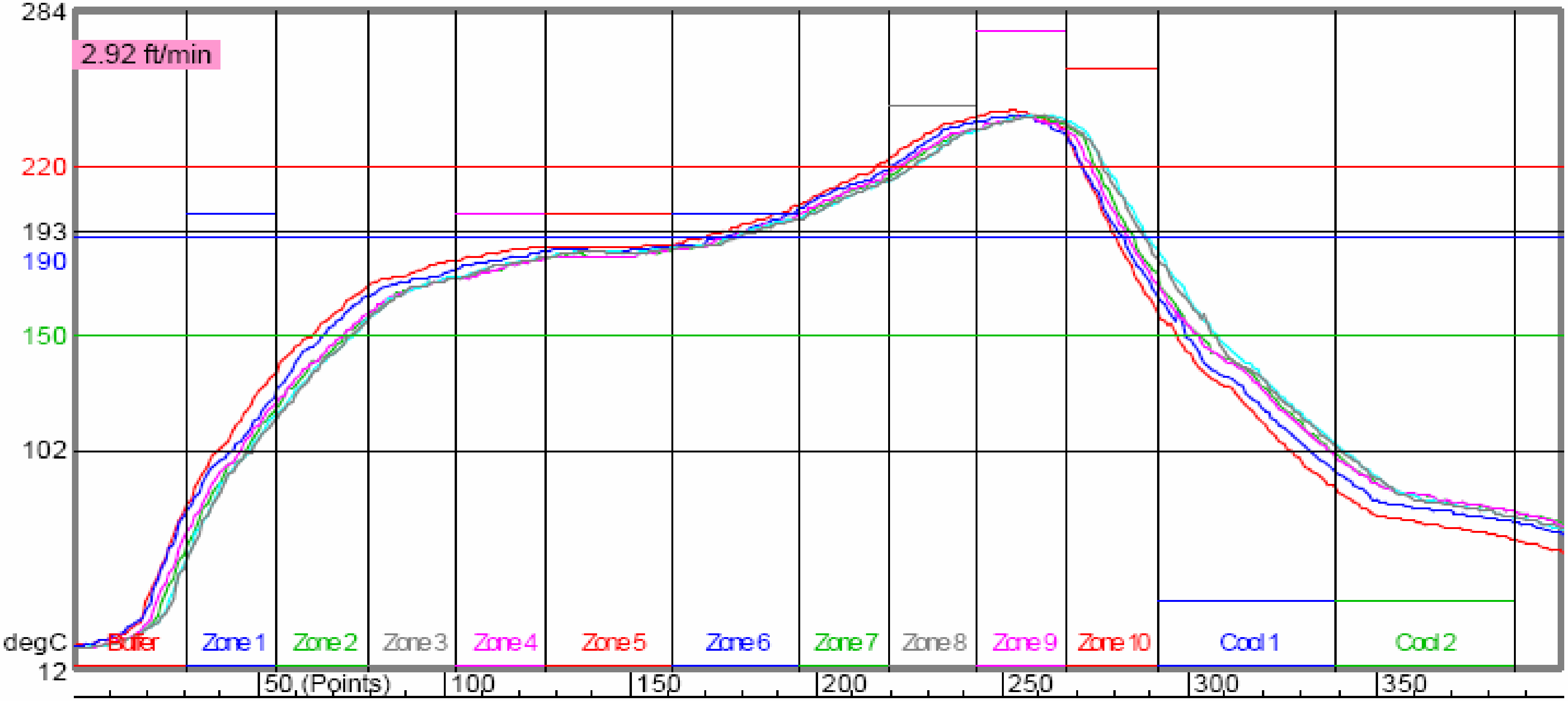
☒	Sensor 2 Location.	00:03:24	00:01:05	00:00:58	0%	Time
☒	Sensor 3 Location.	00:03:22	00:01:05	00:00:59	0%	Time
☒	Sensor 4 Location.	00:03:20	00:01:04	00:00:58	0%	Time
☒	Sensor 5 Location.	00:03:18	00:01:01	00:00:56	0%	Time
☒	Sensor 6 Location.	00:03:22	00:01:04	00:00:57	0%	Time

