iNEMI

International Electronics Manufacturing Initiative

Pb-Free BGAs in SnPB Assemblies Project

Project Chair: Robert Kinyanjui, Ph.D. Sanmina-SCI Corporation

Project Co-Chair: Quyen Chu, Jabil

Celestica-iNEMI Technology Forum
May 15, 2007

Advancing manufacturing technology

Project Formation

Drivers

- **Chairs (Jerry G. - HP and Charlie R. - IBM) and sub project team leaders (Jasbir B. – Solectron, Matt K. – Celestica and Quyen C. – Jabil) from the Lead-Free Assembly & Rework Project identified a need to address backward compatibility as project was near completion**

- **2004 Roadmap identified a gap for process solution of Pb-free BGA in a SnPb process**

- **In November 2004, the backward compatibility project was launched….**

Project Scope

- **For companies choosing to take the RoHS exemption and continue to manufacture SnPb products beyond July 1, 2006, there is a growing issue with the lack of availability of SnPb components. Many companies may be compelled to use Pb-free BGAs in a SnPb process, for which the process and reliability have not yet been characterized.**

Objectives

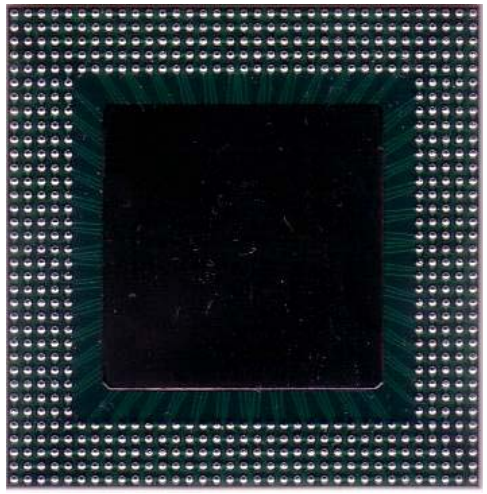
- **Phase 1**
  - **To assess the process parameters for assembling Pb-free SnAgCu BGAs under the temperature constraints of a conventional tin-lead (SnPb) assembly process.**
- **Phase 2**
  - **Characterize homogeneity of Pb-free BGAs in a SnPb process with the following considerations:**
    - **Package size/ball volume**
    - **Reflow temperature**
    - **Time above liquidus**
    - **Solder paste volume**
  - **Examine the thermal and mechanical reliability of Pb-free BGAs in SnPb process**
- **Phase 3**
  - **To develop a "generic" process guideline and risk assessment for assembling Pb-free BGAs in a SnPb assembly process.**

Components Consideration

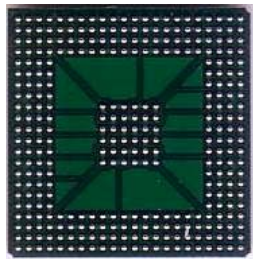
Component Part Numbers	I/O	Pitch (mm)	Size (mm)	Ball Alignment	Quantity per Board
A-SBGA600-1.27mm-45mm	600	1.27	45	Perimeter	3
A-PBGA324-1.0mm-23mm	324	1.00	23	Perimeter	3
A-CABGA288 0.8mm-19mm	288	0.8	19	Array	3
A-CTBGA132-0.5mm-8mm	132	0.5	8	Perimeter	3

Pb-free BGA ball alloy: SAC405

Note:
- SnPb components of each type were used for baseline run.



