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Before & After Reflow Characterization of FCBGA Voiding Utilizing High Resolution CT Scan, X-ray (2D & 3D) Imaging, and Cross Section with Digital Imaging

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ABSTRACT

A joint project between Flextronics Inc. and North Star Imaging Inc. is being conducted to correlate current x-ray imaging and cross-section analysis of BGA voiding with state of the art high resolution CT-Scan imaging. Our primary objective is to validate the void measurements obtained from non-destructive imaging techniques, with the physically measured void measurements of cross sectioning. A secondary goal is to characterize void properties before and after reflow.

Typical AXI inspection equipment provides one to three horizontal planes of reference for BGA void measurements. CT Scan imaging provides a full 3D volumetric representation of the BGA void, allowing for size, volume, and void position data. Information that can be used in failure analysis and process characterization projects, without physical destruction of the printed circuit board.

Five 50.0 mm FCBGA devices and five 52.5mm FCBGA devices, with known voiding, are being used in the study. The voiding for each device has been measured on a 3D AXI machine (Figure 1), a2D off-axis high resolution x-ray machine (Figure 2), and CT-Scan system (Figure 3). The devices will then be placed and reflowed onto printed circuit boards. After reflow, all the voiding will be measured again using each piece of equipment. In addition, select voids will be cross-sectioned, polished, and measured using a high magnification digital microscope and correlated to the other x-ray imaging tools.

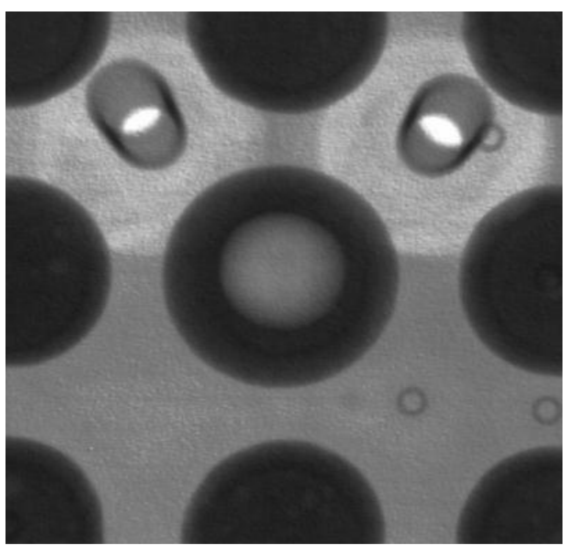


Figure 1 - Transmissive 2D X-ray Image of BGA Void

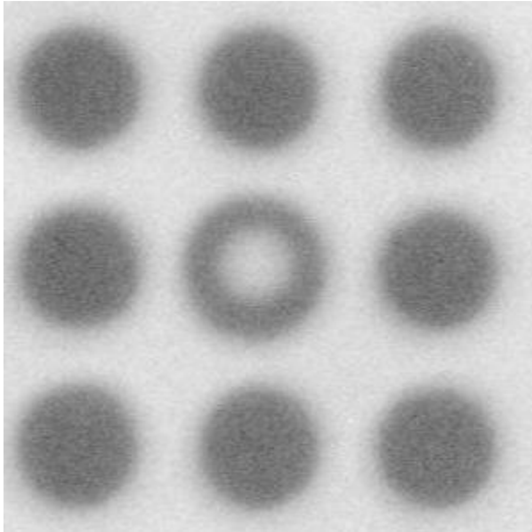


Figure 2 - 3D AXI Mid-Ball Image of BGA Void

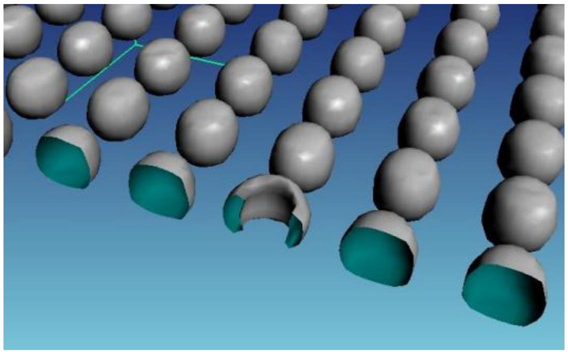


Figure 3 - CT Scan surface model, with partial cross section, of BGA void

INTRODUCTION

As complex electronic assemblies become faster and faster, power with associated heat dissipation, signal integrity (SI) and reliability become more important than ever. Solder joint voiding can potentially impact all of these. With cost pressures on companies producing these types of products, it is more important than ever to be able to properly diagnose and characterize voiding in a non-destructive fashion. Proper characterization will allow for adequate troubleshooting and process development needed to minimize or eliminate voiding. In addition, non-destructive void analysis can be used in failure analysis cases.

Over time, X-Ray technology used in the electronics industry has advanced from 2D transmissive, to 2D Off Axis, to 3D laminography, to 3D tomosynthesis. Resolution of x-ray tools has continued to advance along with the software required for automated analysis. Use of these tools has allowed identification and measurements of the voids in solder joints. Software has allowed for automated inspection of the solder joints to quickly identify and measure up 100 % of the solder joints per component and per assembly in a timely manner. Typically, this software allows for measurement at a specific point in the solder joint (i.e. PCB level, mid joint and Package level).

While many improvements have been made in these tools (including resolution), smaller voids and true position of these voids has been difficult to see without actual cross sectioning. Now with the latest advancements in X-Ray technology, a full high resolution 3D image is available using Cat Scan technology. CT technology allows for infinite cross sectioning in a non-destructive fashion.

The first objective of this work will be to correlate the most common X-Ray technologies used by the electronics industry. Each technology will be correlated, not only to the newest CT Scan technology but also to actual cross sections on a variety of void examples.

The second objective of this work will be to identify and characterize a variety of voids from incoming components through the SMT reflow process. Incoming components identified with solder voids will be subjected to a variety of reflow profile styles to determine what happens to them relative to size and position. Images and measurements will be taken before and after reflow using all the traditional X-Ray tools along with CT Scan. After all imaging has been completed; actual cross sections will be taken for comparison. In addition, components with incoming voids will be subjected to reflow under vacuum in an attempt to remove the voids prior to assembly.

METHODOLOGY

Design and fabricate custom fixtures capable of holding 50 x 50 mm FCBGA and a 52.5 x 52.5 mm FCBGA's in a dead bug position was needed for automated 3D inspection. Figure 4 shows the 10 up fixture while Figure 5 shows a close up view.

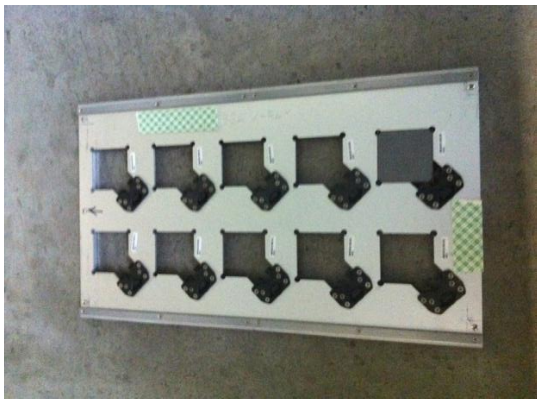


Figure 4 – Fixture for automated 3D X-Ray inspection

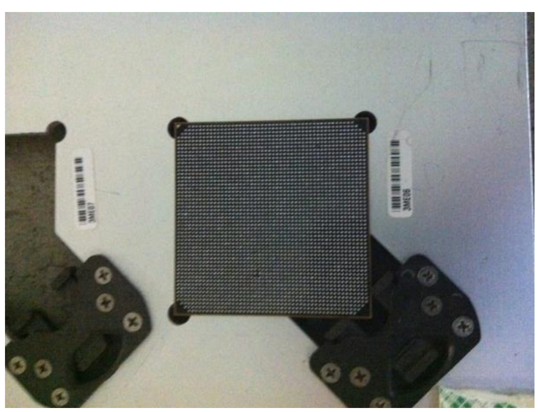


Figure 5 – Close up view of Fixture for automated 3D X-Ray inspection

Assemble one SMT Reflow Profile Board utilizing a large complex PCB with 50 x 50 mm and 52.5 x 52.5 mm FCBGA's.

Create three different style profiles called Ramp to Peak (Figure 6), Long Soak (Figure 7) and Medium Soak (Figure 8)