Pb-free Reflow Profile – 93mil PCB



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☒	Sensor 2 U3 DDR2 Center Ball	00:03:51	00:01:49	00:00:50	0%	Time
☒	Sensor 3 U5 DDR2 Corner Ball	00:03:50	00:01:49	00:00:52	0%	Time
☒	Sensor 4 U5 DDR2 Center Ball	00:03:50	00:01:48	00:00:52	0%	Time
☒	Sensor 5 U1 DDR2 Center Ball	00:03:52	00:01:52	00:00:52	0%	Time
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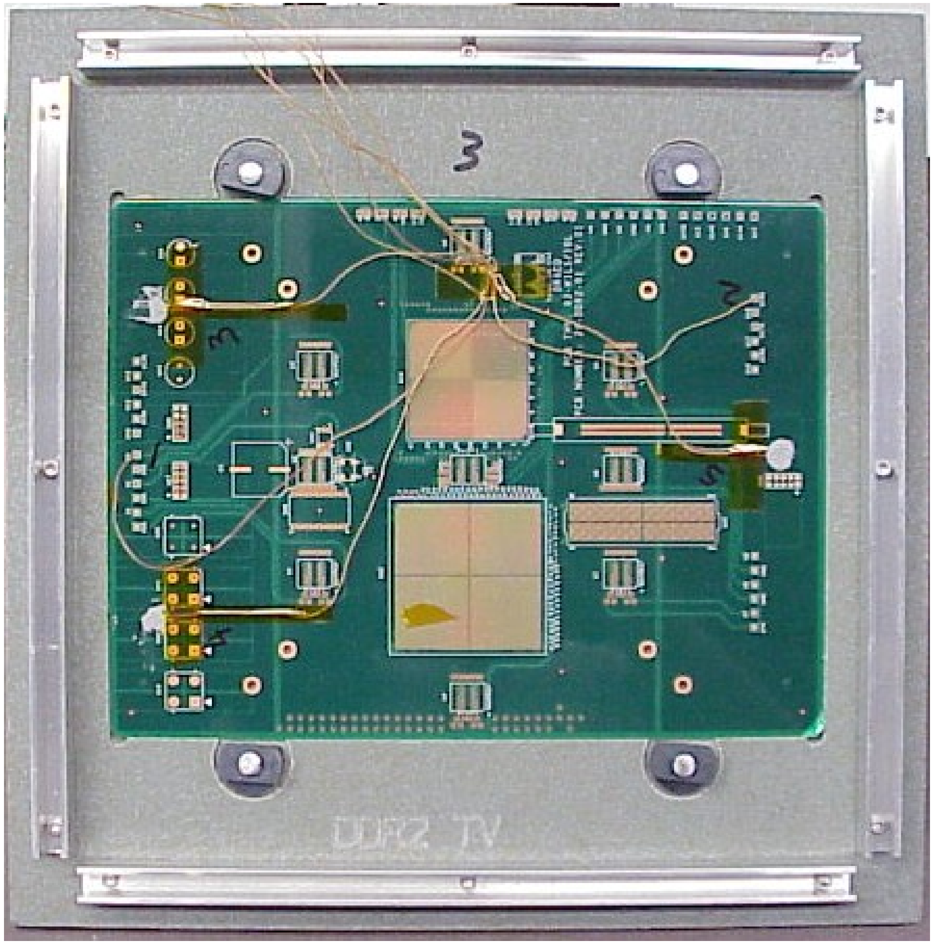
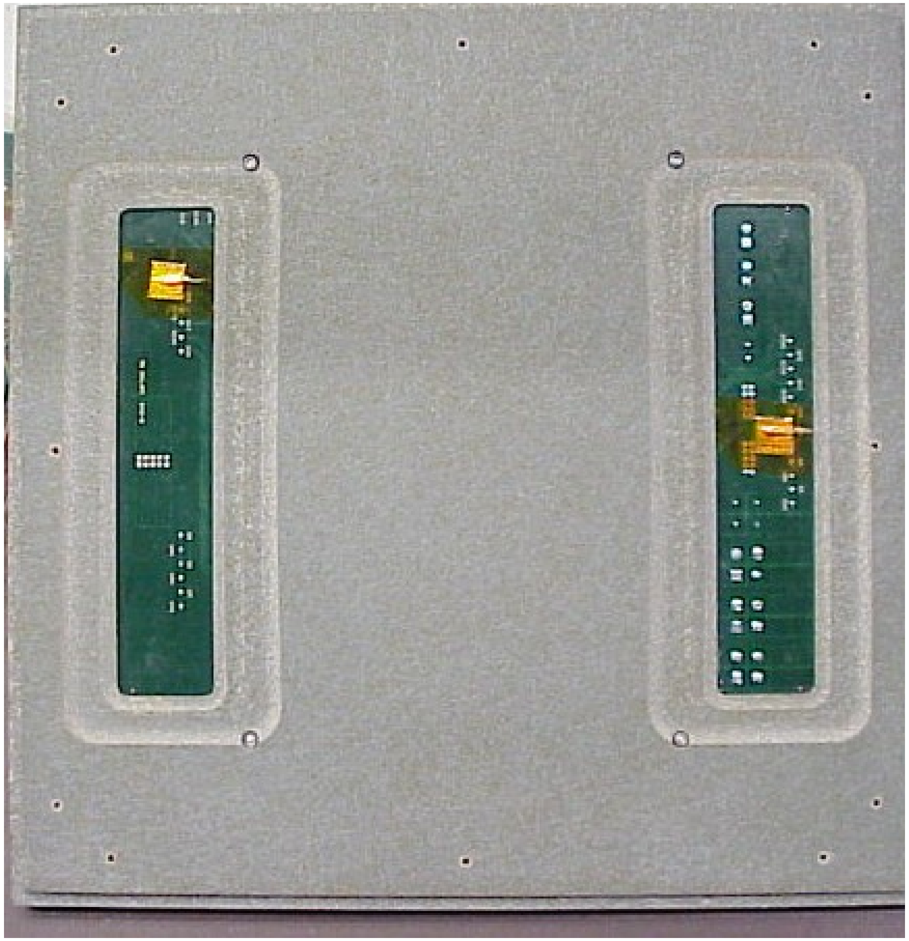
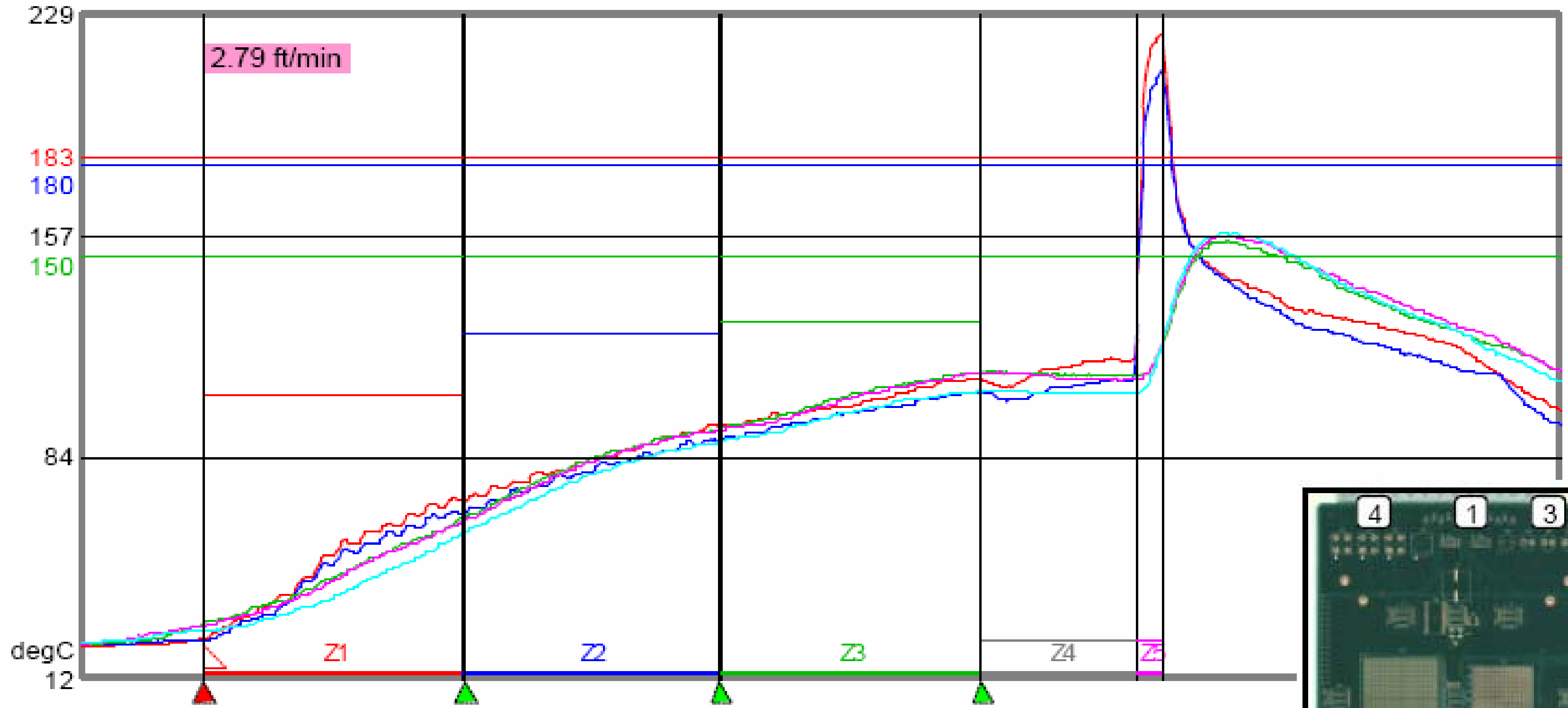
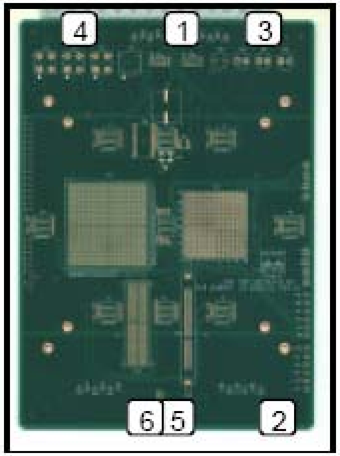
Wave Profile Board

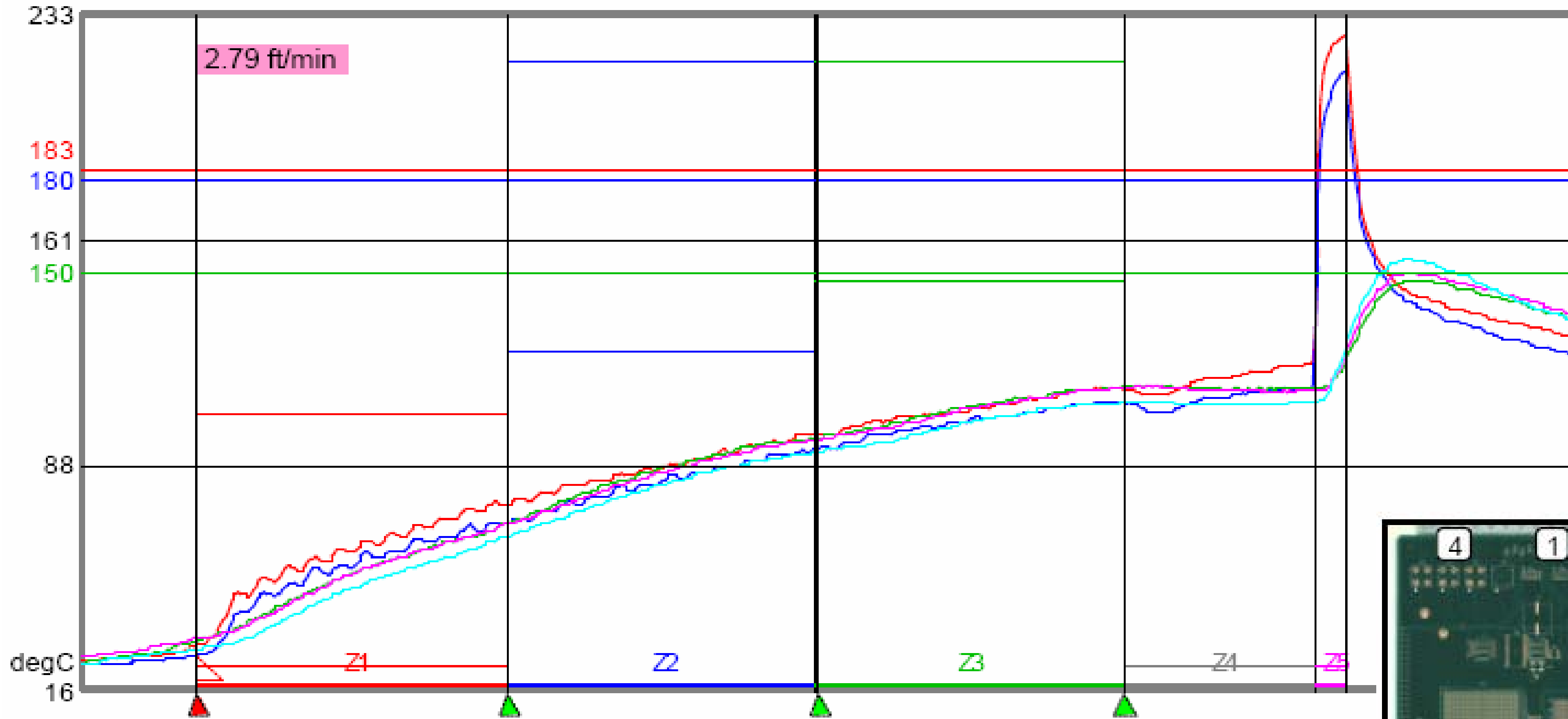
SnPb Wave Profile – 93mil PCB

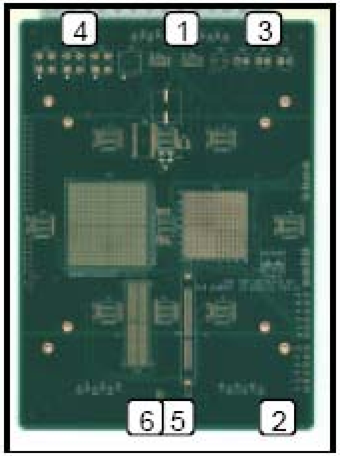


T/C-1 Location: Bottom, near U3
T/C-2 Location: Bottom, near U18G
T/C-3 Location: Top, near U24
T/C-4 Location: Top, near U20
T/C-5 Location: Top, near U29
T/C-6 Location: Top, near U29