1.27mm
SBGA600



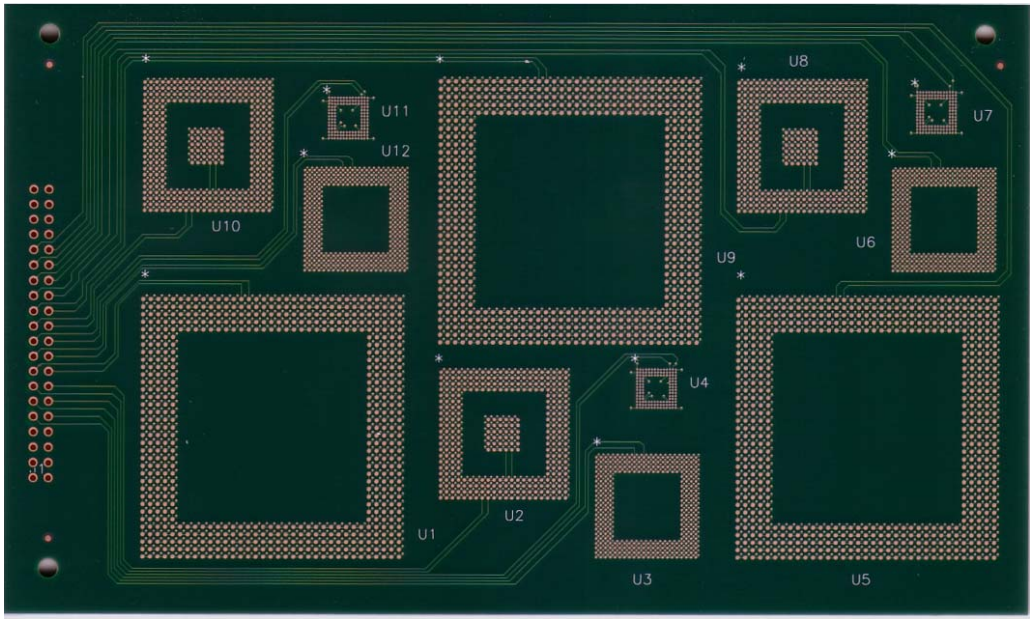
1.0mm
PBGA324

0.8mm
CABGA

0.5mm
CTBGA132

PCB Laminate

- **PCB Dimensions:**
  - –6.800” x 4.075” x 0.093”
- **Finish**
  - –Electroless Nickel Immersion Gold (ENiG)
  - –Copper OSP
- **Number of Layers**
  - –18 Internal board Layers
  - –12 Ground [1 oz.] Layers,
  - –6 Signal Layers
- **Tg = 170ºC**
- **Td = 340ºC**



Bare Test Board

Assembly Consideration

- **Assembly Set-up**
  - **Two thermocouples were placed at the center and corner joints of each component type on a sample test board**
  - **Five profiles were generated**
    - **Peak Temp: 210C, 215, and 235C**
    - **Time Above Liquidus (TAL): 60, 90, 120sec**
- **Stencil**
  - **6 mil foil thick**
  - **Two aperture openings (1:1 and 10% reduction)**
    - **For the 0.5mm pitch component, the same aperture opening was used for better paste release**

Summary of Assembly Matrix

Assembly Process Flow	BGA Ball/ Solder Paste Alloy	Tpeak (°C)	TAL (sec)	Paste Volume (Stencil Opening/Pad ratio)	# of Boards for Initial Test (Dye & Pry and metallography)		# of Boards for Reliability Test				Total # of Boards Built	
							ATC Test (-40 to 125°C)		Mechanical Test (Drop test)			
					ENiG	OSP	ENiG	OSP	ENiG	OSP	ENiG	OSP
1	SnPb/SnPb	210	60	10% Reduction	0	2	3	6	0	5	3	13
2	SAC/SnPb	210	60	10% Reduction	0	2	0	6	0	5	0	13
5				1:1	0	2	3	6	0	5	3	13
3			90	10% Reduction	0	2	0	6	0	5	0	13
6				1:1	0	2	0	6	0	5	0	13
4			120	10% Reduction	1	2	3	6	0	5	4	13
7	SAC/SAC	235	60	10% Reduction	0	2	0	6	0	5	0	13
8	SAC/SnPb	215	60	1:1	0	1	0	3	0	3	0	7
# of boards built					1	15	9	45	0	38	10	98

Representative Reflow Profile

TCs	Max Rising Slope		Soak Time 150-180C		Reflow Time M83C		Peak Temp		Tot Time M83C	
U5 Inner	1.9	-7%	88.7	-25%	62.2	44%	205.0	-100%	62.2	44%
U3 Inner	1.9	-6%	87.3	-54%	63.0	61%	208.8	51%	63.0	61%
U3 Outer	1.9	-3%	91.5	30%	66.0	119%	212.2	189%	66.0	119%
U4 Inner	1.9	-6%	86.8	-65%	60.9	18%	213.2	229%	60.9	18%
U4 Outer	1.9	-3%	86.0	-80%	66.4	127%	210.6	122%	66.4	127%
U2 Outer	1.9	-5%	86.9	-62%	65.7	114%	209.3	71%	65.7	114%
U5 Outer	1.9	-5%	86.1	-78%	68.0	160%	207.5	0%	68.0	160%