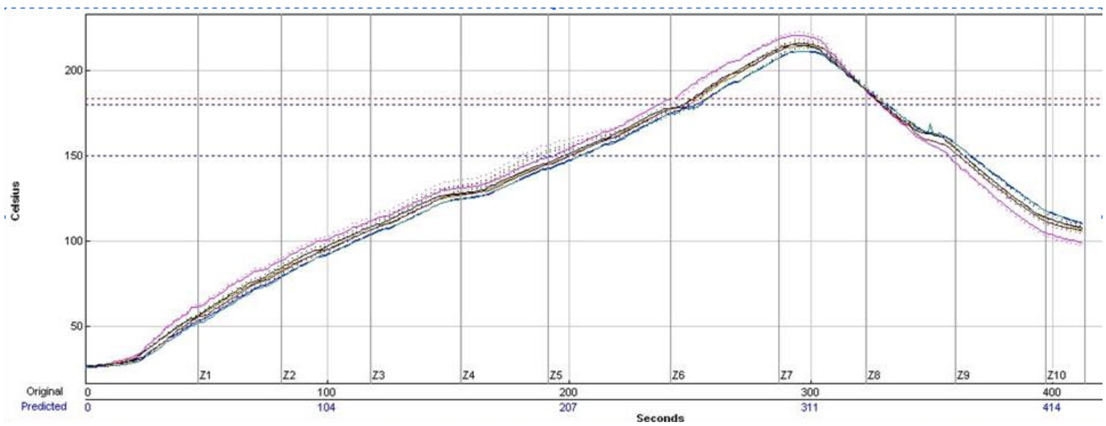


Figure 6 – Ramp to Peak SMT Reflow Profile

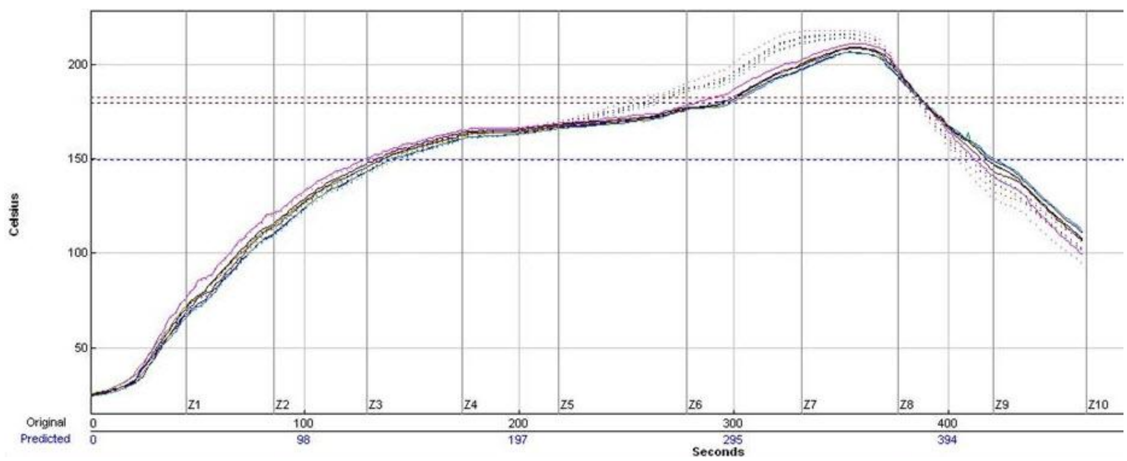


Figure 7 – Long Soak SMT Reflow Profile

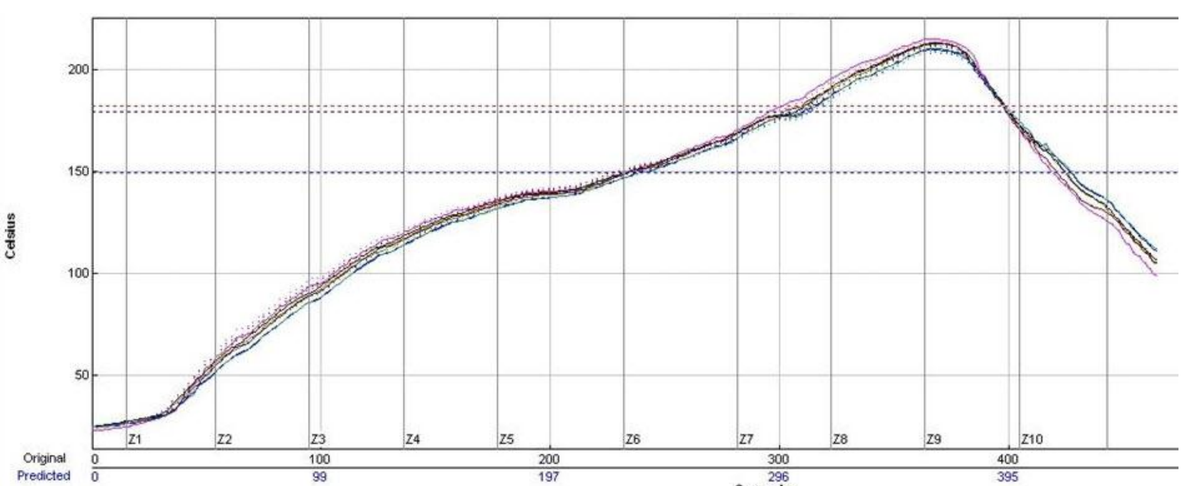


Figure 8 – Medium Soak SMT Reflow Profile

Follow process flow diagram show in Figure 9

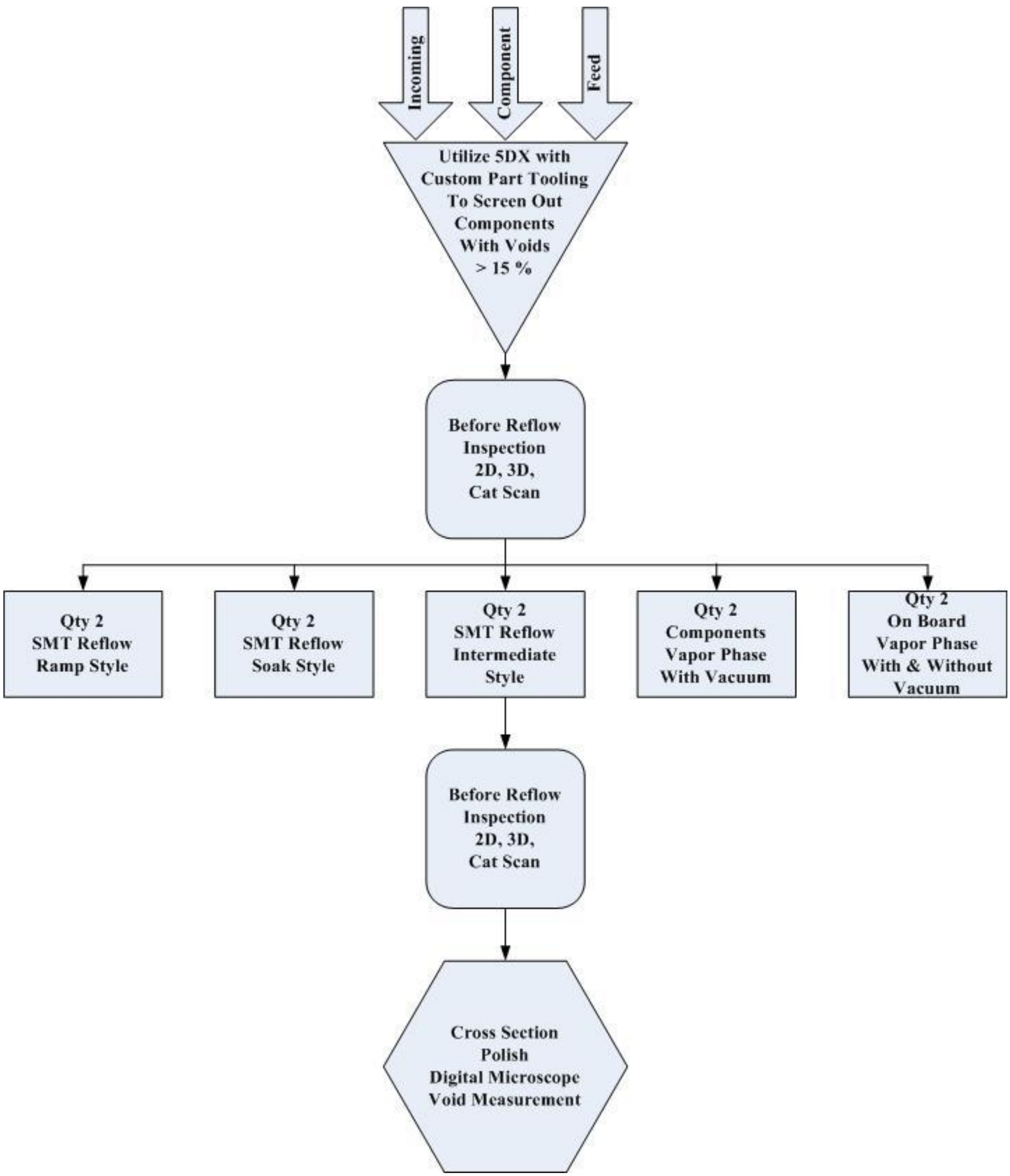


Figure 9 – Void Experiment Flow

VOID DETECTION METHODOLOGY

Three typical tools will be used for the experiment including 3D AXI (Figure 10), 2D X-Ray (Figure 11), Cross-Sectioning (Figure 12) along with a fourth non-typical tool called High Resolution CT Scan (Figure 13)

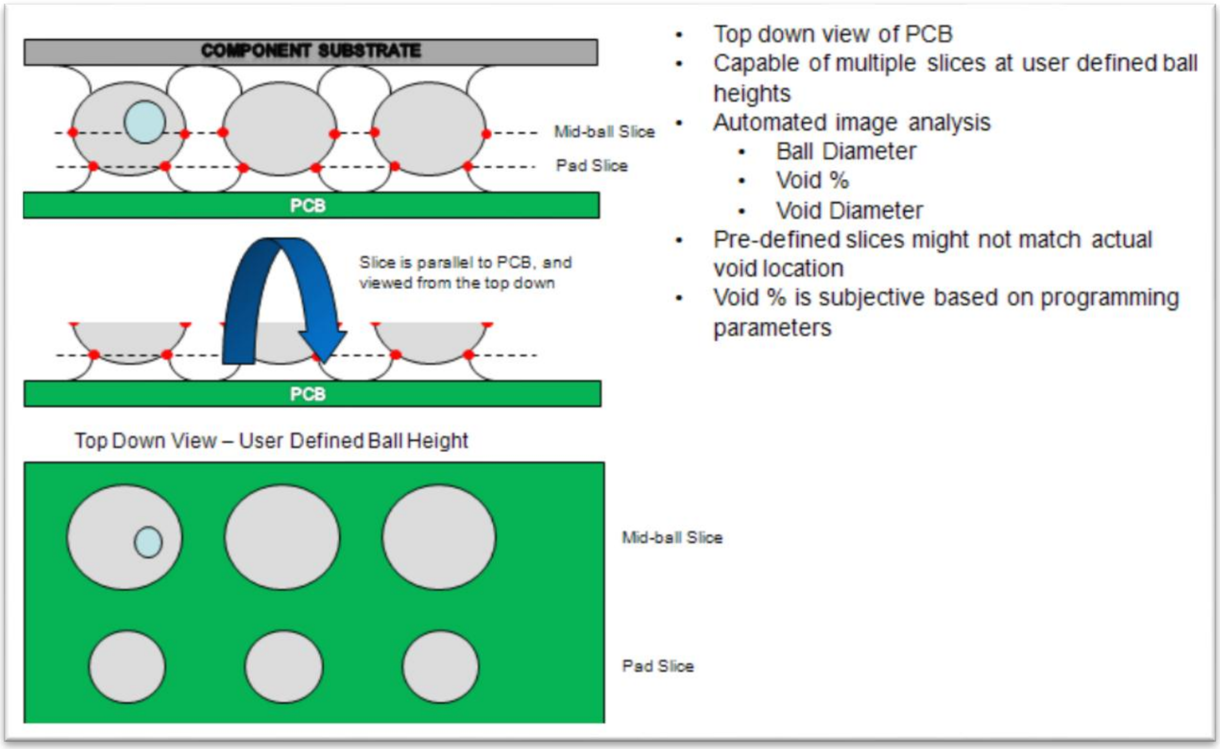


Figure 10 – 3D AXI Tool

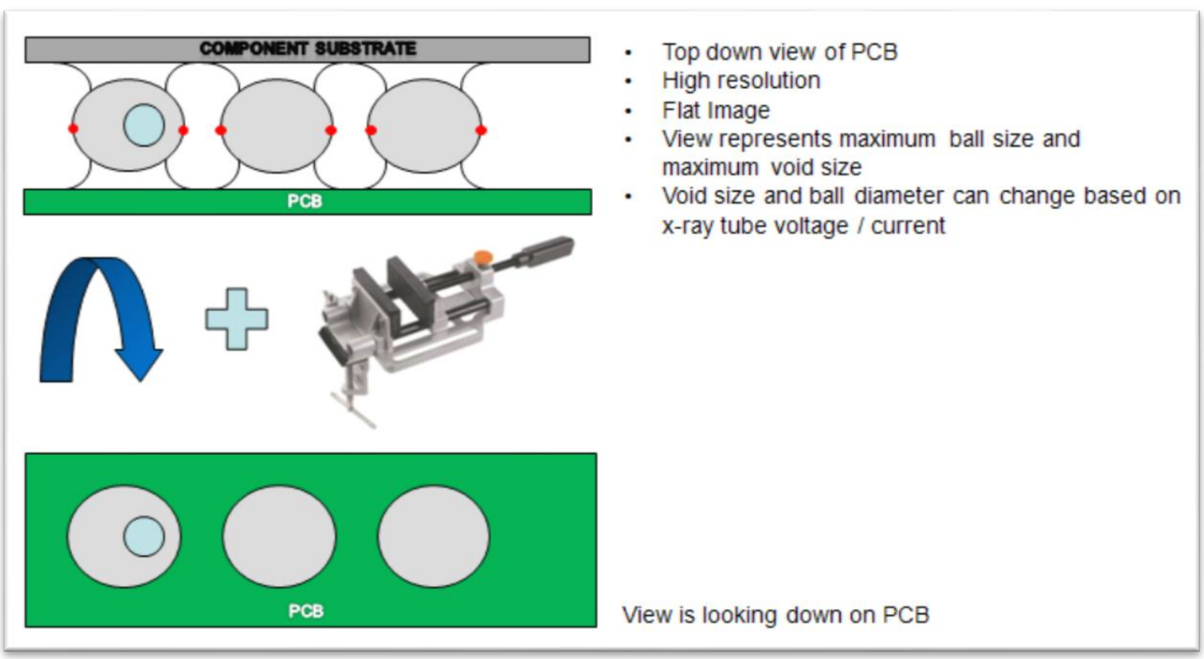


Figure 11 – 2D X-Ray Tool

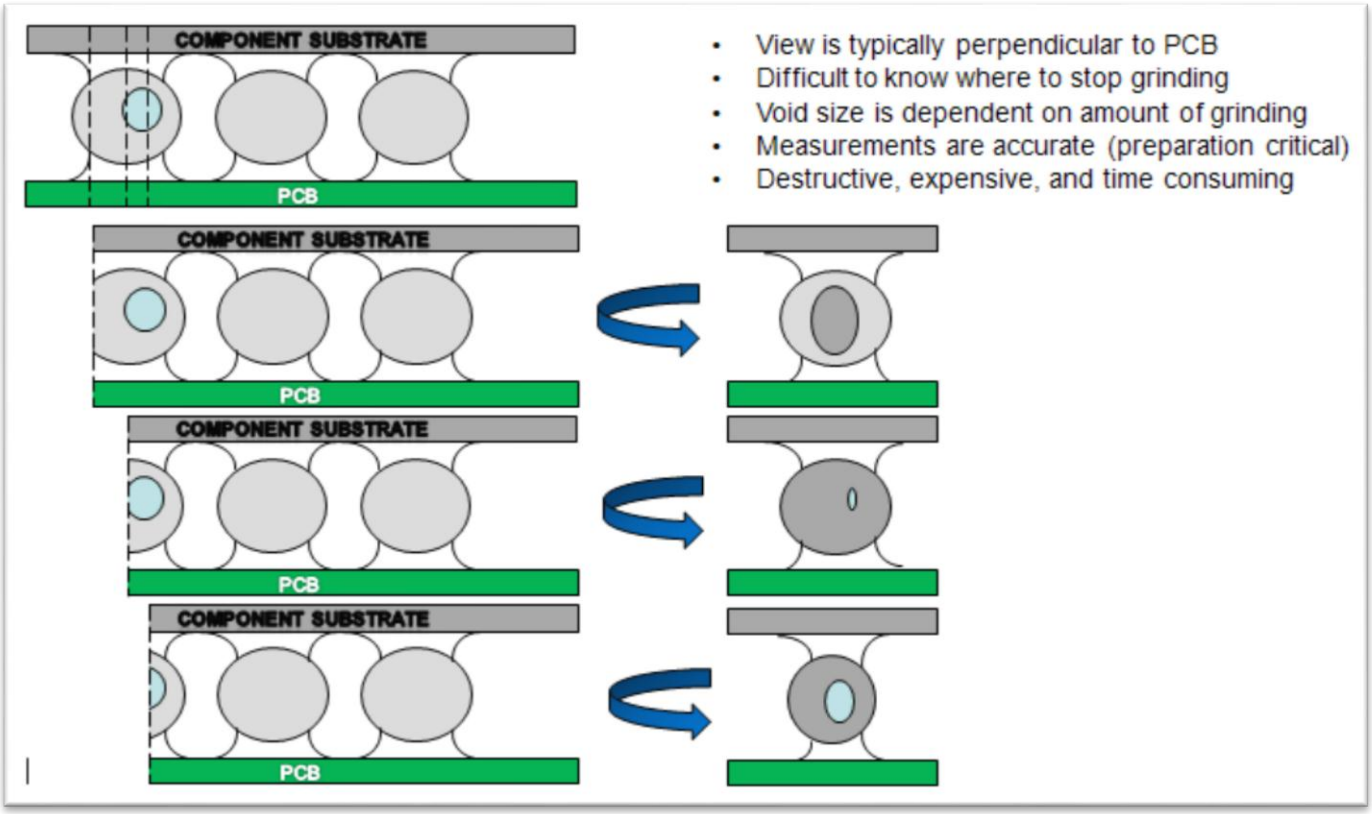


Figure 12 – Cross-Sectioning Tool

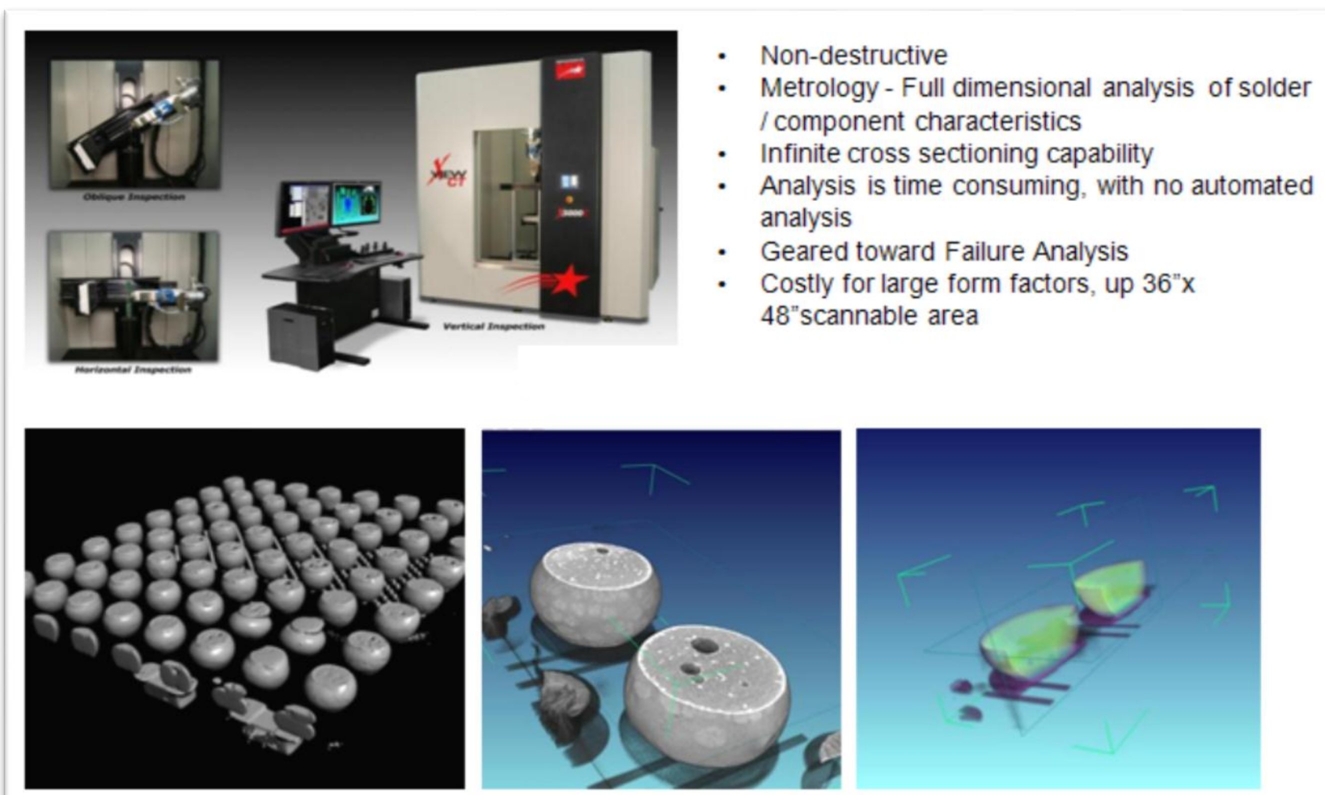


Figure 13 – High Resolution CT Scan Tool

Results

Figures 14 and Figure 15 show examples of the images collected from the experiment.