Pb-Free Wave Profile – 93mil PCB

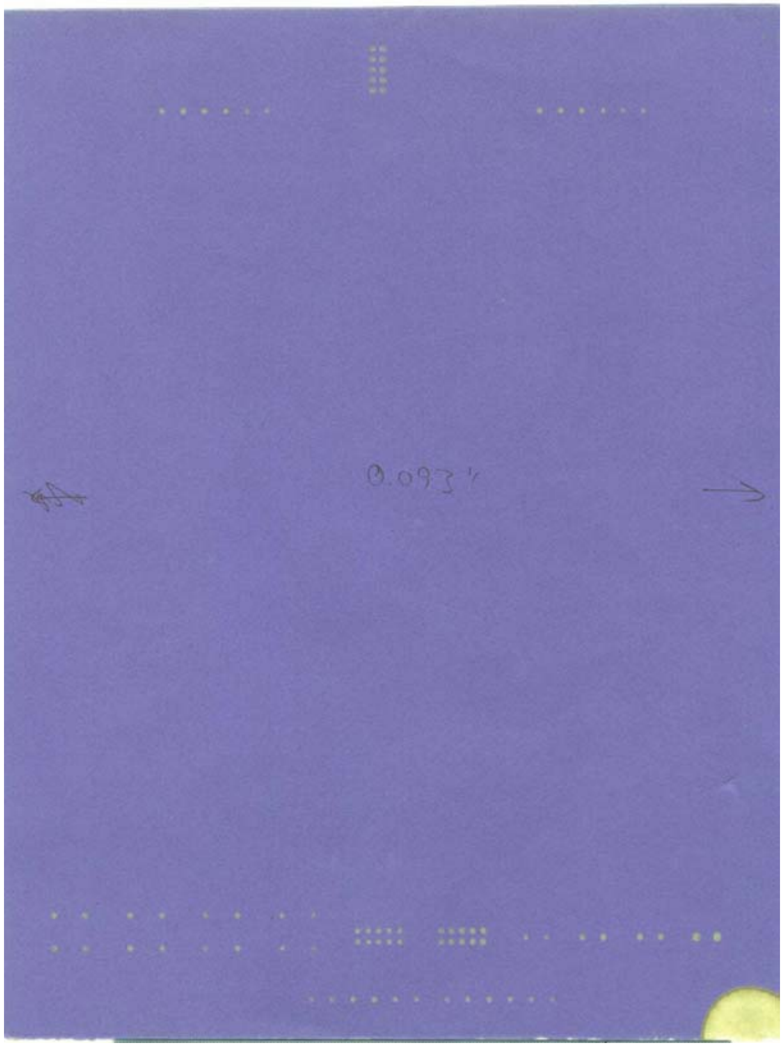


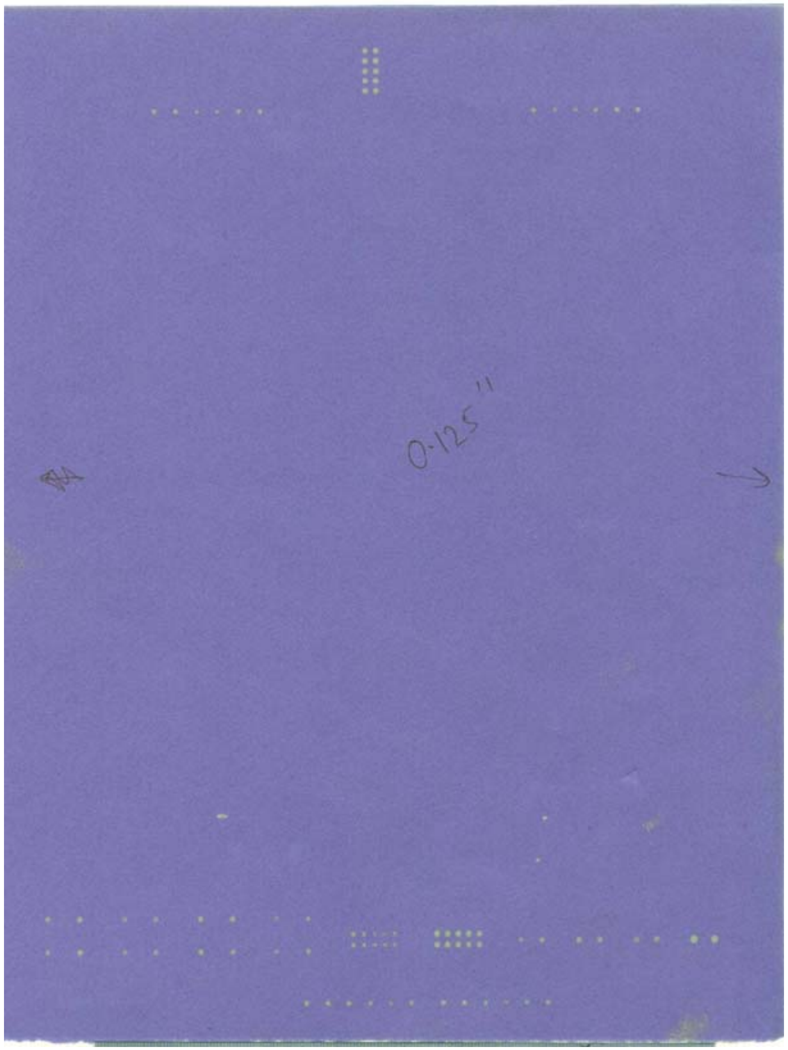


T/C-1 Location: Bottom, near U3
T/C-2 Location: Bottom, near U18G
T/C-3 Location: Top, near U24
T/C-4 Location: Top, near U20
T/C-5 Location: Top, near U29
T/C-6 Location: Top, near U29