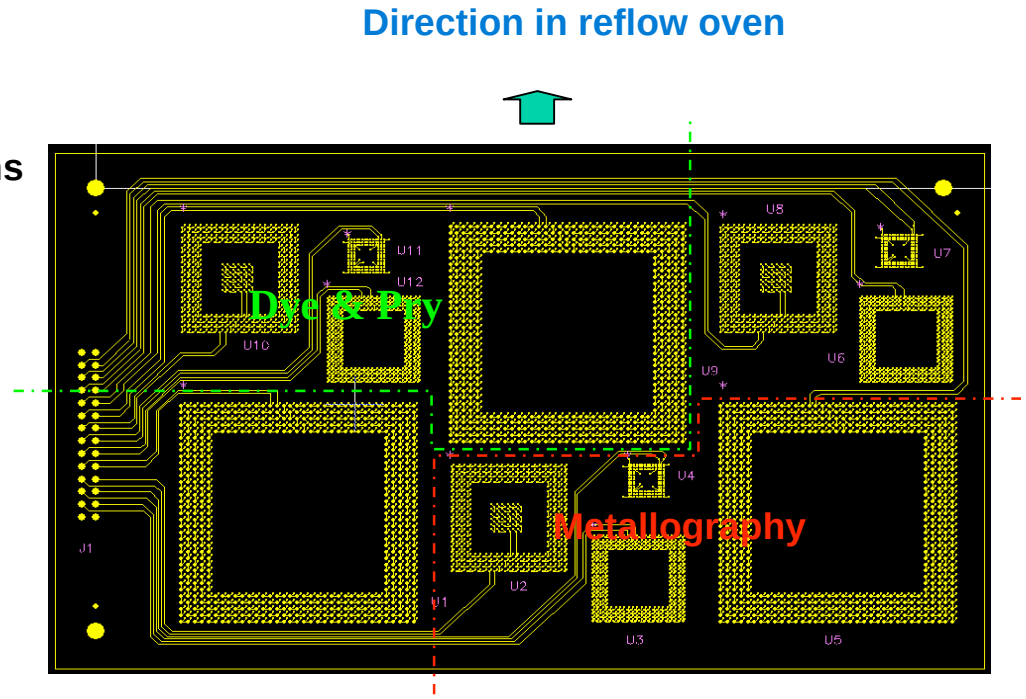
Reflow Profile Conditions: Peak Temp. = 210^{o}C; TAL = 60sec

Assembled Test Board

Reflow Profile Conditions = Peak Temp. = 210°C; TAL = 60sec

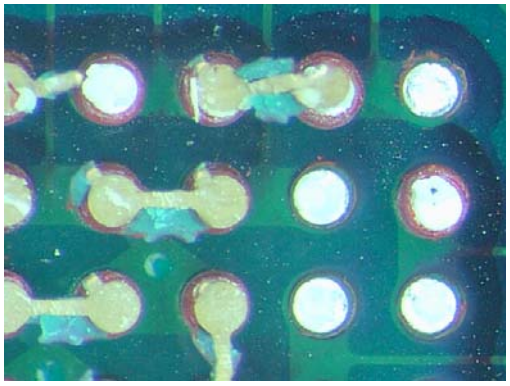
Initial PCBA Analysis

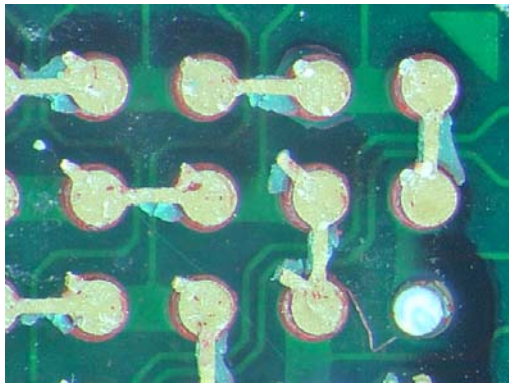
- **Analysis of as-reflowed BGA solder joints integrity through dye & pry and metallography**
  - **One board from each of the conditions was subjected to dye & pry followed by metallographic analysis:**
    - **Determine the solder joint structure**
    - **Examine the degree of mixing between SnPb and Sn-Ag-Cu solder alloys**
    - **Characterize the solder joint height/diameter**