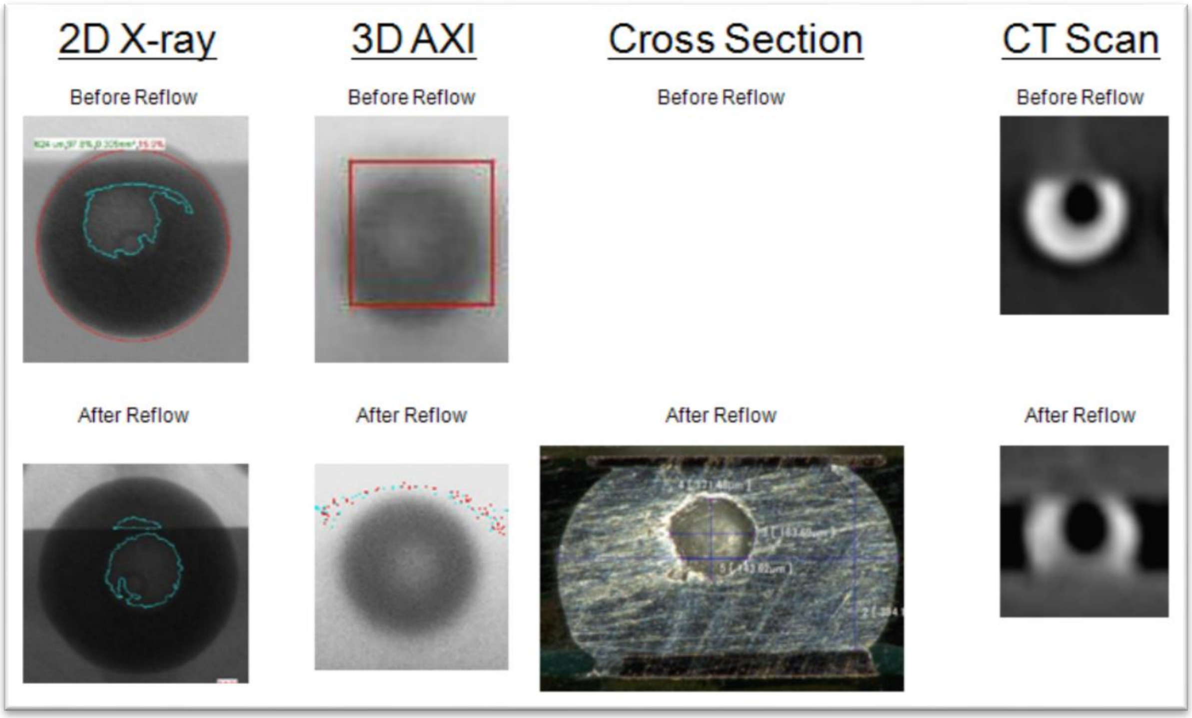


Figure 14 – Example 1 Of Images Collected using various tools

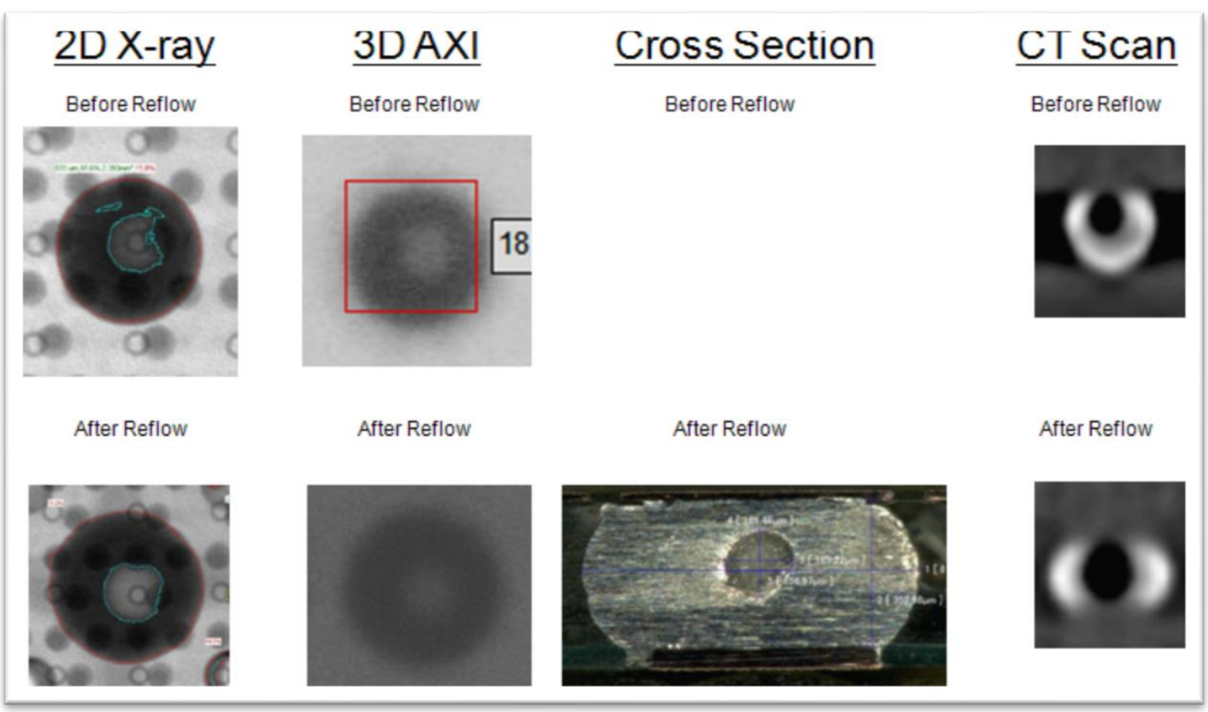
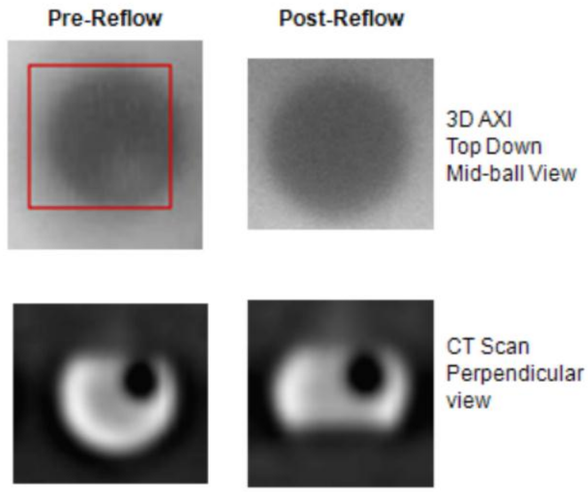


Figure 15 – Example 2 Of Images Collected using various tools

Tables 1 through 4 show the various measurements for comparison along with images to help explain the data.

Table 1 – 3D AXI Results

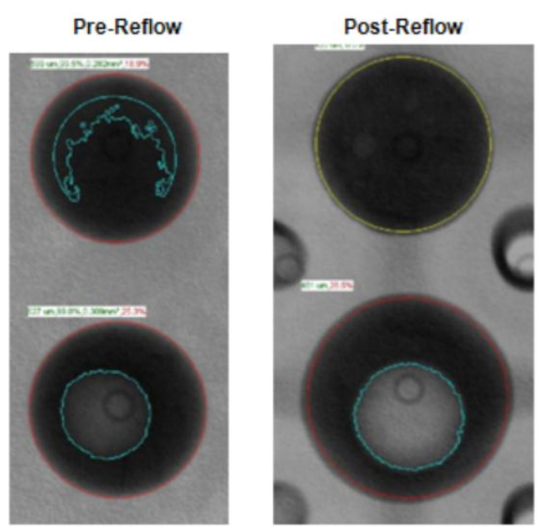
3D AXI					
Component	Pin Location	Oven Profile	Before Reflow - % Area Voided	After Reflow - % Area Voided	% Void Area Increase
Sample 1	37	Long Soak	19.92%	21.60%	8.43%
Sample 1	122	Long Soak	18.57%	23.67%	27.45%
Sample 2	6	Long Soak	15.12%	0.00%	-100.00%
Sample 2	318	Long Soak	13.15%	23.36%	77.64%
Sample 2	733	Long Soak	12.04%	14.44%	19.93%
Sample 2	2254	Long Soak	10.73%	0.00%	-100.00%
Sample 3	2090	Medium Soak	16.00%	41.57%	159.81%
Sample 4	111	Medium Soak	19.40%	28.32%	45.98%
Sample 5	363	Ramp to Peak	16.59%	19.38%	16.82%
Sample 6	521	Ramp to Peak	13.10%	35.00%	167.18%
Sample 6	1165	Ramp to Peak	10.73%	25.79%	140.35%
Sample 6	1185	Ramp to Peak	10.73%	21.77%	102.89%
Sample 6	1385	Ramp to Peak	18.77%	43.82%	133.46%
Sample 6	1388	Ramp to Peak	15.72%	22.80%	45.04%
Sample 7	917	Vapor Phase	12.75%		
Sample 7	1174	Vapor w/ Vacuum	24.00%		
Sample 7	1679	Vapor w/ Vacuum	12.00%		
Sample 8	366	Vapor Phase	22.43%		
Sample 8	2194	Vapor Phase	12.37%		
Sample 9	275	Vapor w/ Vacuum	11.89%		
Sample 9	379	Vapor w/ Vacuum	14.89%		



- Max void size position does not always align with pre-defined AXI slices

Table 2 – 2D X-RayResults

2D X-ray					
Component	Pin Location	Oven Profile	Before Reflow - % Area Voided	After Reflow - % Area Voided	% Void Area Increase
Sample 1	37	Long Soak	15.90%	16.40%	3.14%
Sample 1	122	Long Soak	15.80%	15.20%	-3.80%
Sample 2	6	Long Soak	12.00%	0.00%	-100.00%
Sample 2	318	Long Soak	11.70%	15.70%	34.19%
Sample 2	733	Long Soak	13.70%	16.00%	16.79%
Sample 2	2254	Long Soak	11.80%	0.00%	-100.00%
Sample 3	2090	Medium Soak	17.00%	23.40%	37.65%
Sample 4	111	Medium Soak	16.60%	18.10%	9.04%
Sample 5	363	Ramp to Peak	11.60%	11.30%	-2.59%
Sample 6	521	Ramp to Peak	15.20%	20.10%	32.24%
Sample 6	1165	Ramp to Peak	11.00%	15.40%	40.00%
Sample 6	1185	Ramp to Peak	9.90%	11.10%	12.12%
Sample 6	1385	Ramp to Peak	25.30%	28.50%	12.65%
Sample 6	1388	Ramp to Peak	13.60%	17.10%	25.74%
Sample 7	917	Vapor Phase	16.80%	0.00%	-100.00%
Sample 7	1174	Vapor w/ Vacuum	11.74%	0.00%	-100.00%
Sample 7	1679	Vapor w/ Vacuum	11.70%	0.00%	-100.00%
Sample 8	366	Vapor Phase	21.30%		
Sample 8	2194	Vapor Phase	9.70%		
Sample 9	275	Vapor w/ Vacuum	11.40%	0.00%	
Sample 9	379	Vapor w/ Vacuum	14.30%	0.00%	



- Max ball diameter, void diameter with only x,y void position information
- Void diameter increase not proportional to void % area increase

Table 3 – Cross-Sectioning Results

Physcial Cross Section					
Componen	Pin Location	Oven Profile	Max Void X	Void Y	% Void Area
Sample 1	37	Long Soak	183.69	171.48	11.2%
Sample 1	122	Long Soak	169.22	161.46	10.0%
Sample 2	6	Long Soak	195.94	219.36	14.6%
Sample 2	318	Long Soak			
Sample 2	733	Long Soak			
Sample 2	2254	Long Soak			
Sample 3	2090	Medium Soak	207.07	193.75	15.5%
Sample 4	111	Medium Soak	219.32	182.62	14.2%
Sample 5	363	Ramp to Peak	213.75	203.77	15.0%
Sample 6	521	Ramp to Peak			
Sample 6	1165	Ramp to Peak	283.92	302.87	29.6%
Sample 6	1185	Ramp to Peak			
Sample 6	1385	Ramp to Peak	262.73	227.16	22.0%
Sample 6	1388	Ramp to Peak	251.6	220.49	18.9%

- Measurements are most accurate among utilized technologies
- Difficult to know which direction to grind into ball without other x-ray tools as a guide
- Difficult to grind parallel to component package
- Easy to stop short, or grind past maximum void position