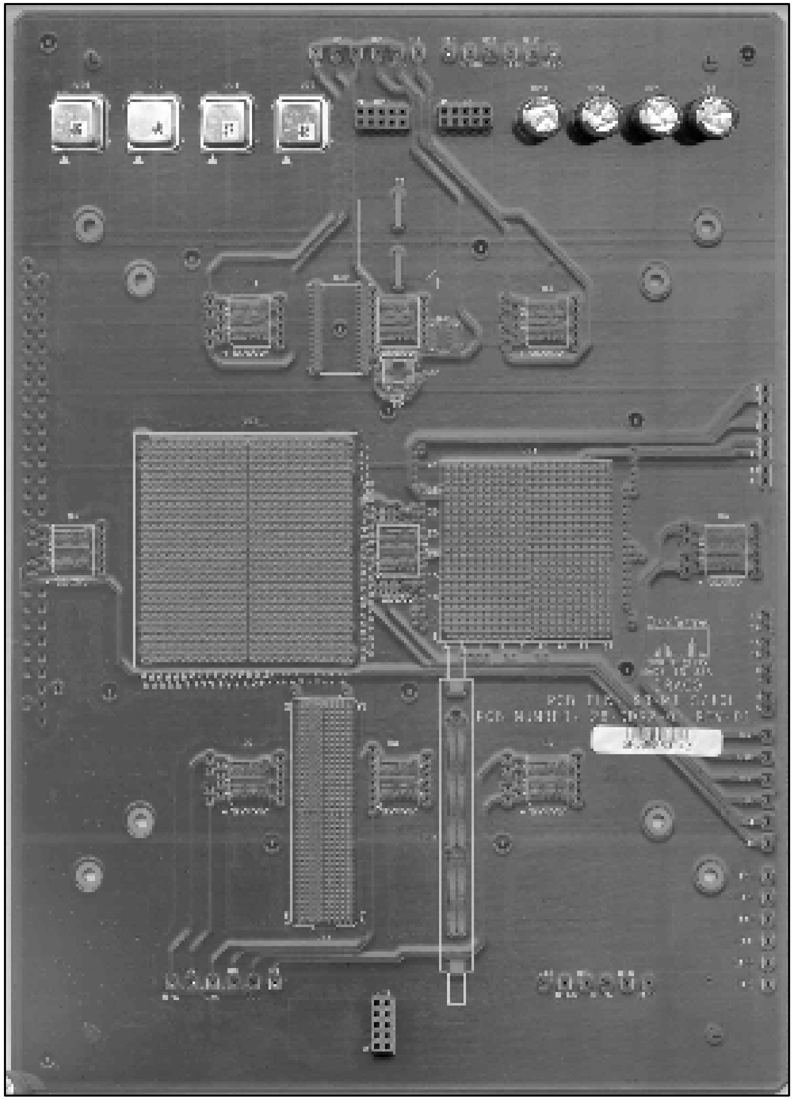
Flux Pattern – SnPb 93mil PCB

Flux Pattern – Pb-Free 93 & 125mil PCB



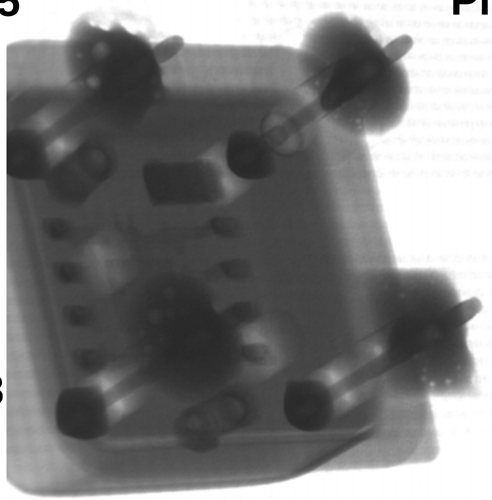


Wave Soldered Assembly



Dage & Sectioning - PbFree/N_2/93mil

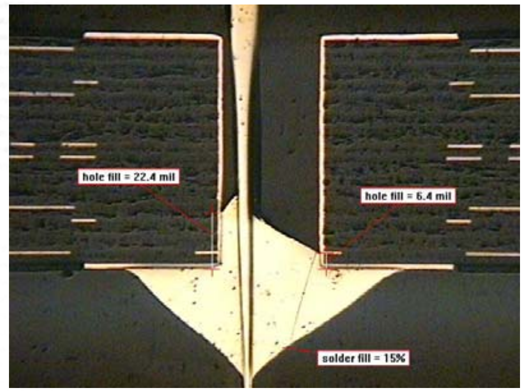
Pin 5 Pin 4



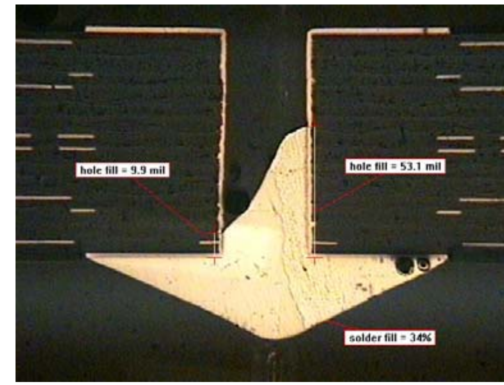
Pin 8 Pin 1

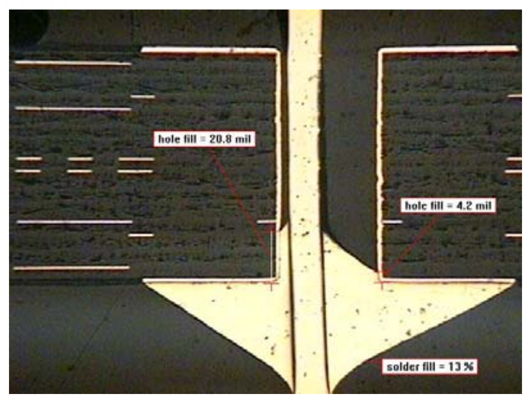
U19

Pin 5

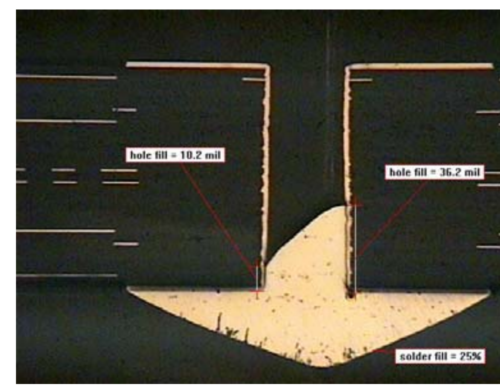


Pin 4





Pin 8



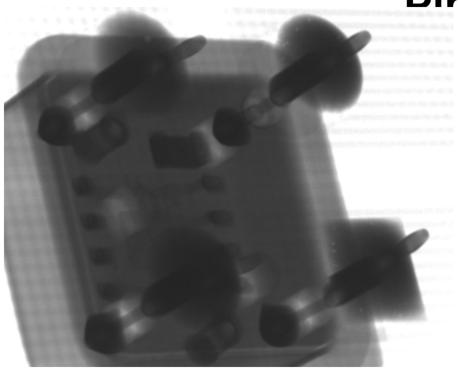
Pin 1

Note: One board was cross sectioned for each chemistry, regular and Pb-free OSP, on all locations of Pb-F/N_2/93mil. Images for all locations are not shown in this presentation