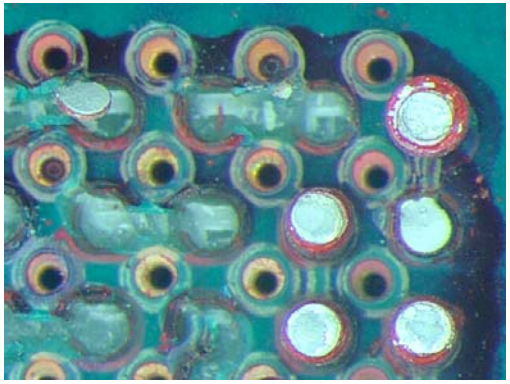
Representative Dye & Pry Results

Package Side

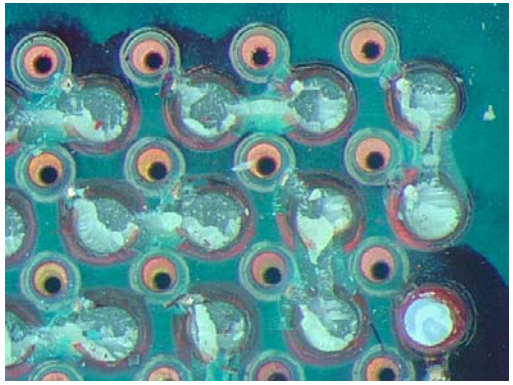




PCB Side



0.8mm
CABGA288

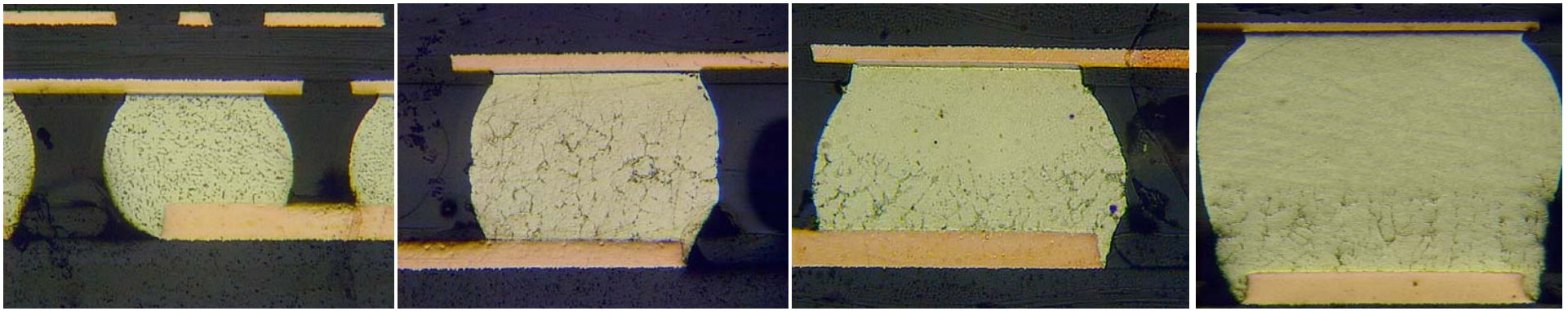


1.0mm
PBGA324

- No dye intrusion was observed → no signs of open joints

Effect of Package Size on the Solder Joint Microstructural Homogeneity @ Tpeak = 210C & TAL = 60 secs