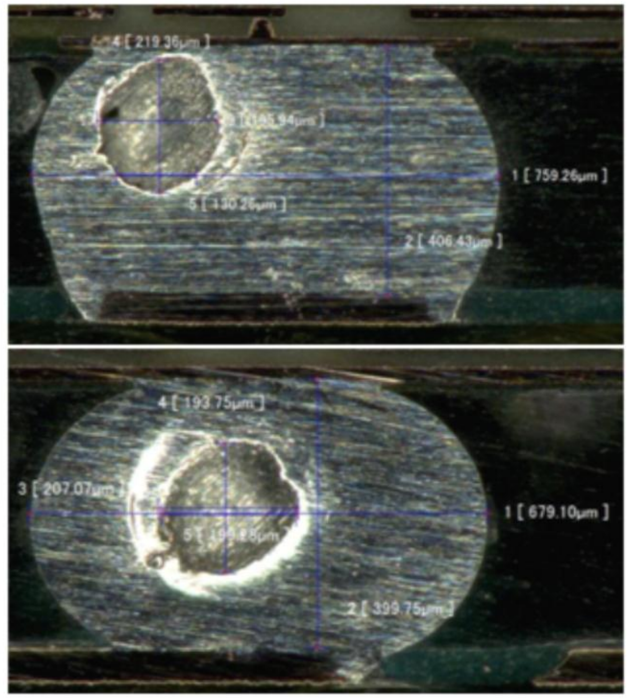
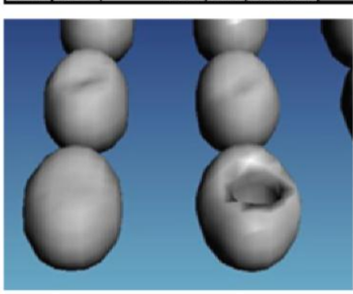
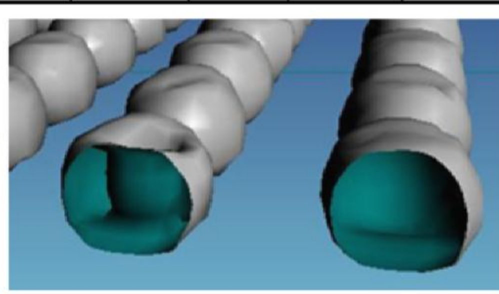


Table 4 – High Resolution Cat Scan Results

CT Scan								
Component	Pin Location	Oven Profile	Before - Void X-Dim (um)	Before - Void Y-Dim (um)	After - Void X-Dim (um)	After - Void Y-Dim (um)	Percent X - Dim Increase	Percent Y - Dim Increase
Sample 1	37	Long Soak	228.73	264.25	265.39	317.90	16.0%	20.3%
Sample 1	122	Long Soak	234.53	292.93	333.08	392.93	42.0%	34.1%
Sample 2	6	Long Soak	171.42	182.96	176.91	204.34	3.2%	11.7%
Sample 2	318	Long Soak	205.07	260.82	304.17	406.58	48.3%	55.9%
Sample 2	733	Long Soak	221.06	255.09	311.70	391.72	41.0%	53.6%
Sample 2	2254	Long Soak	205.43	273.83	245.52	338.25	19.5%	23.5%
Sample 3	2090	Medium Soak	278.26	331.69	389.63	475.51	40.0%	43.4%
Sample 4	111	Medium Soak	233.43	306.76	288.22	363.27	23.5%	18.4%
Sample 5	363	Ramp to Peak	241.36	189.54	248.69	316.29	3.0%	66.9%
Sample 6	521	Ramp to Peak			365.50	466.49		
Sample 6	1165	Ramp to Peak			395.58	270.45		
Sample 6	1185	Ramp to Peak						
Sample 6	1385	Ramp to Peak			414.28	478.52		
Sample 6	1388	Ramp to Peak						

- CT Imaging allows for complete void and ball characterization





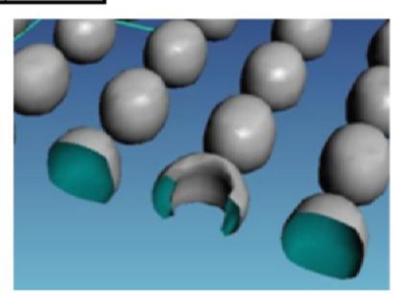


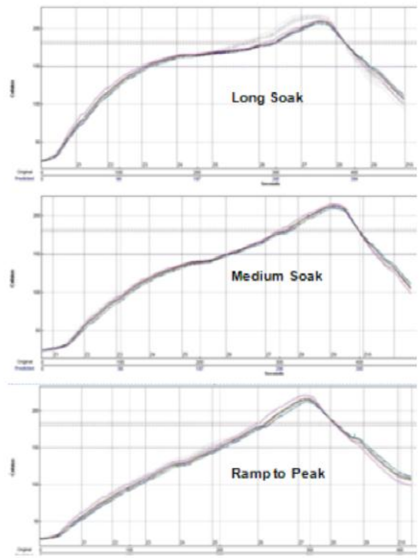
Table 5 shows the effect of the various profiles tried.

Table 5 = Effect of Profiling On Void Growth

Void Growth Analysis

Profile	2D X-ray Top Down Slice	3D AXI Top Down Slice	CT Scan Perp. Slice
Long Soak	13%	33%	31%
Medium Soak	23%	103%	31%
Ramp to Peak	20%	101%	35%

- X-ray void measurements are not 100% driven by increase / decrease in void size.
- Measurements for x-ray are affected by void positioning within ball and changes in ball diameter.
- Full void characterization requires both parallel and perpendicular slices through void area



Part of the experiment involved reflowing components in a Vapor Phase Reflow machine and turning on vacuum. Figure 16 show some basic information about the oven used, chemistry and parameters.

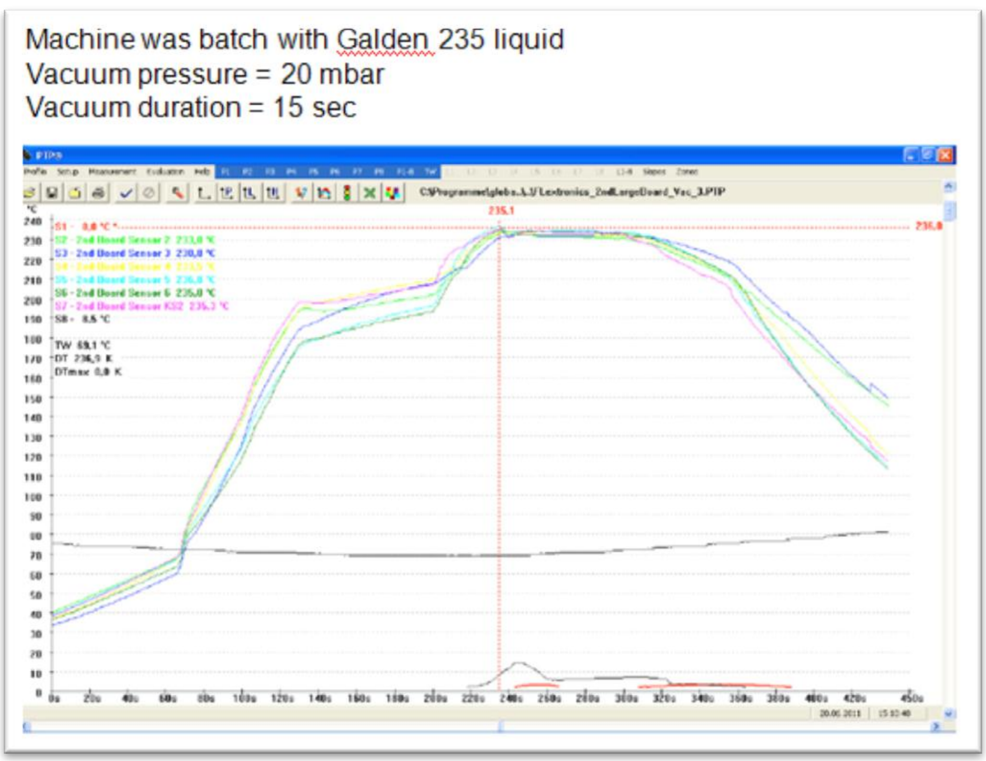


Figure 16 – Vapor Phase Reflow Details

Figure 17 shows the 2D X-Ray images before and after reflowing in the Vapor Phase oven using vacuum. 3D AXI was first used to confirm there were no detectable voids. 2D X-Ray images compare the same balls which confirm voids have mostly been removed beyond detection. CT Scans were not taken based on these results.

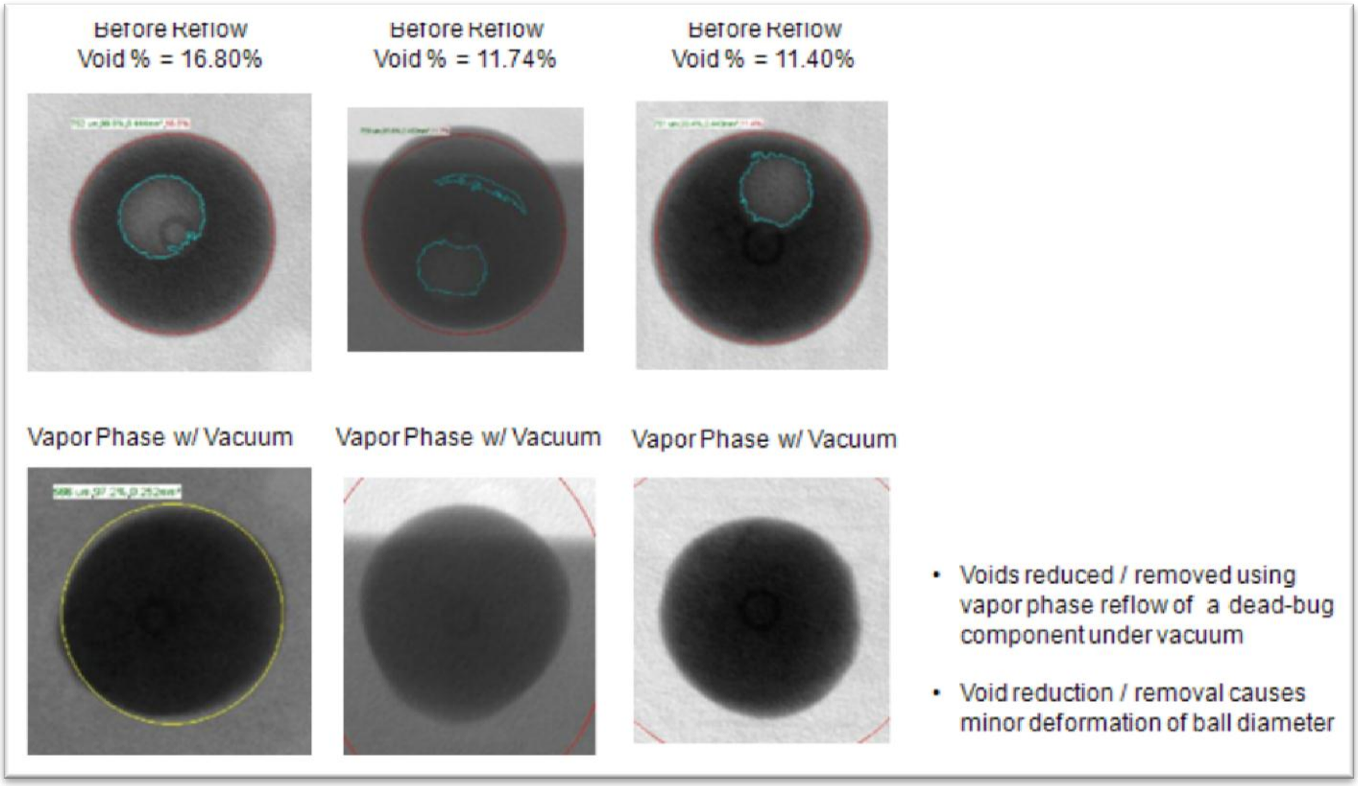


Figure 17 – Before and After results from Vapor Phase testing

DISCUSSION

From multiple void studies, it has been demonstrated that a soak style profile can greatly reduce voiding. Figure 18 shows an example of a void study using data from 3D X-Ray. This study was conducted on OSP PCB finish in Nitrogen environment. While one vendor may work slightly better at a ramp style profile, most tend to benefit from this style of profile (confused – benefit from soak?). While SMT solder pastes are mostly designed to work in air, most work well in N2 and will survive a longer profile which is what a soak style profile would represent. If running in air, perhaps a ramp or intermediate profile may work better so the vendor and part number of the SMT solder paste needs to be considered for the expected run environment.

In this figure, the Y axis represents number of voids. X axis represents void size bin.