Dage & Sectioning - PbFree/N_2/93mil

Pin 5

Pin 4

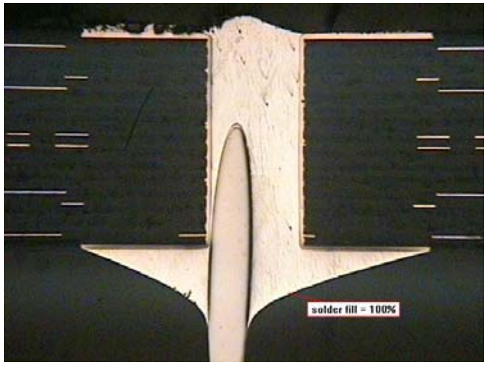


Pin 1

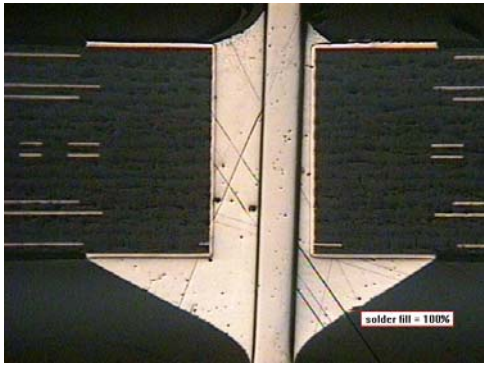
Pin 8

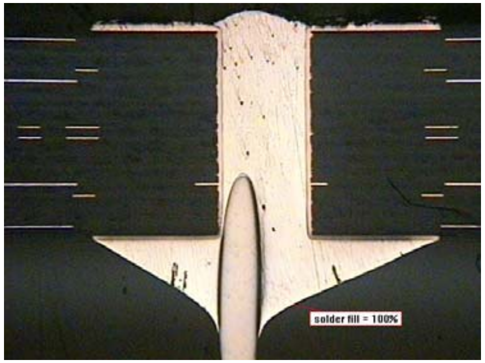
U19-Pb-free

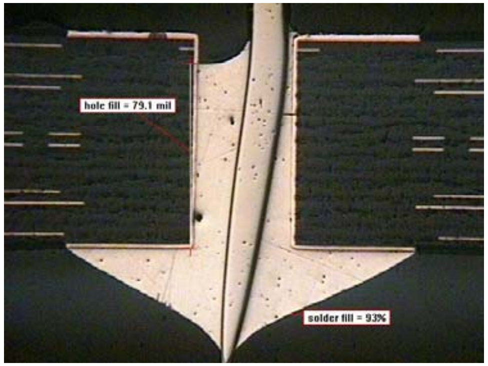
Pin 5



Pin 4





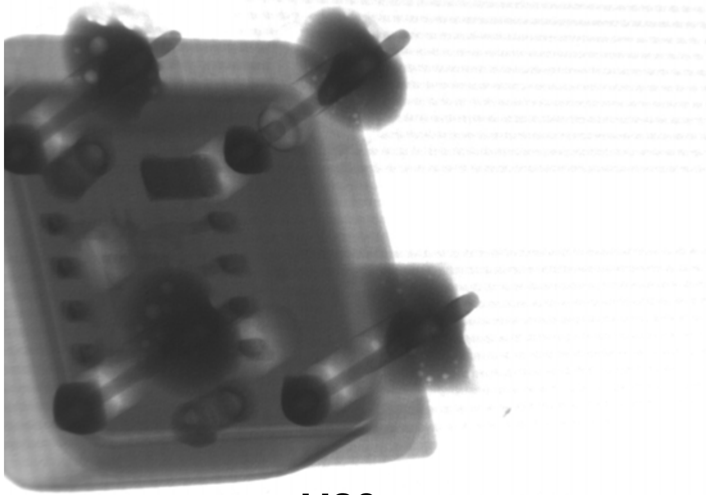


Pin 8

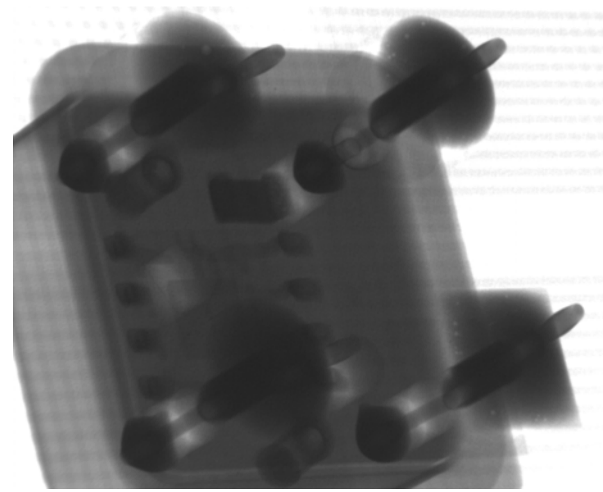
Pin 1

Dage Images – PbFree/N_2/93mil

U19



U19-Pb-free



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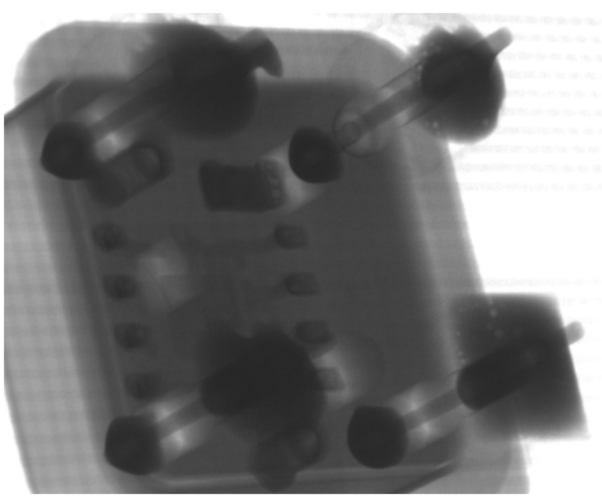
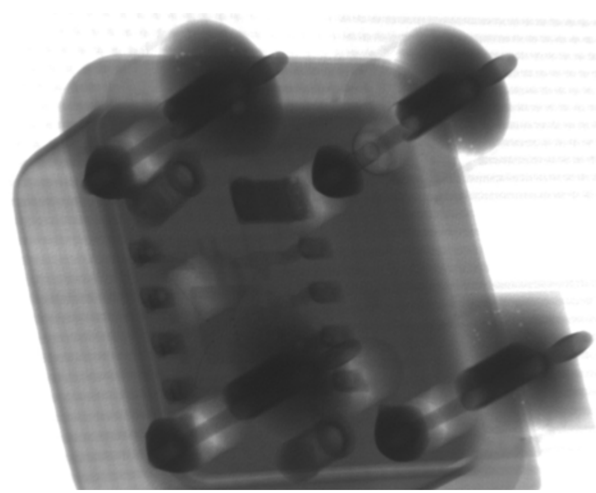
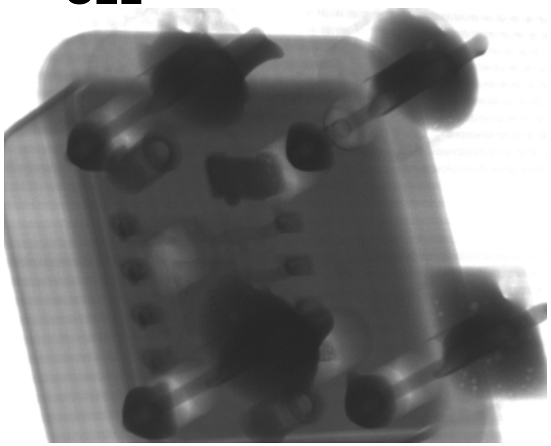