Increasing Package Size →

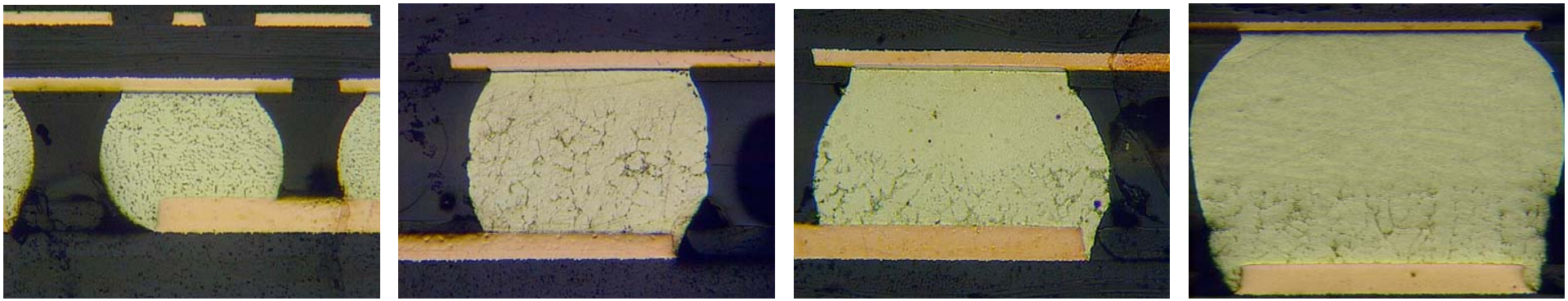


0.5mm CTBGA132	0.8mm CABGA288	1.0mm PBGA324	1.27mm SBGA600

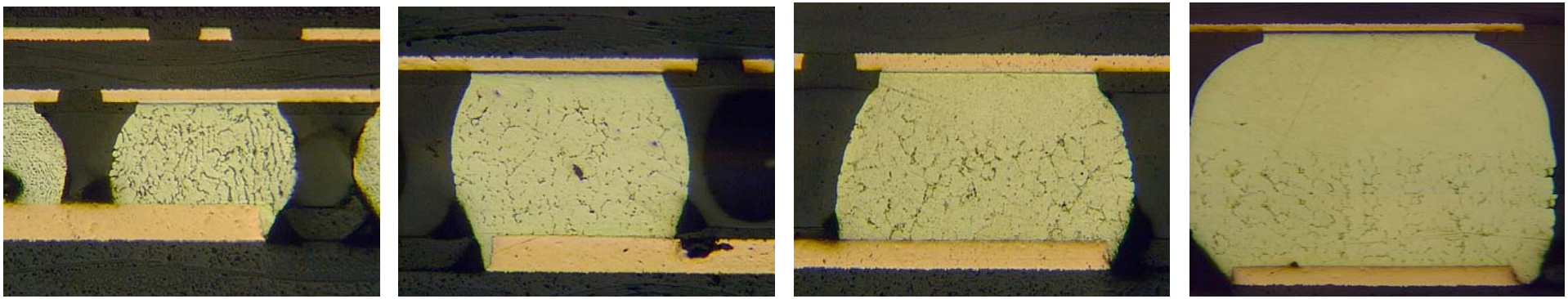
- The degree of mixing decreases with increasing package (or solder ball volume) size.

Effect of Time Above Liquidus @ Tpeak = 210C

TAL: 60sec



TAL: 120sec

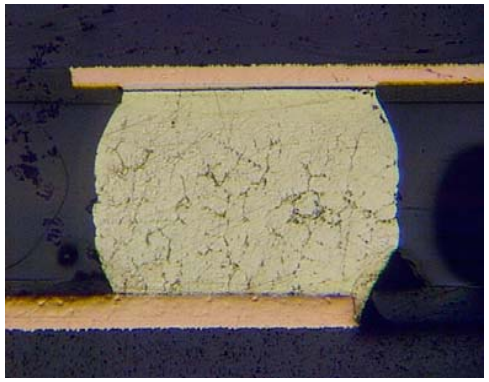


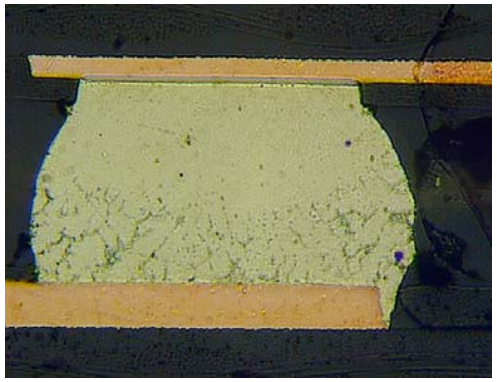
0.5mm CTBGA132	0.8mm CABGA288	1.0mm PBGA324	1.27mm SBGA600