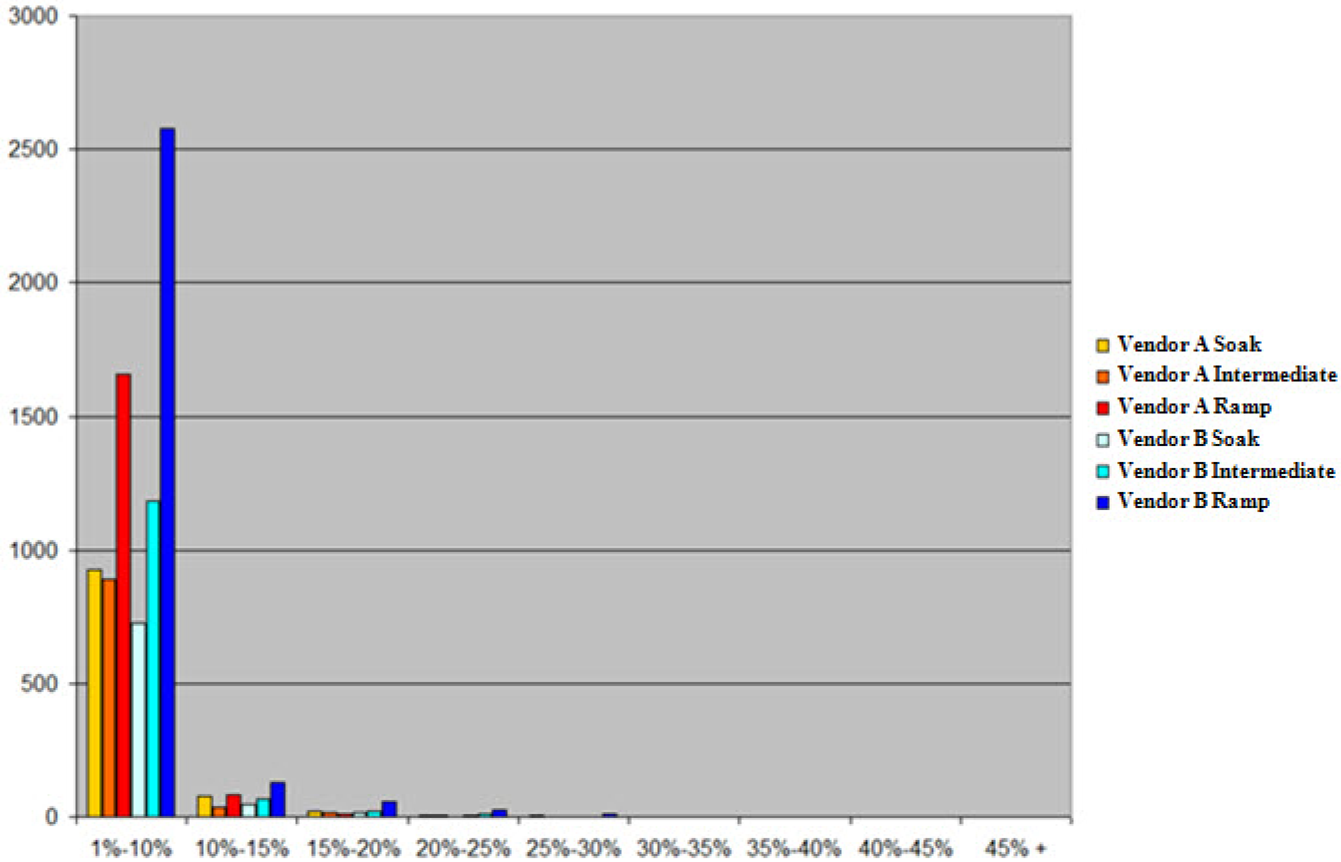


Figure 18 – Example of void study using size distribution

Based on the consistency of results from a variety of void studies in both SnPb and Pb Free, we concluded that a soak style profile eliminates or greatly reduces voiding when compared to an Intermediate style or Ramp style reflow profile. It is from this position that this experiment was conducted.

Knowing and understanding the characteristics of voiding relative to a particular brand and part number of solder paste will point users to whether the reflow process and/or chemistry (SMT solder paste) is causing the voiding issue. Inspection of incoming components will determine if voids are present on incoming parts. 2D or 3D x-ray can easily be used to inspect for voids on incoming components.

CONCLUSIONS

Table 6 was created to summarize the key characteristics of each tool. A number was assigned to rank the various tools in these characteristics based on experience. Depending on eash user and type of products / business, these may change slightly. Also, a weighting factor could be applied. The color (red, gree & yellow) is an added visual indicator.

Table 6 – Void Detection Tool Characteristic Rankings

	2D X-ray	3D AXI	CT Scan	Cross-Section
Image Resolution	3	4	2	1
Preparation Time	1	2	3	4
Automation	2	1	3	4
Measurement Accuracy	3	4	2	1
Slice Qty & Position	4	2	1	3
Analysis Time	2	1	3	4
Void Location	4	3	1	2

1 = Best   4 = Worst

3D AXI is necessary to screen out significant quantities of components as data points, prior to further characterization

Combination of available void detection technologies are needed for complete characterization of process and components, especially for increased complexity (i.e. via in pad, finer pitch, etc,,,)

PCB and Component Design, Reflow profile parameters as well as chemistry can all affect growth and positioning of voids

High Resolution CT Imaging allows for a complete analysis of components before and after assembly in non-destructive manner

While IPC 7095B introduced tables for void process indicators and troubleshooting and JEDEC Std 217 has a guideline for component voids allowed (pre-reflow), a clear joint industry specification needs to be considered to create better linkage between component manufacturing and PCB Assembly & Inspection

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Jochen Lipp – IBL USA

Before and After Reflow Characterization of FCBA Voiding

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Contents

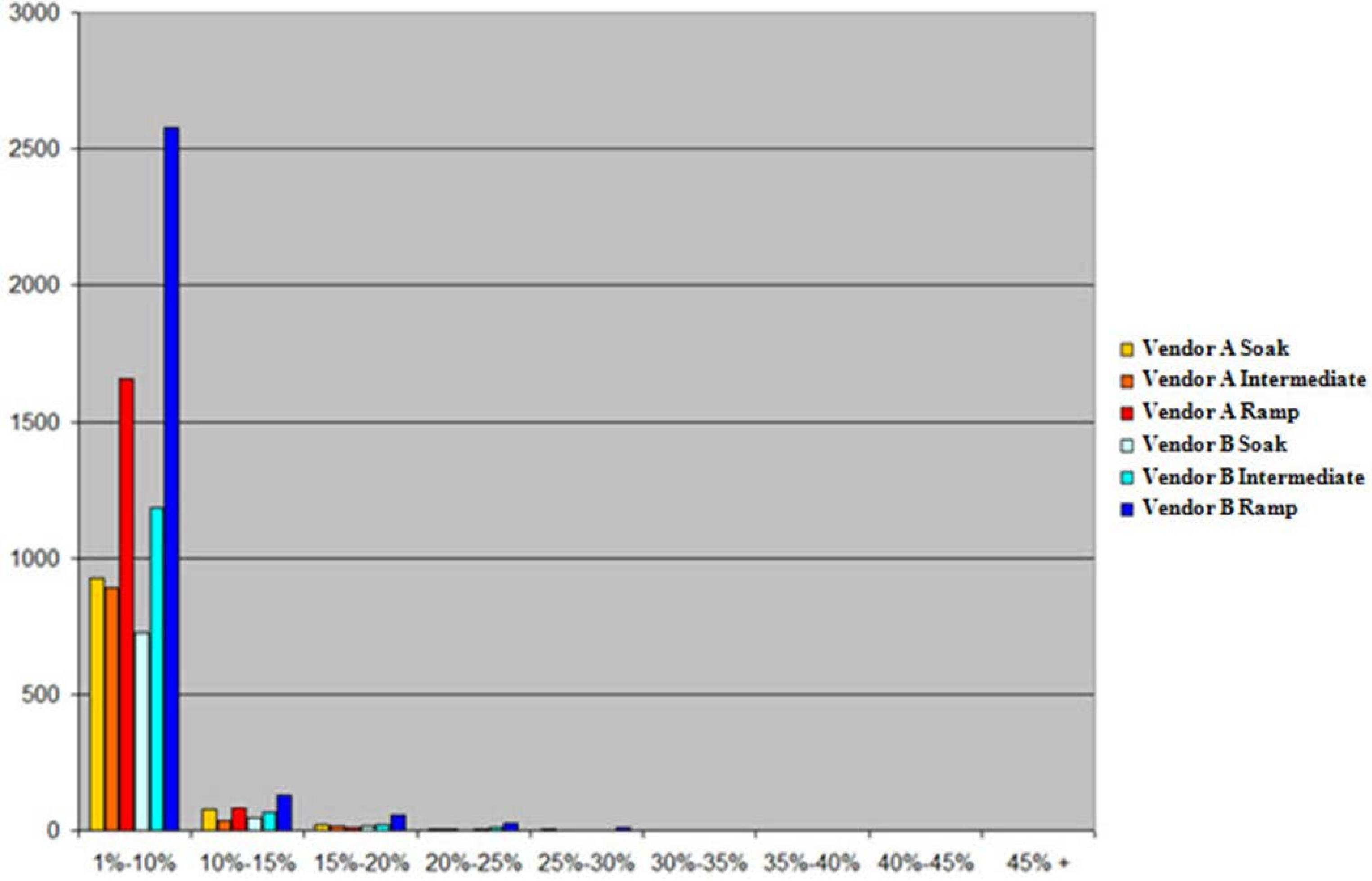
- Background
- Experiment Parameters
- Tools for Void Identification
- Before & After Void Characterization
- Process Considerations for Void Minimization
- Void Removal
- Conclusions

BACKGROUND

Background

- 3% component level fallout at 3D AXI due to voids failing to meet customer requirements
- Expensive component replacement cost
- Voiding isolated to specific component type from single source supplier
- Process and chemistry set characterized
- Test results indicted incoming component issue
- Developed tooling and AXI program for screening incoming material to <15% void area per JEDEC Standard 217 guidelines

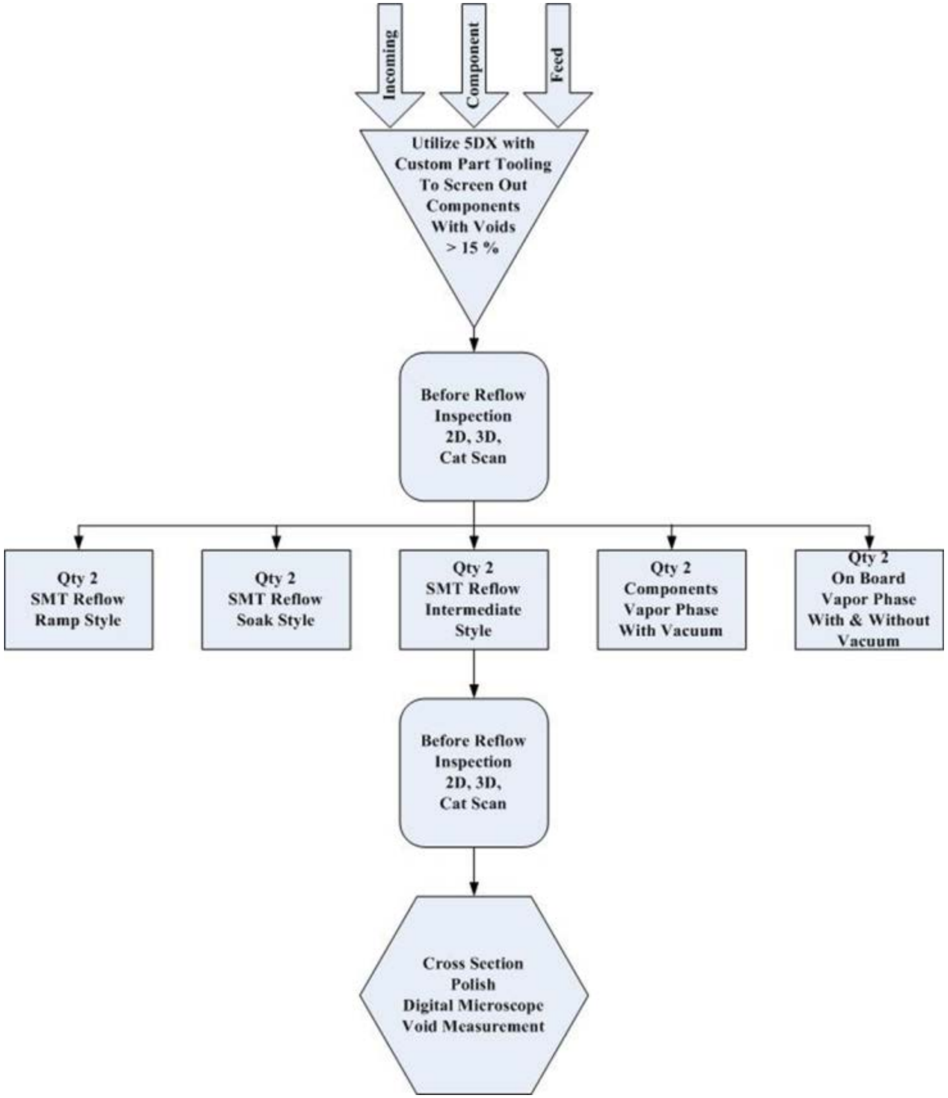
Process Characterization



Fixture for 3D AXI Screening

EXPERIMENT PARAMETERS

Experiment Flow Chart

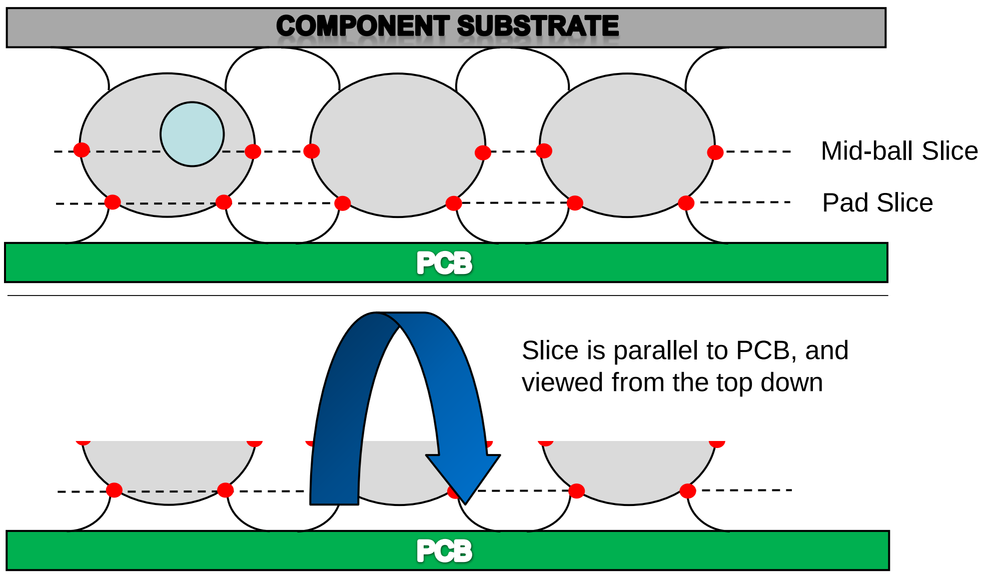


- 10 FCBGA ASICS used for Analysis
- Before / After Reflow Void Characterization
    - 2D X-ray
    - 3D AXI
    - High Resolution CT Imaging
- After Reflow Cross-Sectioning