U20-Pb-free

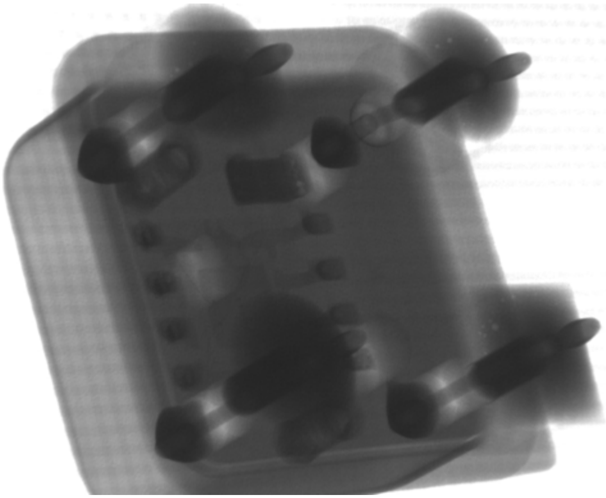


Dage Images – PbFree/N_2/93mil

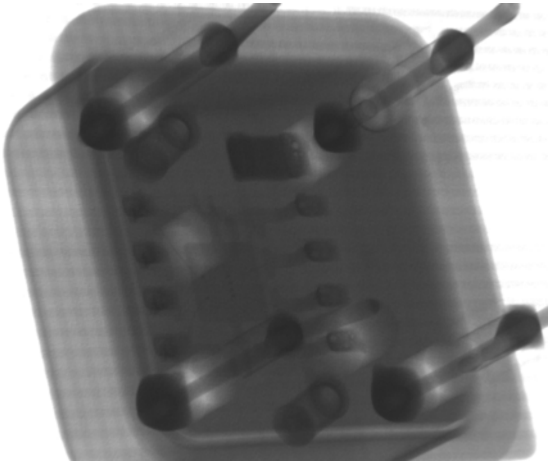
U21



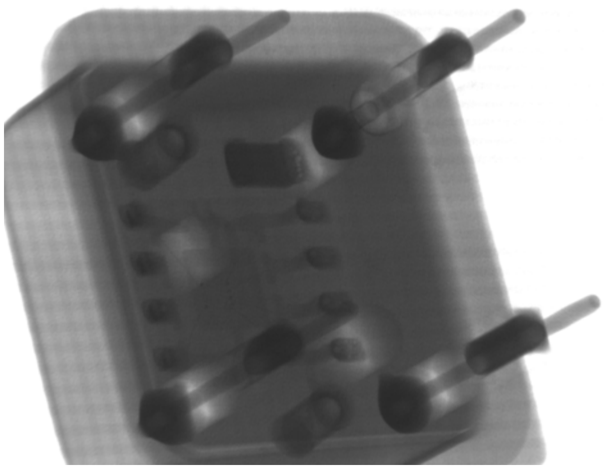
U21-Pb-free



U22

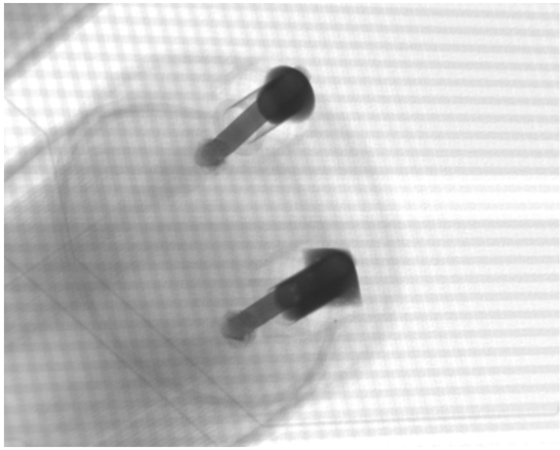


U22-Pb-free

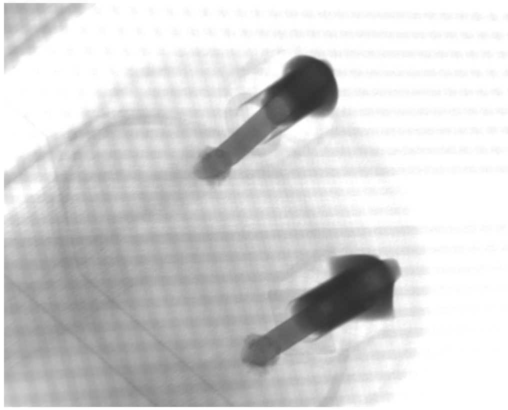


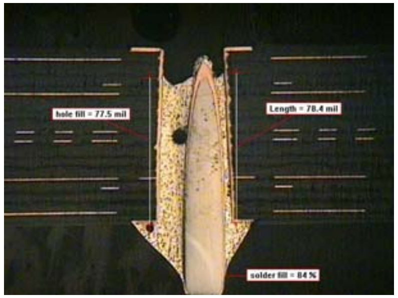
Dage & Sectioning – PbFree/N_2/93mil

U23

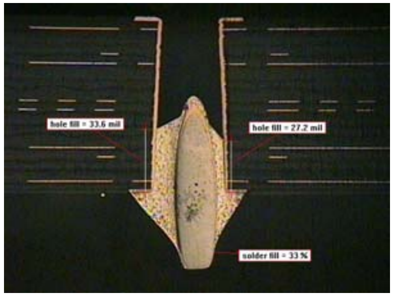


U23-Pb-free





Pin 1



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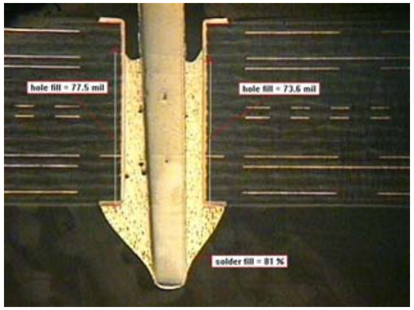
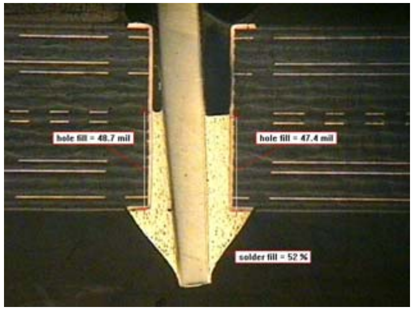