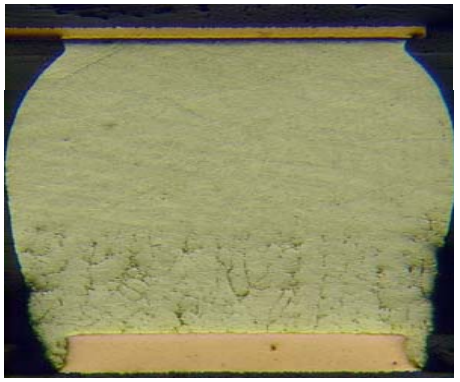
- **Doubling the time above liquidus leads to significant increase in the degree of mixing.**

Effect of Paste Volume @ 210C/60sec on Degree of Mixing

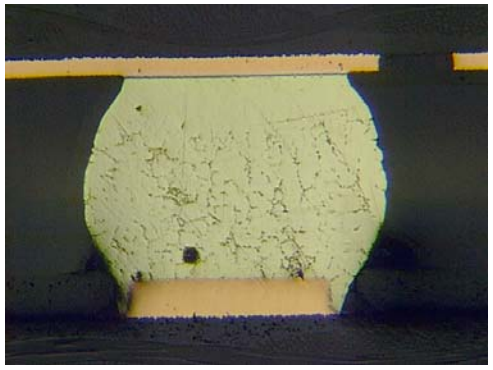
10% Paste Reduction



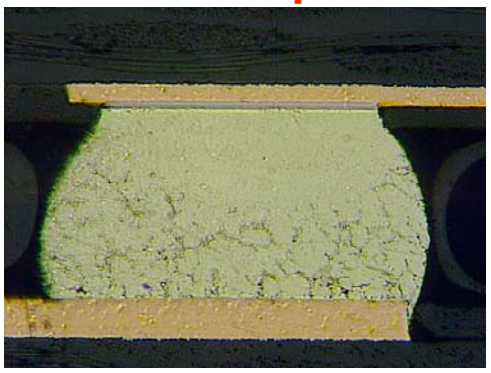




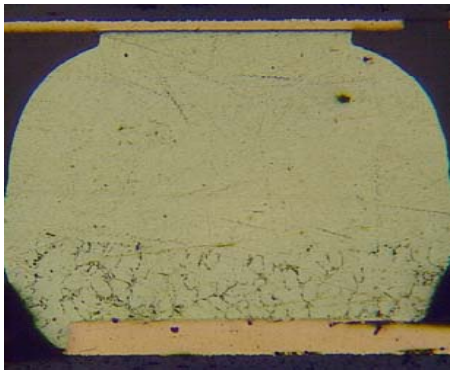
1:1 Paste Aperture



0.8mm
CABGA288



1.0mm
PBGA324

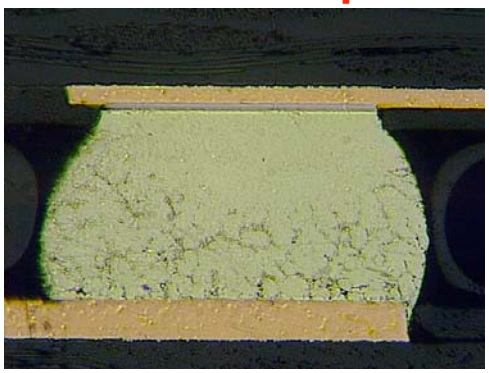


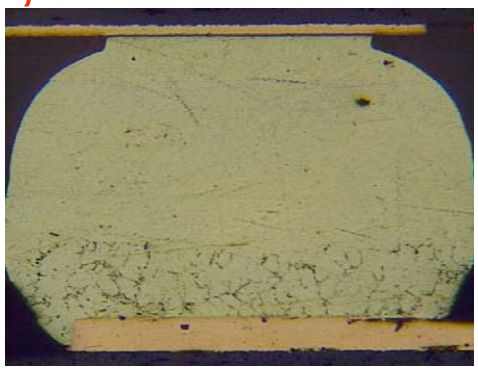
1.27mm
SBGA600

- Little or no discernable difference is observed in the degree of mixing.