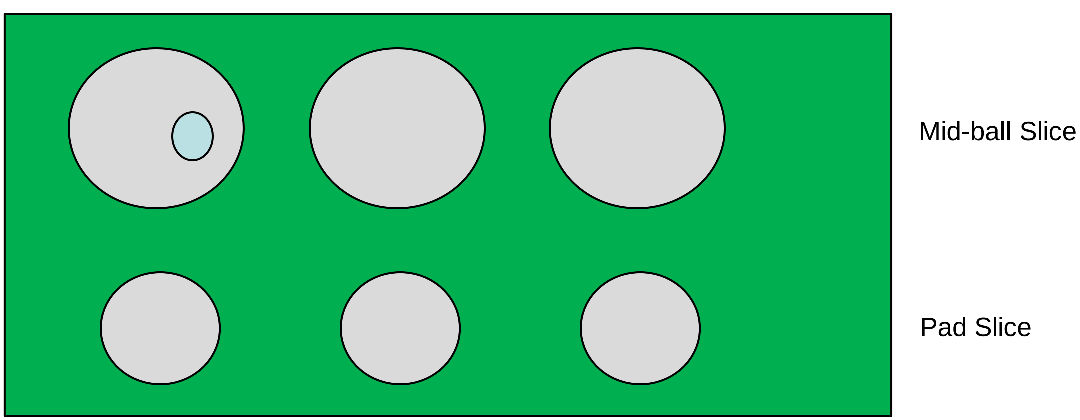
Void Detection Methodology

TOOLS FOR VOID IDENTIFICATION

3D AXI

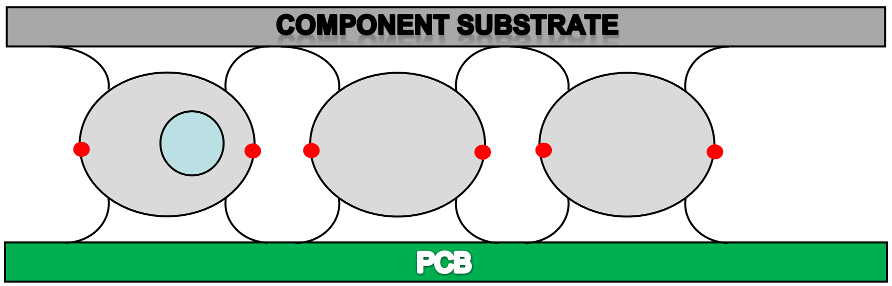


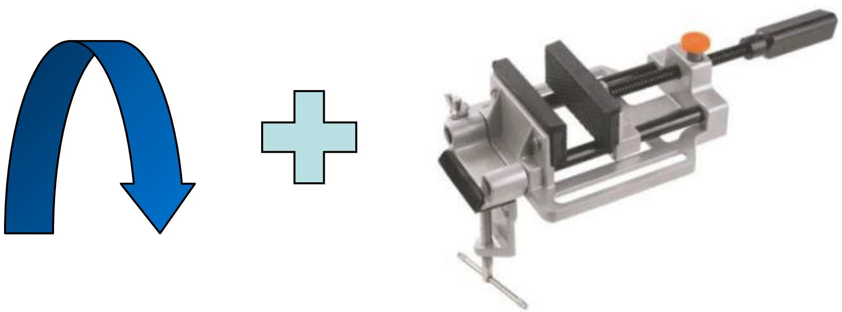
Top Down View – User Defined Ball Height

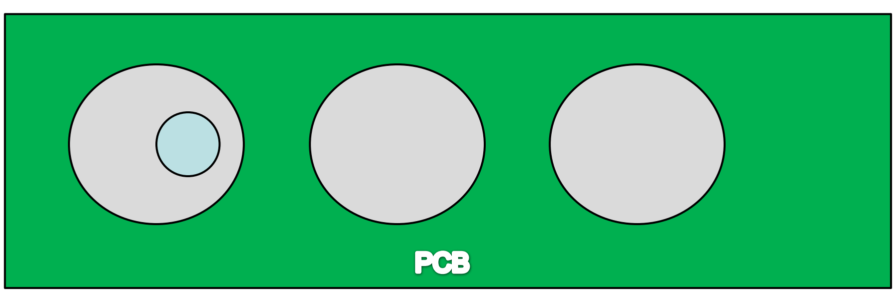


- Top down view of PCB
- Capable of multiple slices at user defined ball heights
- Automated image analysis
  - Ball Diameter
  - Void %
  - Void Diameter
- Pre-defined slices might not match actual void location
- Void % is subjective based on programming parameters

2D X-ray



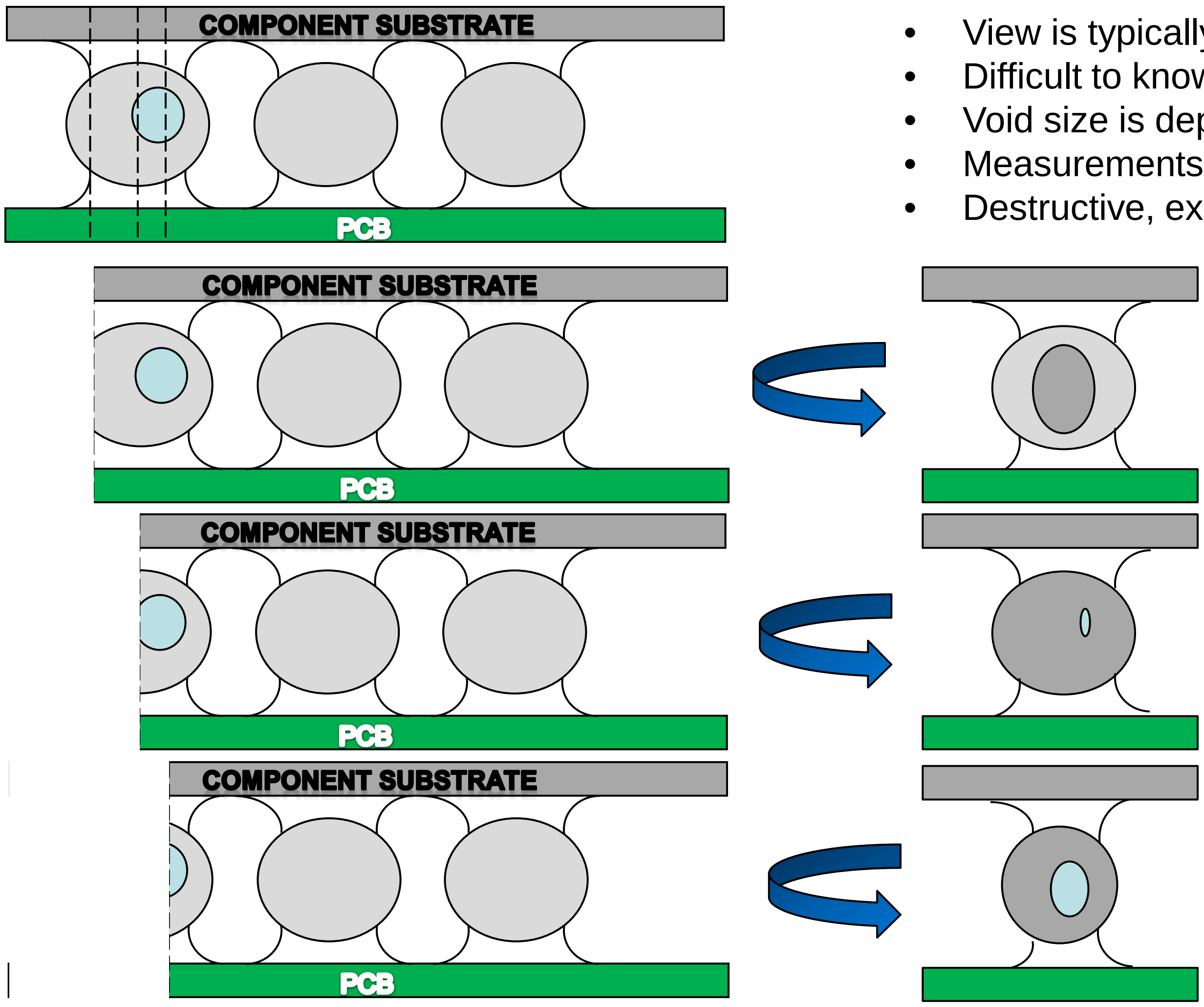




- Top down view of PCB
- High resolution
- Flat Image
- View represents maximum ball size and maximum void size
- Void size and ball diameter can change based on x-ray tube voltage / current

View is looking down on PCB

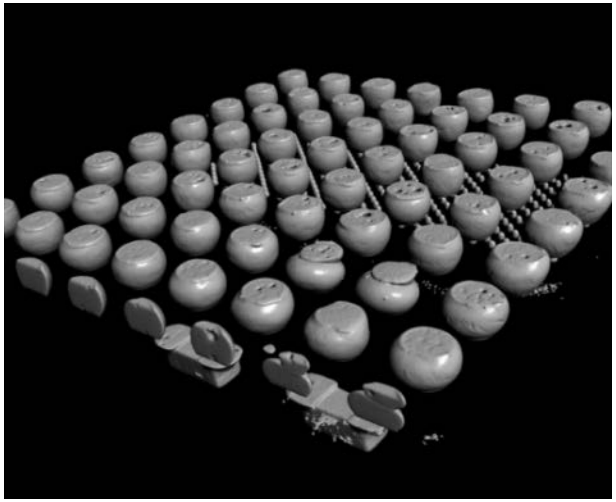
Cross-Sectioning

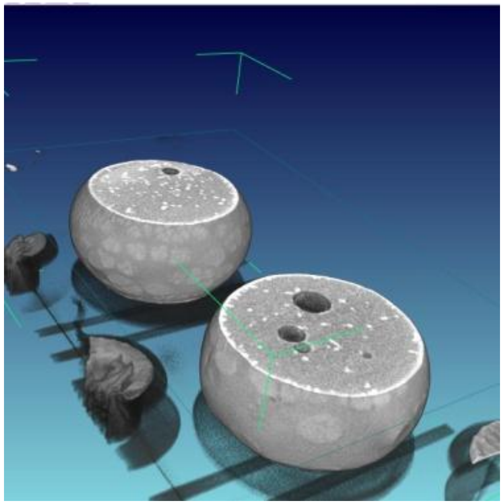


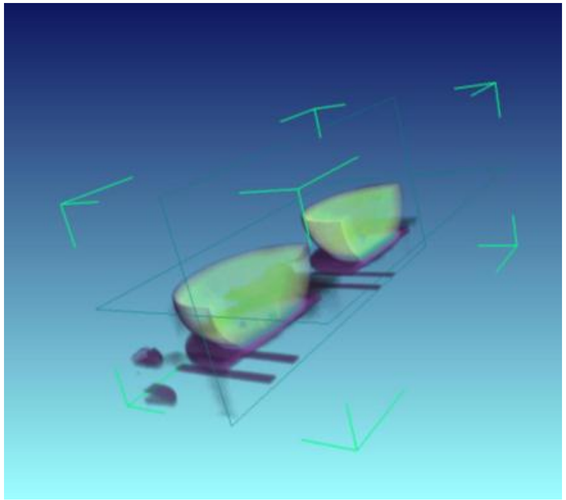
- View is typically perpendicular to PCB
- Difficult to know where to stop grinding
- Void size is dependent on amount of grinding
- Measurements are accurate (preparation critical)
- Destructive, expensive, and time consuming

High Resolution CT Scan

- Non-destructive
- Metrology - Full dimensional analysis of solder / component characteristics
- Infinite cross sectioning capability
- Analysis is time consuming, with no automated analysis
- Geared toward Failure Analysis
- Costly for large form factors, up 36”x 48”scannable area