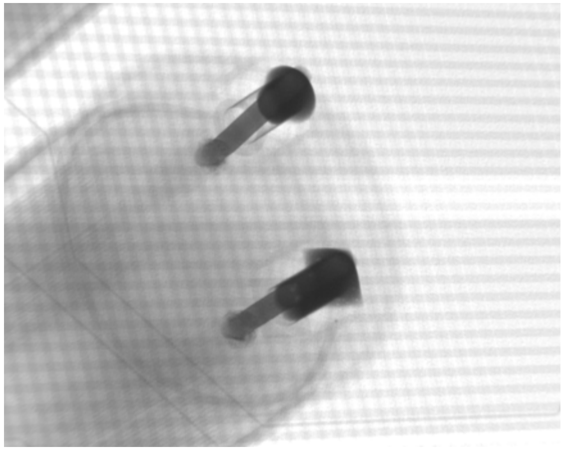
Pin 1



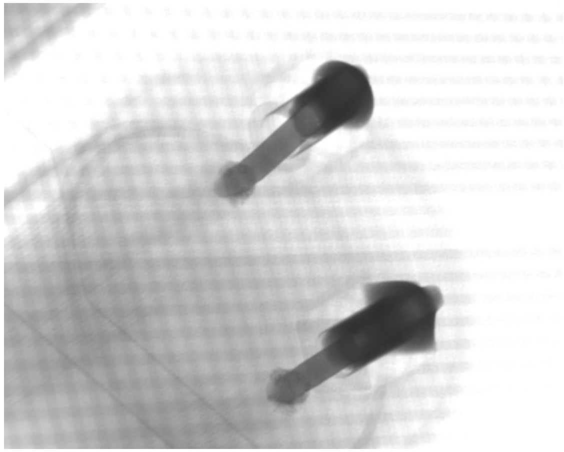
Pin 2

Dage Images – PbFree/N_2/93mil

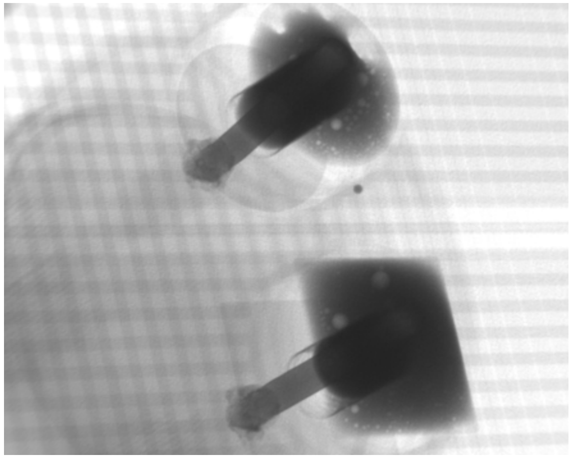
U23



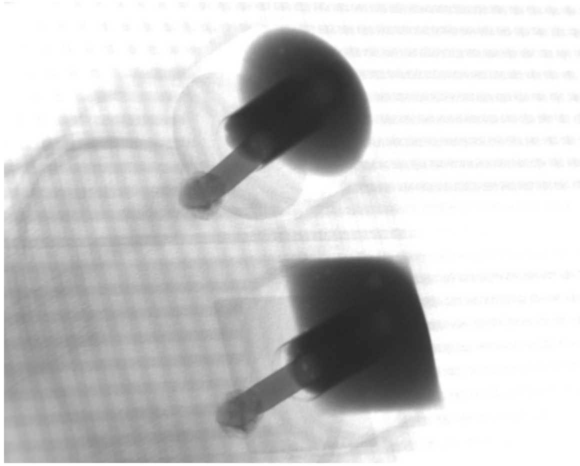
U23-Pb-free



U24

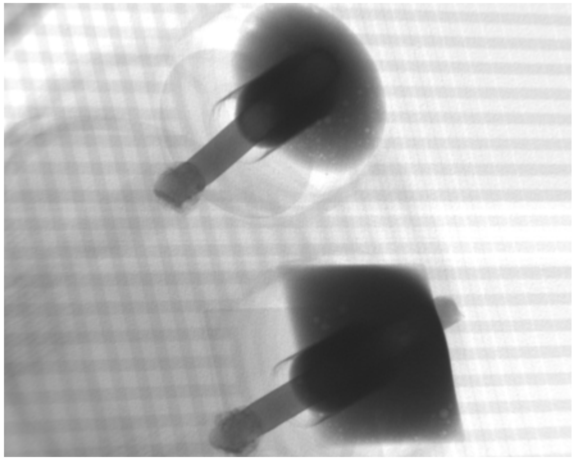


U24-Pb-free

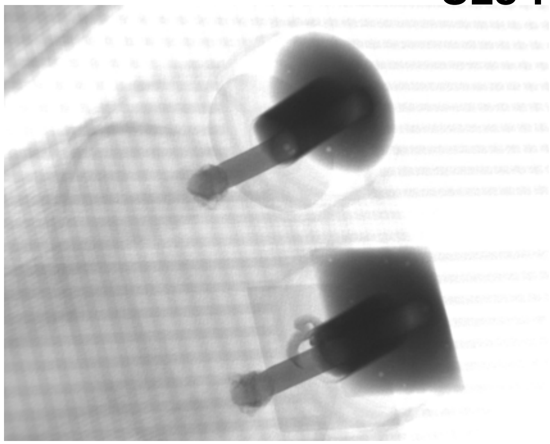


Dage Images – PbFree/N_2/93mil

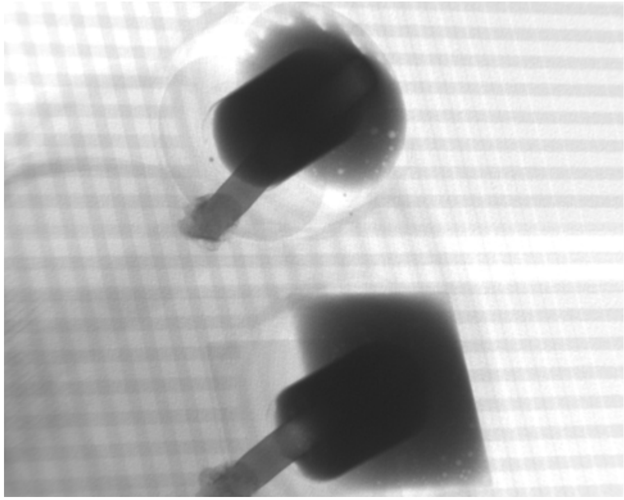
U25



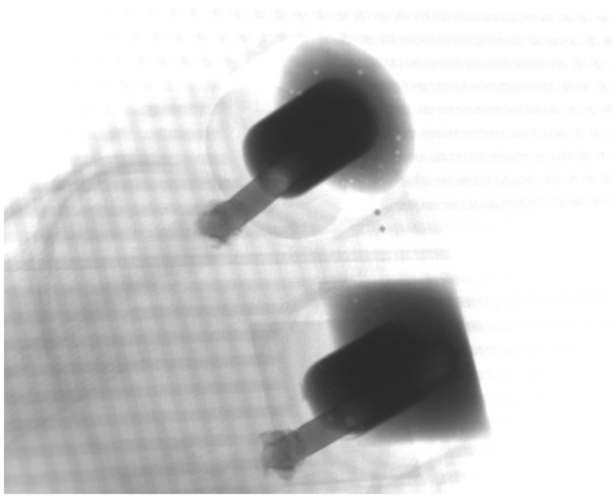
U25-Pb-free



U26

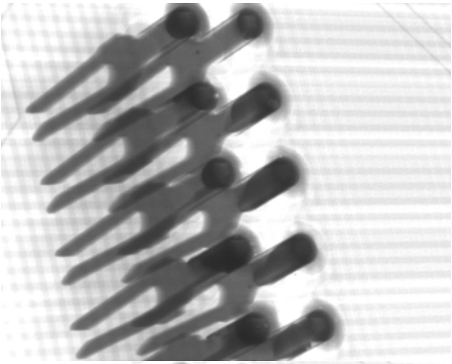


U26-Pb-free



Dage Images – PbFree/N_2/93mil

U27



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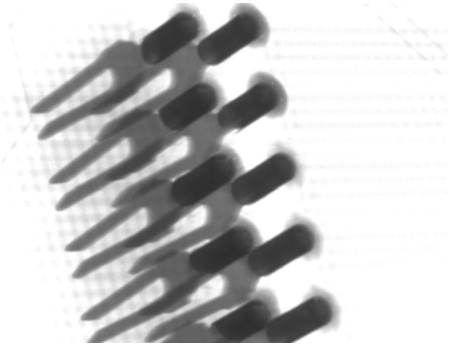
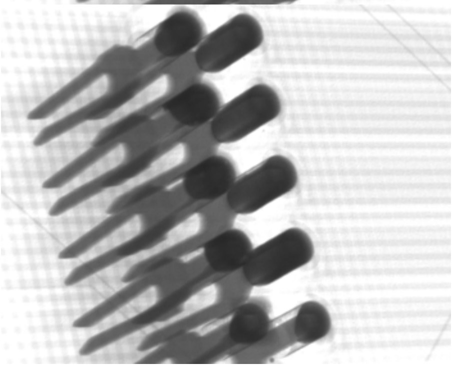
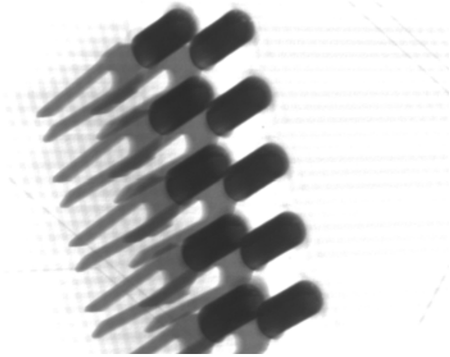


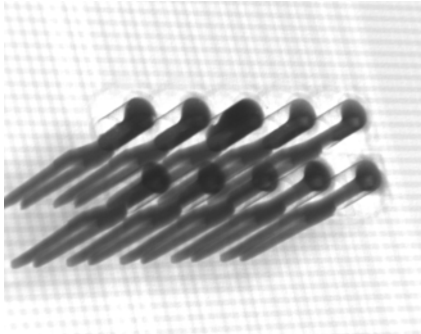
U28



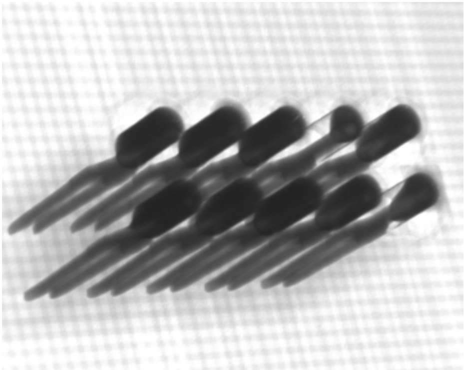
U28-Pb-free



U29



U29-Pb-free

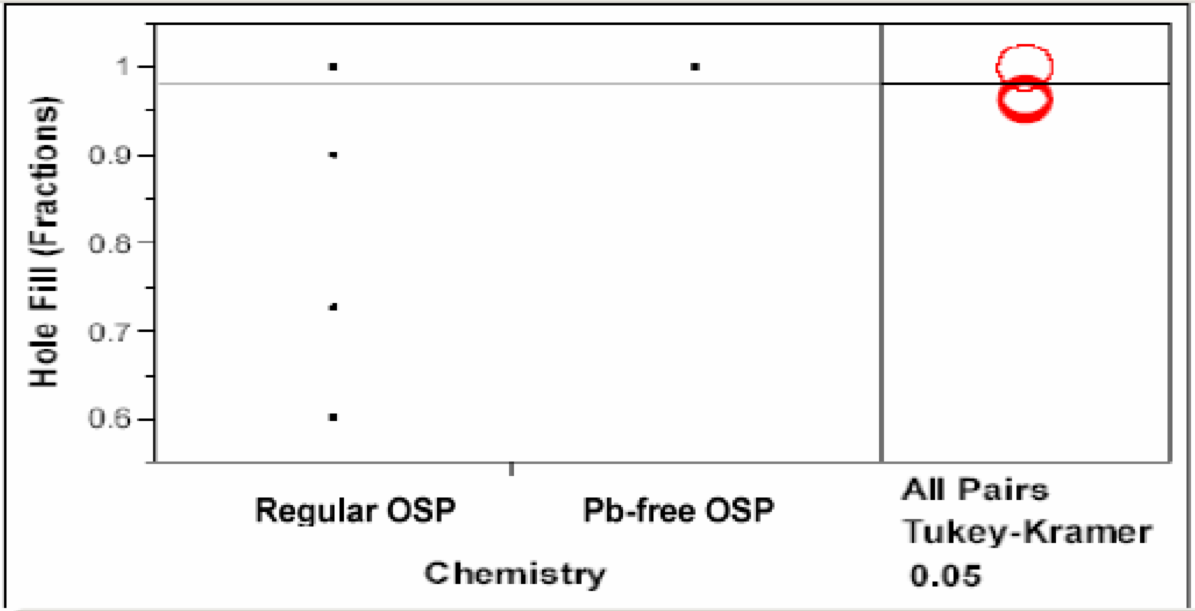


Data Analysis

- Mean hole fill data for various locations were plotted to observe board to board variation for any given location
- Statistical significance test methods were employed to compare the mean hole fills
- Few data points were removed due to the following reasons:
  - part movement during wave soldering
  - shortage of parts
- The lowest hole fill % was recorded, if the hole fill had a slanting surface i.e., solder wicking height difference as we go around the circumference of the hole

Statistical Significance
SnPb / Nitrogen / 93mil

Oneway Analysis of Hole Fill (Fractions) By Chemistry



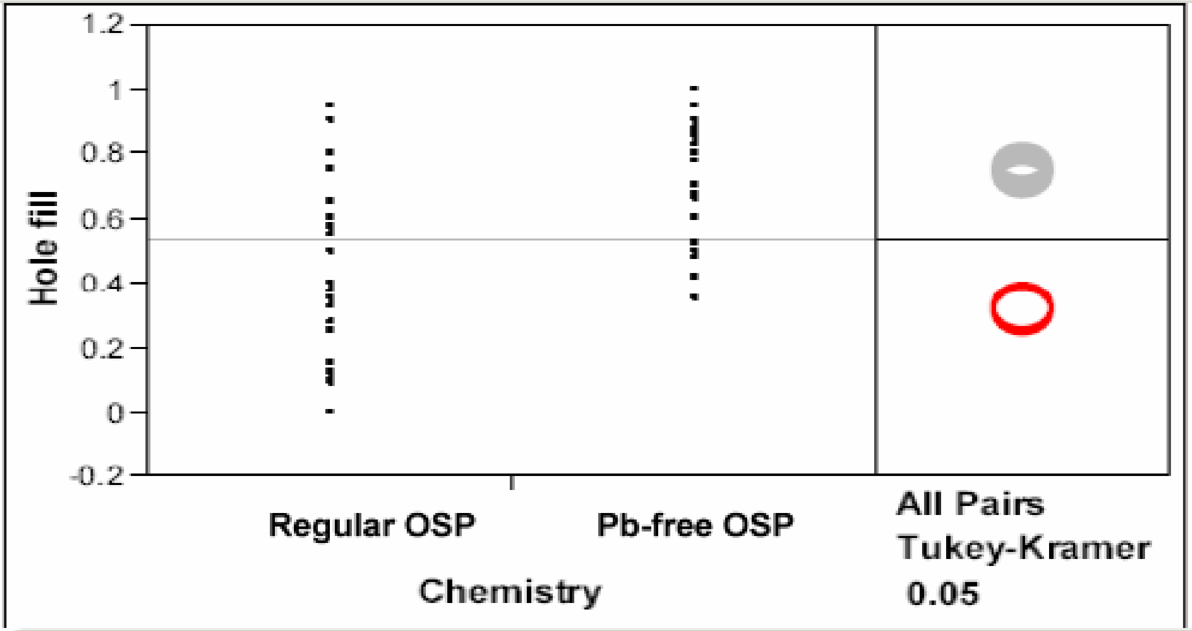
Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Regular OSP	32	0.96328	0.108134	0.01912	0.9243	1.0023
Pb-free OSP	33	1.00000	0.000000	0.00000	1.0000	1.0000