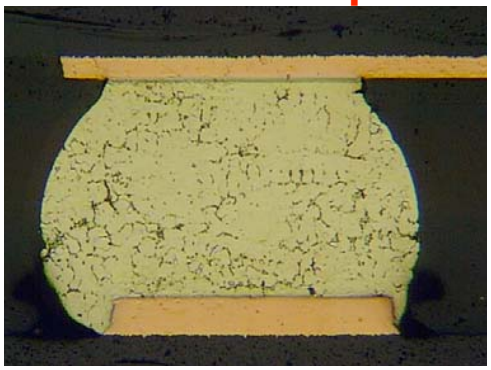
Effect of Peak Temperature on Degree of Mixing

Tpeak = 210C, TAL = 60sec

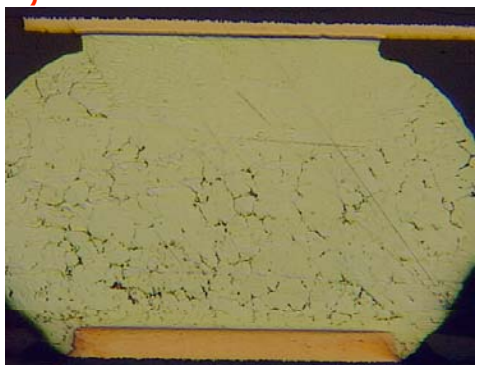




Tpeak = 215C, TAL = 60sec



1.0mm PBGA324



1.27mm SBGA600

- Increasing the peak temperature by 5°C with TAL = 60 sec, leads to an increased degree of mixing for both PBGA324 and SBGA600.

Summary of Observations

- **The larger the package/ball volume, the lower the degree of mixing observed.**
  - **CTBGA132 (0.5mm Pitch) showed a 100% mixing at 210oC and 60sec time above liquidus**
- **Doubling the time above liquidus (from 60sec to 120sec), increased the degree of mixing (~30% increase in mixing was observed).**
- **For the small packages (reduced SAC solder ball volume), increased paste volume corresponds to increased degree of mixing.**
  - **However, for the largest (SBGA600) package no significant change in mixing was observed.**
- **Increasing the peak temperature from 210°C to 215°C led to a significant increase in the degree of mixing (almost doubled) the extent of mixing.**

Project Status

- **Phase 1: Completed and report presented at APEX 2006**
- **Phase 2:**
  - **ATC: -40 to 125°C (currently @ ~ 2800 cycles) testing**
    - **Failure analysis is in progress**
  - **Mechanical test (Drop Test) is in progress**
- **Phase 3:**
  - **"A Mixed Soldering Guidelines Document" will be released as part of the final project report**

Phase 2 Project Timeline

Activities/Ownership

Reliability Test: (Thermal test) **Project Members**

Sourcing of Components: **Project Members**

Laminates: **Tyco Electronics**

Assembly Service: **Jabil Circuit Inc.**

Mechanical testing (Drop test): **Henkel Technologies**

Failure Analysis (75 X-sections) Optical & Electron Microscopy work) **Celestica**

Activity cleared to go

Yet to confirm start date

1.5 Months	1 Month	2 Months	4 Months	2 Months	2 Month
Comp. & PCB Procurement	Assembly	Preliminary Analysis	Reliability Testing	Failure Analysis	Final Report Write-up
BGA Components High Td and Tg PCB Laminate	Single Sided SMT Assembly	Optical Analysis X-ray Analysis Dye and Pry Cross-Section Analysis	ATC:-40<->125°C for 3000 cycles Mechanical test: Drop Test	Dye and Pry Cross-Section Analysis Metallographic Analysis	Word Doc Presentation
Closed	Closed	Closed	In-Progress	In-Progress	

August 15, 2006 — **Nov 1, 2007**

Project Participants

Agilent Technologies

Cookson

NIST

Alcatel·Lucent

PLEXUS®

CELESTICA

IBM

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CISCO

JABIL

SOLECTRON®

iNEMI