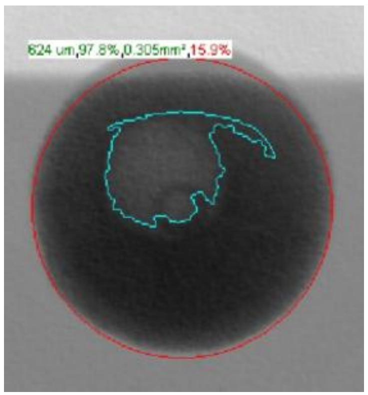


BEFORE & AFTER VOID CHARACTERIZATION

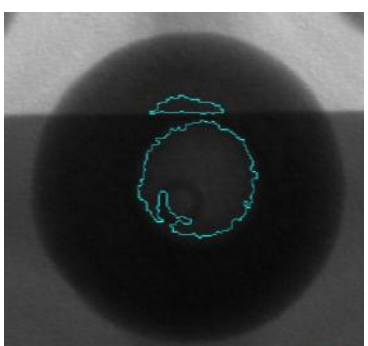
Before / After – Example 1

2D X-ray

Before Reflow

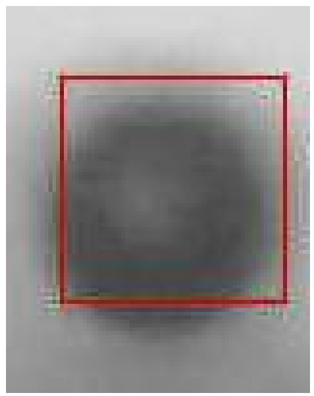


After Reflow

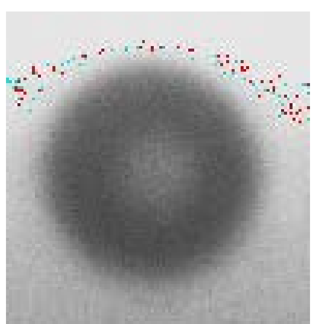


3D AXI

Before Reflow



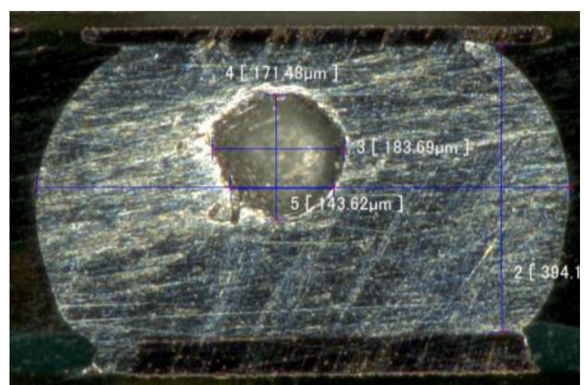
After Reflow



Cross Section

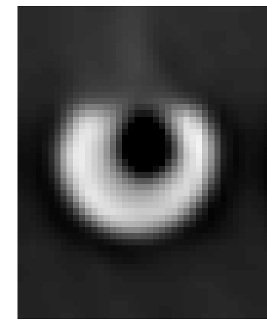
Before Reflow

After Reflow

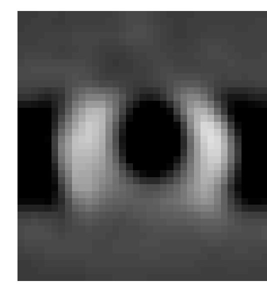


CT Scan

Before Reflow



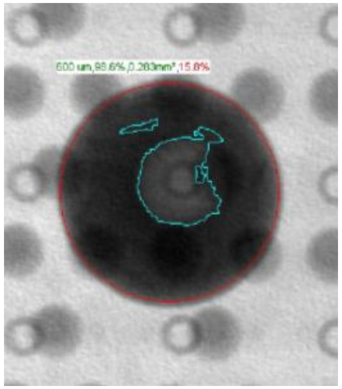
After Reflow



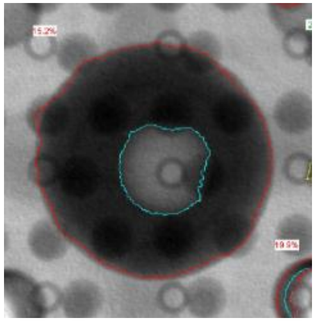
Before / After – Example 2

2D X-ray

Before Reflow

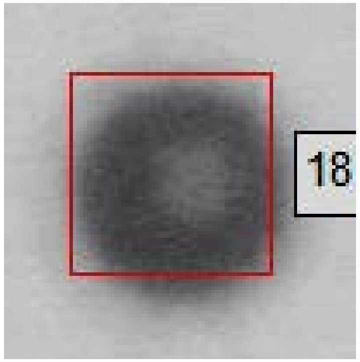


After Reflow

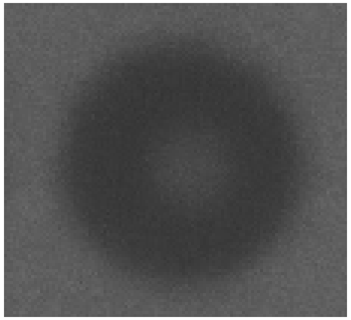


3D AXI

Before Reflow



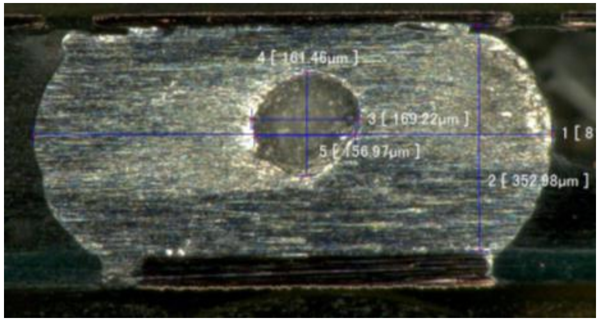
After Reflow



Cross Section

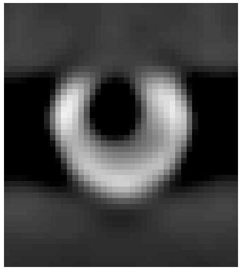
Before Reflow

After Reflow

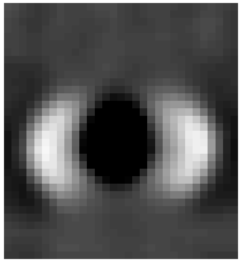


CT Scan

Before Reflow



After Reflow

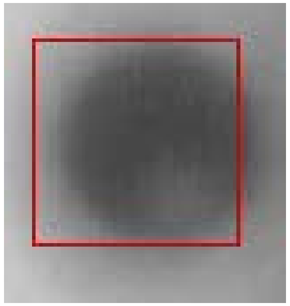


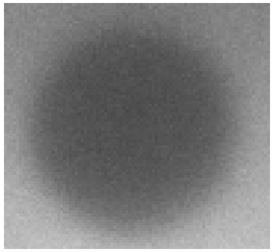
As originally published in the IPC APEX EXPO Proceedings.

Before / After Results – 3D AXI

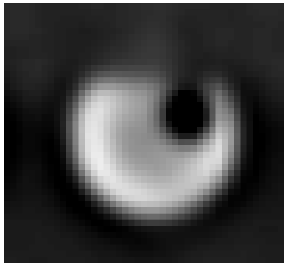
3D AXI					
Component	Pin Location	Oven Profile	Before Reflow - % Area Voided	After Reflow - % Area Voided	% Void Area Increase
Sample 1	37	Long Soak	19.92%	21.60%	8.43%
Sample 1	122	Long Soak	18.57%	23.67%	27.45%
Sample 2	6	Long Soak	15.12%	0.00%	-100.00%
Sample 2	318	Long Soak	13.15%	23.36%	77.64%
Sample 2	733	Long Soak	12.04%	14.44%	19.93%
Sample 2	2254	Long Soak	10.73%	0.00%	-100.00%
Sample 3	2090	Medium Soak	16.00%	41.57%	159.81%
Sample 4	111	Medium Soak	19.40%	28.32%	45.98%
Sample 5	363	Ramp to Peak	16.59%	19.38%	16.82%
Sample 6	521	Ramp to Peak	13.10%	35.00%	167.18%
Sample 6	1165	Ramp to Peak	10.73%	25.79%	140.35%
Sample 6	1185	Ramp to Peak	10.73%	21.77%	102.89%
Sample 6	1385	Ramp to Peak	18.77%	43.82%	133.46%
Sample 6	1388	Ramp to Peak	15.72%	22.80%	45.04%
Sample 7	917	Vapor Phase	12.75%		
Sample 7	1174	Vapor w / Vacuum	24.00%		
Sample 7	1679	Vapor w / Vacuum	12.00%		
Sample 8	366	Vapor Phase	22.43%		
Sample 8	2194	Vapor Phase	12.37%		
Sample 9	275	Vapor w / Vacuum	11.89%		
Sample 9	379	Vapor w / Vacuum	14.89%		

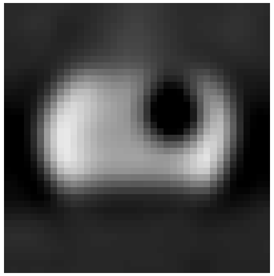
Pre-Reflow | **Post-Reflow**





3D AXI
Top Down
Mid-ball View





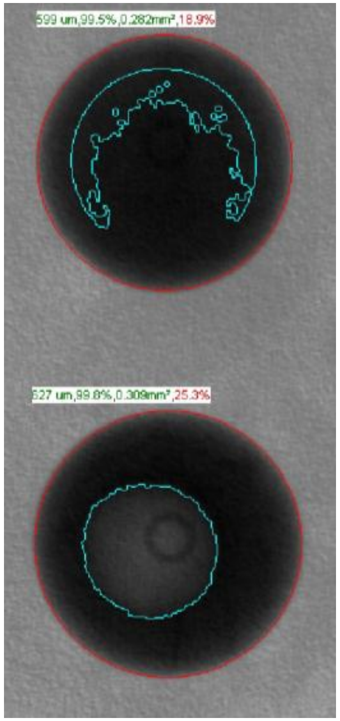
CT Scan
Perpendicular
view

- Max void size position does not always align with pre-defined AXI slices

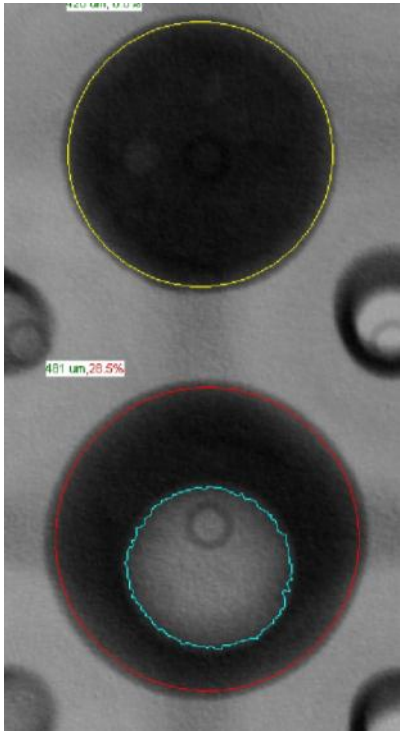
Before / After Results – 2D X-ray

2D X-ray					
Component	Pin Location	Oven Profile	Before Reflow - % Area Voided	After Reflow - % Area Voided	% Void Area Increase
Sample 1	37	Long Soak	15.90%	16.40%	3.14%
Sample 1	122	Long Soak	15.80%	15.20%	-3.80%
Sample 2	6	Long Soak	12.00%	0.00%	-100.00%
Sample 2	318	Long Soak	11.70%	15.70%	34.19%
Sample 2	733	Long Soak	13.70%	16.00%	16.79%
Sample 2	2254	Long Soak	11.80%	0.00%	-100.00%
Sample 3	2090	Medium Soak	17.00%	23.40%	37.65%
Sample 4	111	Medium Soak	16.60%	18.10%	9.04%
Sample 5	363	Ramp to Peak	11.60%	11.30%	-2.59%
Sample 6	521	Ramp to Peak	15.20%	20.10%	32.24%
Sample 6	1165	Ramp to Peak	11.00%	15.40%	40.00%
Sample 6	1185	Ramp to Peak	9.90%	11.10%	12.12%
Sample 6	1385	Ramp to Peak	25.30%	28.50%	12.65%
Sample 6	1388	Ramp to Peak	13.60%	17.10%	25.74%
Sample 7	917	Vapor Phase	16.80%	0.00%	-100.00%
Sample 7	1174	Vapor w / Vacuum	11.74%	0.00%	-100.00%
Sample 7	1679	Vapor w / Vacuum	11.70%	0.00%	-100.00%
Sample 8	366	Vapor Phase	21.30%		
Sample 8	2194	Vapor Phase	9.70%		
Sample 9	275	Vapor w / Vacuum	11.40%	0.00%	
Sample 9	379	Vapor w / Vacuum	14.30%	0.00%	

Pre-Reflow



Post-Reflow

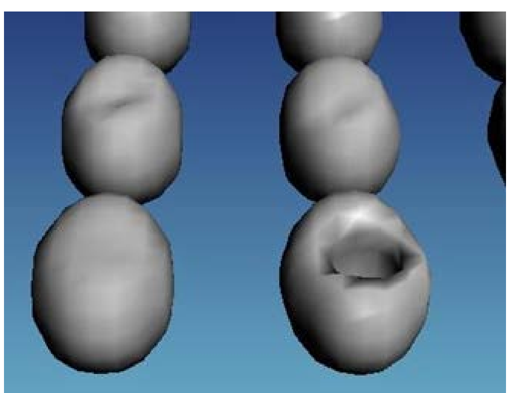


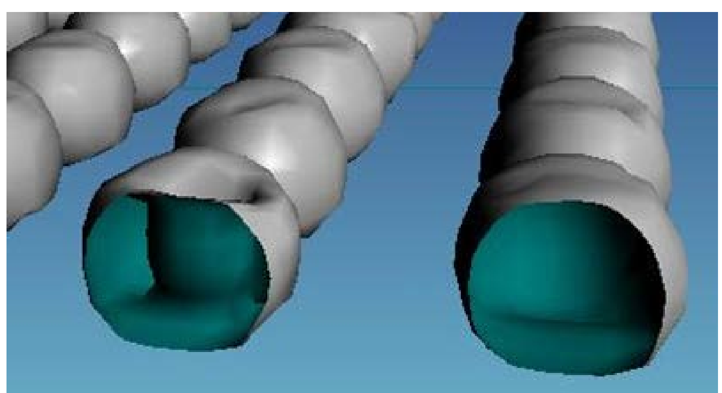
- Max ball diameter, void diameter with only x,y void position information
- Void diameter increase not proportional to void % area increase

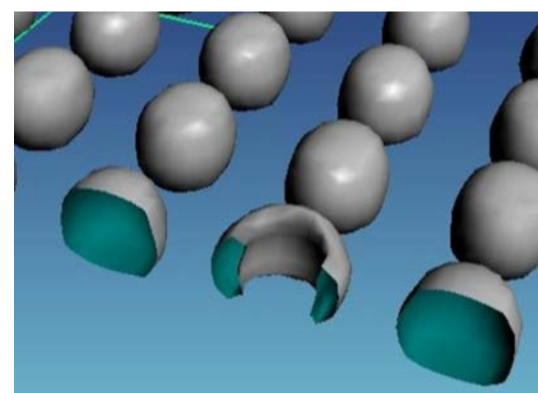
Before / After Results – CT Scan

CT Scan								
Component	Pin Location	Oven Profile	Before - Void X-Dim (um)	Before - Void Y-Dim (um)	After - Void X-Dim (um)	After - Void Y-Dim (um)	Percent X - Dim Increase	Percent Y - Dim Increase
Sample 1	37	Long Soak	228.73	264.25	265.39	317.90	16.0%	20.3%
Sample 1	122	Long Soak	234.53	292.93	333.08	392.93	42.0%	34.1%
Sample 2	6	Long Soak	171.42	182.96	176.91	204.34	3.2%	11.7%
Sample 2	318	Long Soak	205.07	260.82	304.17	406.58	48.3%	55.9%
Sample 2	733	Long Soak	221.06	255.09	311.70	391.72	41.0%	53.6%
Sample 2	2254	Long Soak	205.43	273.83	245.52	338.25	19.5%	23.5%
Sample 3	2090	Medium Soak	278.26	331.69	389.63	475.51	40.0%	43.4%
Sample 4	111	Medium Soak	233.43	306.76	288.22	363.27	23.5%	18.4%
Sample 5	363	Ramp to Peak	241.36	189.54	248.69	316.29	3.0%	66.9%
Sample 6	521	Ramp to Peak			365.50	466.49		
Sample 6	1165	Ramp to Peak			395.58	270.45		
Sample 6	1185	Ramp to Peak						
Sample 6	1385	Ramp to Peak			414.28	478.52		
Sample 6	1388	Ramp to Peak						