- Pb-free chem was not significantly different compared to the regular
- Pb-free chem provided marginal increase (~4%) in mean hole-fill

Statistical Significance
Pb-Free / Nitrogen / 93mil

Oneway Analysis of Hole fill By Chemistry



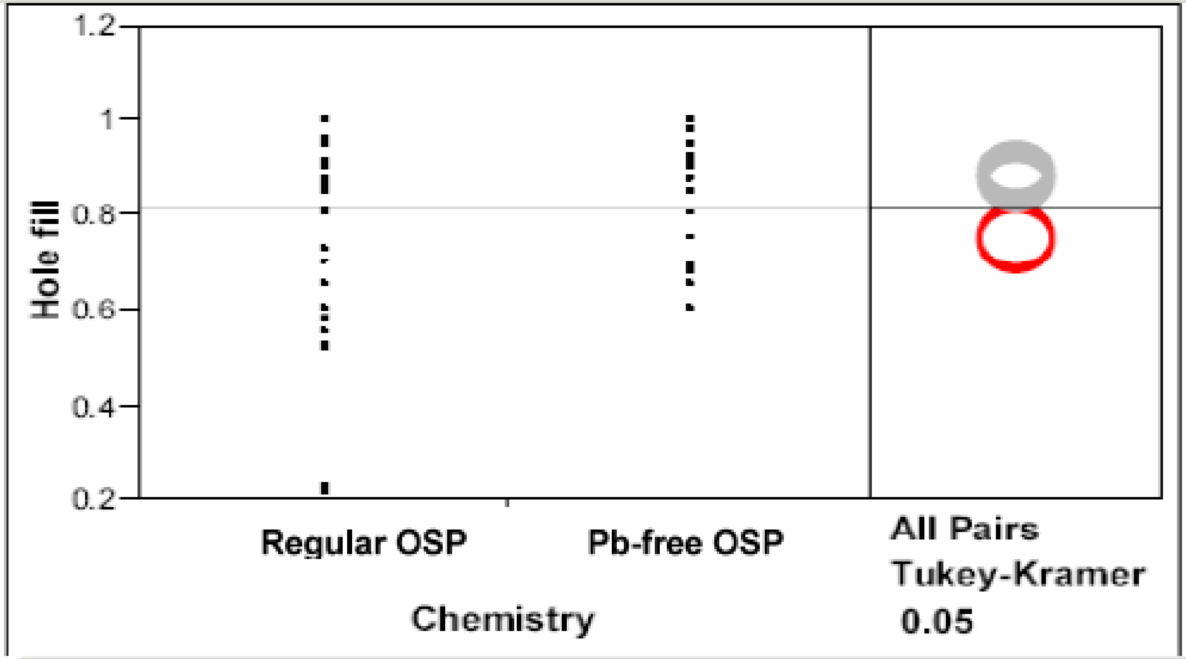
Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Regular OSP	33	0.318939	0.298676	0.05199	0.21303	0.42485
Pb-free OSP	33	0.747727	0.180395	0.03140	0.68376	0.81169

- Pb-free chem was significantly different compared to the Regular
- Pb-free improved the Mean hole-fill by 40%

Statistical Significance
Pb-Free / Air / 93mil

Oneway Analysis of Hole fill By Chemistry



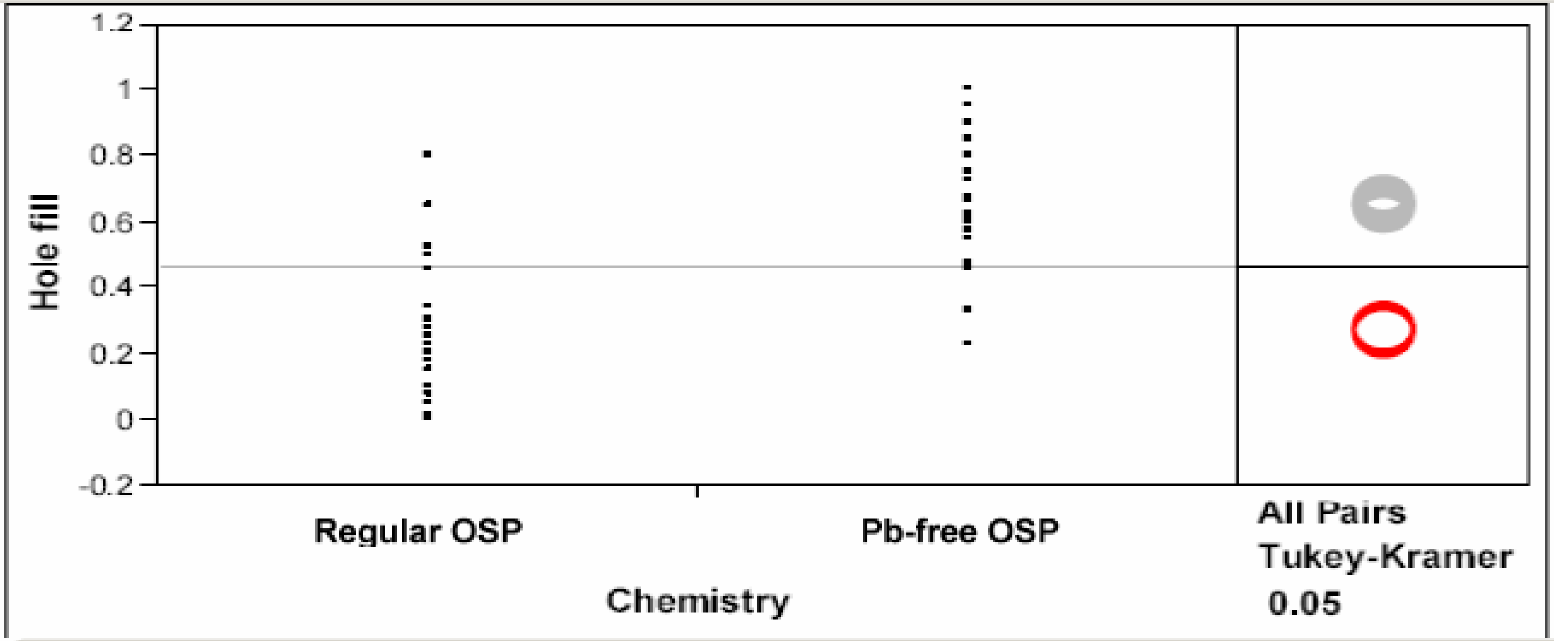
Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Regular OSP	33	0.748864	0.251207	0.04373	0.65979	0.83794
Pb-free OSP	32	0.880938	0.175305	0.03099	0.81773	0.94414

- Pb-free chem was significantly different compared to the Regular
- Pb-free chem improved the Mean hole-fill by 15%

Statistical Significance
Pb-Free / Nitrogen / 125mil

Oneway Analysis of Hole fill By Chemistry



Means and Std Deviations

Level	Number	Mean	Std Dev	Std Err Mean	Lower 95%	Upper 95%
Regular OSP	24	0.268750	0.209878	0.04284	0.18013	0.35737
Pb-free OSP	24	0.653646	0.216239	0.04414	0.56234	0.74496

- Pb-free chem was significantly different compared to the Regular
- Pb-free chem improved the Mean hole-fill by 35%

Note: Test headers data removed

Hole Fill Results

Worst Best

OSP Chemistry	SMT Precon	Wave Solder Alloy	PCB Thkns	FHS+16	FHS+24	FHS+40	1 Plane	3 Plane
Regular	**Nitrogen**	**SnPb**	**93**	**92%**	**95%**	**100%**	**100%**	**100%**
Regular	**Nitrogen**	**Pb-free**	**93**	**26%**	**44%**	**82%**	**55%**	**58%**
Regular	**Air**	**Pb-free**	**93**	**38%**	**79%**	**98%**	**83%**	**81%**
Regular	**Nitrogen**	**Pb-free**	**125**	**17%**	**24%**	**66%**	**53%**	**25%**
Pb-free	**Nitrogen**	**SnPb**	**93**	**100%**	**100%**	**100%**	**100%**	**100%**
Pb-free	**Nitrogen**	**Pb-free**	**93**	**50%**	**81%**	**98%**	**84%**	**81%**
Pb-free	**Air**	**Pb-free**	**93**	**61%**	**91%**	**100%**	**92%**	**90%**
Pb-free	**Nitrogen**	**Pb-free**	**125**	**40%**	**71%**	**98%**	**77%**	**69%**

Pb-free OSP Chemistry performed consistently better than the Regular

Conclusion

- For Pb-free wave soldering, Pb-free OSP chemistry can improve hole-fill by 40% and also the process repeatability
- FHS of pin plus 40mils provided the best results compared to the other designs for thicker PCBs
- SMT reflow with air preconditioning was better than nitrogen
- 125mil thick PCBs can still cause problems in meeting IPC standards

Q & A

Back Up