- CT Imaging allows for complete void and ball characterization



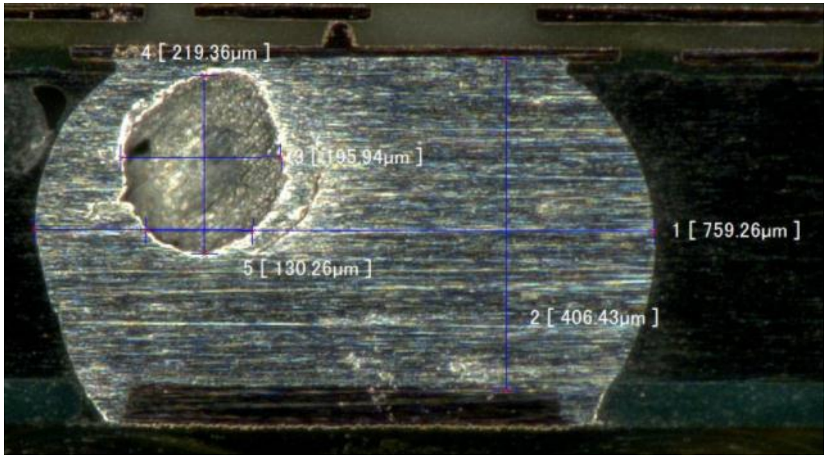


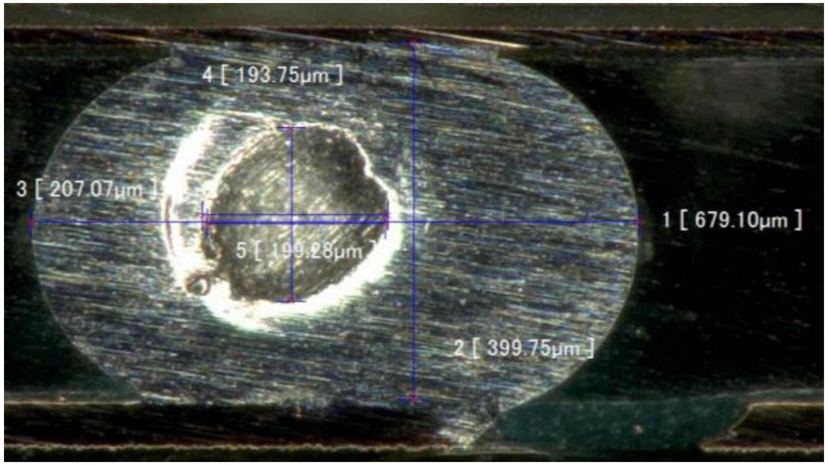


Cross-Section Results

Physcial Cross Section					
Componen	Pin Location	Oven Profile	Max Void X	Void Y	% Void Area
Sample 1	37	Long Soak	183.69	171.48	11.2%
Sample 1	122	Long Soak	169.22	161.46	10.0%
Sample 2	6	Long Soak	195.94	219.36	14.6%
Sample 2	318	Long Soak			
Sample 2	733	Long Soak			
Sample 2	2254	Long Soak			
Sample 3	2090	Medium Soak	207.07	193.75	15.5%
Sample 4	111	Medium Soak	219.32	182.62	14.2%
Sample 5	363	Ramp to Peak	213.75	203.77	15.0%
Sample 6	521	Ramp to Peak			
Sample 6	1165	Ramp to Peak	283.92	302.87	29.6%
Sample 6	1185	Ramp to Peak			
Sample 6	1385	Ramp to Peak	262.73	227.16	22.0%
Sample 6	1388	Ramp to Peak	251.6	220.49	18.9%

- Measurements are most accurate among utilized technologies
- Difficult to know which direction to grind into ball without other x-ray tools as a guide
- Difficult to grind parallel to component package
- Easy to stop short, or grind past maximum void position





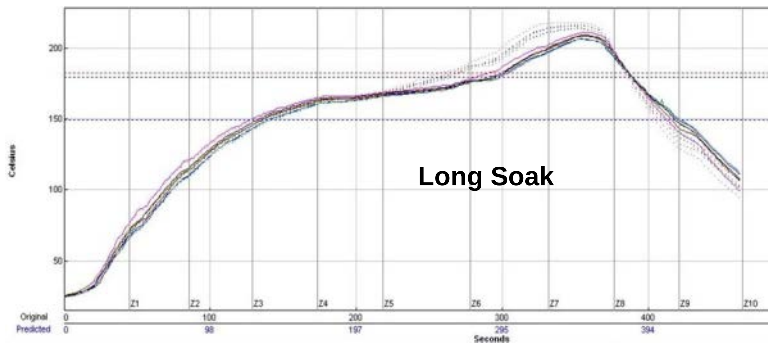
PROCESS CONSIDERATIONS FOR VOID MINIMIZATION

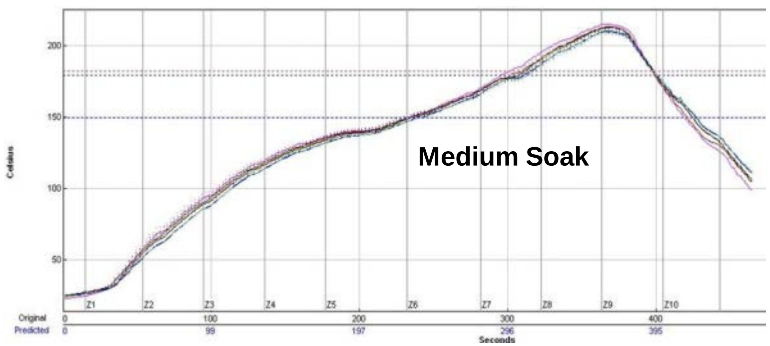
Oven Reflow Profiles

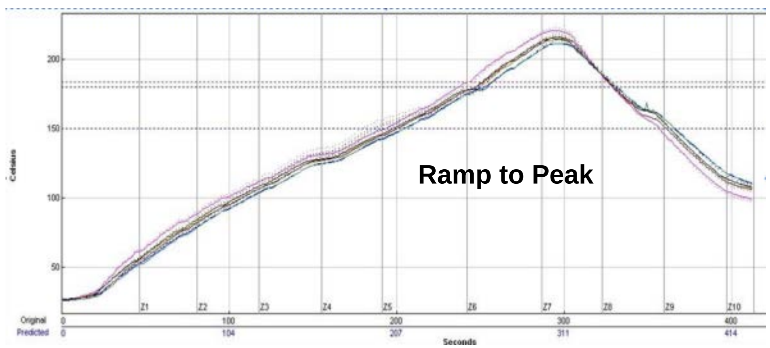
Void Growth Analysis

Profile	2D X-ray Top Down Slice	3D AXI Top Down Slice	CT Scan Perp. Slice
Long Soak	13%	33%	31%
Medium Soak	23%	103%	31%
Ramp to Peak	20%	101%	35%

- X-ray void measurements are not 100% driven by increase / decrease in void size.
- Measurements for x-ray are affected by void positioning within ball and changes in ball diameter.
- Full void characterization requires both parallel and perpendicular slices through void area



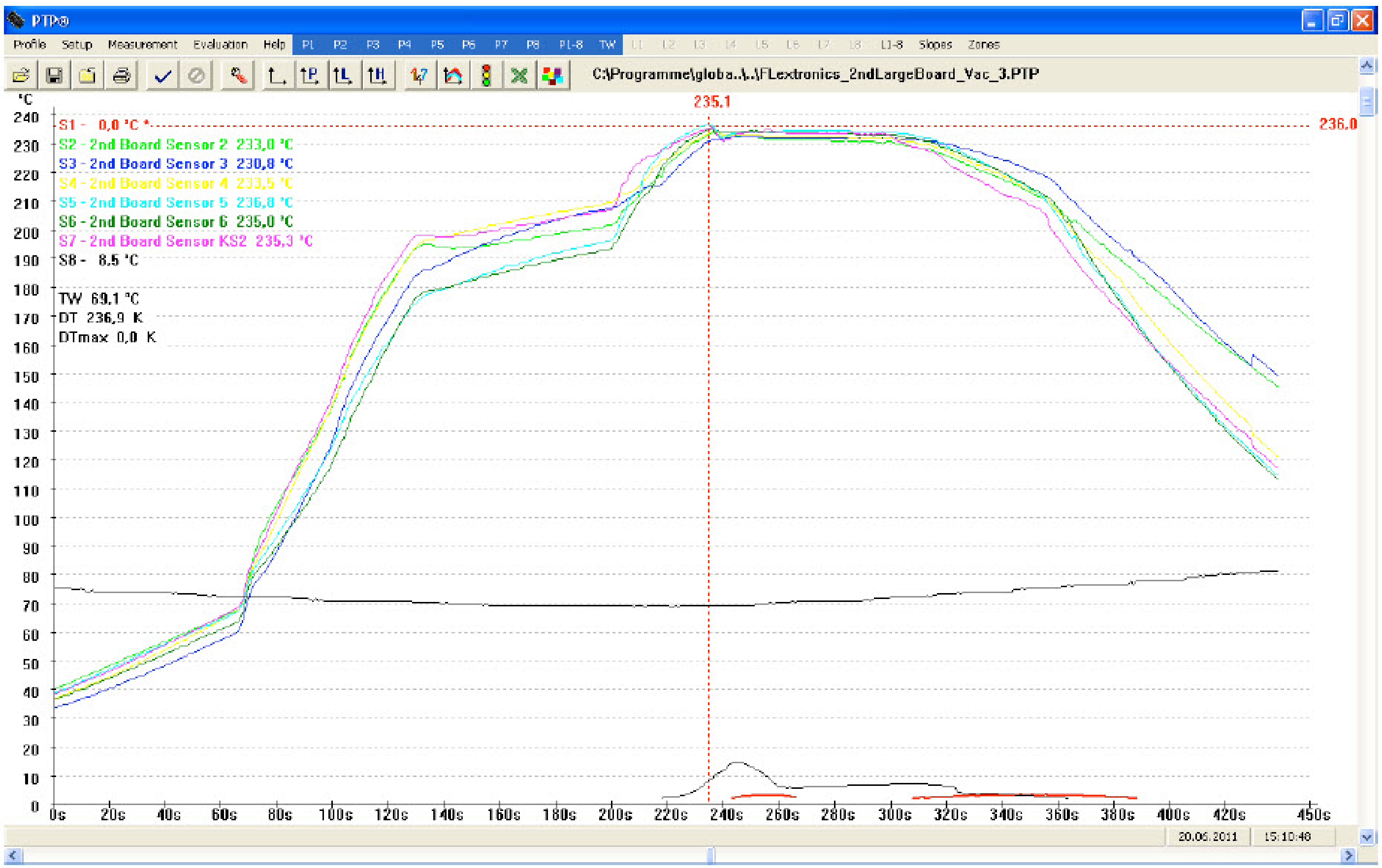




VOID REMOVAL

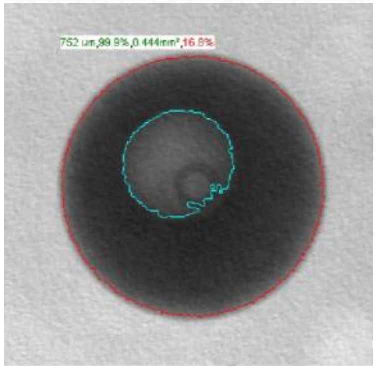
Vapor Phase Details

Machine was batch with Galden 235 liquid
Vacuum pressure = 20 mbar
Vacuum duration = 15 sec

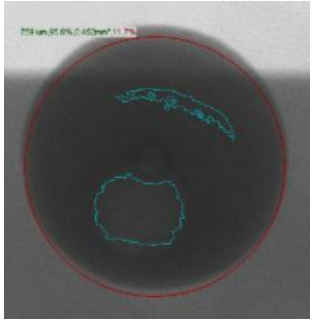


Void Removal

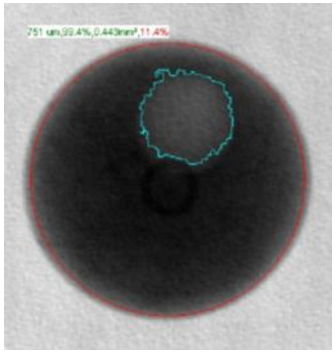
Before Reflow
Void % = 16.80%



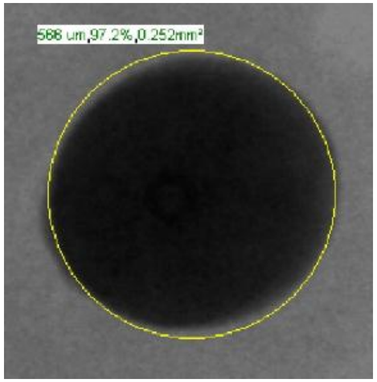
Before Reflow
Void % = 11.74%



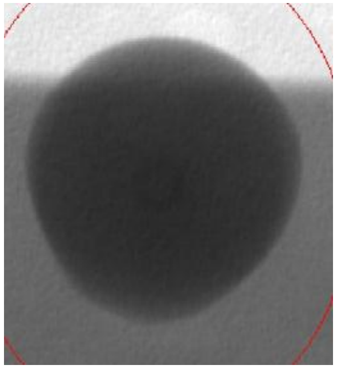
Before Reflow
Void % = 11.40%



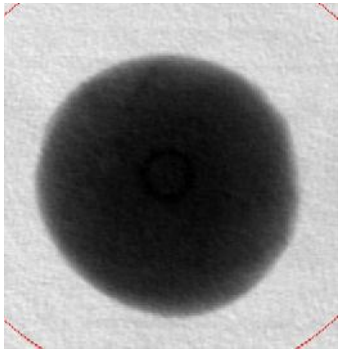
Vapor Phase w/ Vacuum



Vapor Phase w/ Vacuum



Vapor Phase w/ Vacuum



- Voids reduced / removed using vapor phase reflow of a dead-bug component under vacuum
- Void reduction / removal causes minor deformation of ball diameter

CONCLUSIONS

Technology Comparison

	2D X-ray	3D AXI	CT Scan	Cross-Section
Image Resolution	3	4	2	1
Preparation Time	1	2	3	4
Automation	2	1	3	4
Measurement Accuracy	3	4	2	1
Slice Qty & Position	4	2	1	3
Analysis Time	2	1	3	4
Void Location	4	3	1	2

1 = Best   4 = Worst

Final Thoughts

- 3D AXI is necessary to screen out significant quantities of components as data points, prior to further characterization
- Combination of available void detection technologies are needed for complete characterization of process and components, especially for increased complexity (i.e. via in pad, finer pitch, etc,,,)
- PCB and Component Design, Reflow profile parameters as well as chemistry can all affect growth and positioning of voids
- High Resolution CT Imaging allows for a complete analysis of components before and after assembly in non-destructive manner
- While IPC 7095B introduced tables for void process indicators and troubleshooting and JEDEC Std 217 has a guideline for component voids allowed (pre-reflow), a clear joint industry specification needs to be considered to create better linkage between component manufacturing and PCB Assembly & Inspection

Acknowledgements

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THANK YOU