Low/No Silver Alloy Solder Paste

Definition Stage : Phase 1
Process Feasibility Study

Project Leader: Jennifer Nguyen, Flextronics

Project Facilitator: John Davignon

HDP User Group Member Meeting

Feb 26, 2014

Project Background

- Price of the metals and particularly silver (Ag) has been increasing in recent years. This has created an increased interest in the use of low/no silver alloy in the manufacturing processes.
- Low silver alloys (such as SAC105) for the BGA solder balls are being used in products.
- Within the past couple years, many alternative low/no silver alloy solder pastes have been developed and are available in the market.

© 2013 HDP User Group International, Inc. All rights reserved

Project Drivers/Gaps

- A need to reduce the assembly cost for some products
- A need to expand the process window by lowering the process temperature
- There is very little information about the alternative (low/no) alloy solder paste, its process feasibility and reliability. (Reliability studies have been done for the alternative low/no silver alloys solder balls).
- There are no other industry projects that we are aware of on low/no silver alloy solder paste.

© 2013 HDP User Group International, Inc. All rights reserved

Purpose of Project

- Provide data on the process feasibility and reliability of Low Ag Alloys solderpaste for <u>some market segments.</u>
- <u>Low Ag/High Temp Alloys could provide a lower cost assembly/product</u>
- Low Ag/Low Temp Alloys could provide:
  - Less Thermal Stress on PCBA's with large BGA's
  - Lower Peak Temperatures and therefore potentially lower PCB/component warpage
  - Lower Environmental impact, Lower Energy Use therefore Lower Carbon Footprint

© 2013 HDP User Group International, Inc. All rights reserved

Scope

- This project will characterize the process feasibility and measure the reliability of low/no silver alloy solder pastes including
  - Low/no silver high temperature alloy solder pastes (liquidus temperature >217°C)
  - Low/no silver low temperature alloy solder pastes. (liquidus temperature <217°C)
- This project <u>will not</u> focus on low/no silver alloy composition or material evaluation nor recommend a low/no silver alloy solder paste.

© 2013 HDP User Group International, Inc. All rights reserved

Project Objectives

- Complete a process feasibility characterization on Low Ag Alloy Solderpaste
  - Design/run a DOE for both high and low temp alloys
  - Analyze the microstructure and morphology
  - Publish the results of the Process Feasibility evaluation.
- Complete a reliability evaluation on Low Ag Alloy Solderpaste and compare the data with SAC305
  - Design/run a DOE for both high and low temp alloys
  - Thermal/Mechanical stress the solder joints and compare to baseline
  - Publish the results of the Reliability evaluation

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ Deliverables

- Publish the Process Window for Low Ag Alloys Solderpaste
- Publish the results of Low Ag Alloys Solderpaste evaluation, including :
  - Printability
  - Wettability
  - Voiding Behavior
  - Bridging
  - Common Defects
- The HDP Membership will receive the complete un-coded alloy results
- The team will publish a coded version of the results in a paper/presentation at several major conferences (SMTA/IPC) to help encourage the industry to accept alternative alloys solderpaste

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ Benefits and Impacts

- Low Ag / High Temperature Alloys can enable a more cost effective product though the reduction of silver usage. (*This will benefit both CMS/EMS and OEM/ODM's*)

- Low Ag / Low Temperature Alloys can extend the temperature headroom for assembly. We are running out of temperature headroom with Pb Free especially for large components. (*This will benefit the CMS/EMS and component suppliers*)

- Low Ag / Low Temperature Alloys can provide a more flexible product, example; Hand Soldering can be done at lower temperatures and lower rework damage. (*This will benefit CMS/EMS*)

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ Benefits and Impacts

- Low Ag / Low Temperature Alloys can improve reliability of the final product by lowering thermal stress and warpage on the components/PBCA. (*This will benefit OEM and OEM Customers*)

- Low Ag / Low Temperature Alloys are more Environmentally Friendly. They lower ground pollution, lower energy consumption by lower processing temperature. (*This will benefit the Global Population and reduce the carbon footprint of products for the OEM*).

- The wider acceptance of Low Ag Alloy will open markets for our Alloy Material Suppliers. (*This will benefit the Alloy Suppliers*)

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ Execution Plan

Tasks	Plan
•Project Planning	Q3/2013
•DOE Define	Q4/2013
•Material Selection	Q4/2013
•Material Procurement	Q2/2014
•Test Vehicle	
• Components	
•DOE1 Assembly	Q4/2014
•DOE 2 Assembly	Q4/2014
•Failure Analysis	Q1/2015
•Report	Q2/2015
•Phase 2 Reliability	Q1/2015

© 2013 HDP User Group International, Inc. All rights reserved

Technical Discussion

Phase 1_ Variables

- Alloy composition (see candidate list)
  - Low Ag High Melting Temperature
  - Low Ag Low Melting Temperature
- Reflow temperature
  - Low/Medium/Hot (profiles will depend on the alloy liquidus temperature).
  - N2 vs. Air
- Component type
  - BGAs, QFNs, chip components, PTHs
- Board surface finish
  - OSP
  - ENIG, I-Ag (will be tested with only 1 reflow condition for all alternative solder pastes)

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ Candidates

1. Low Silver High Temperature Alloy Candidates

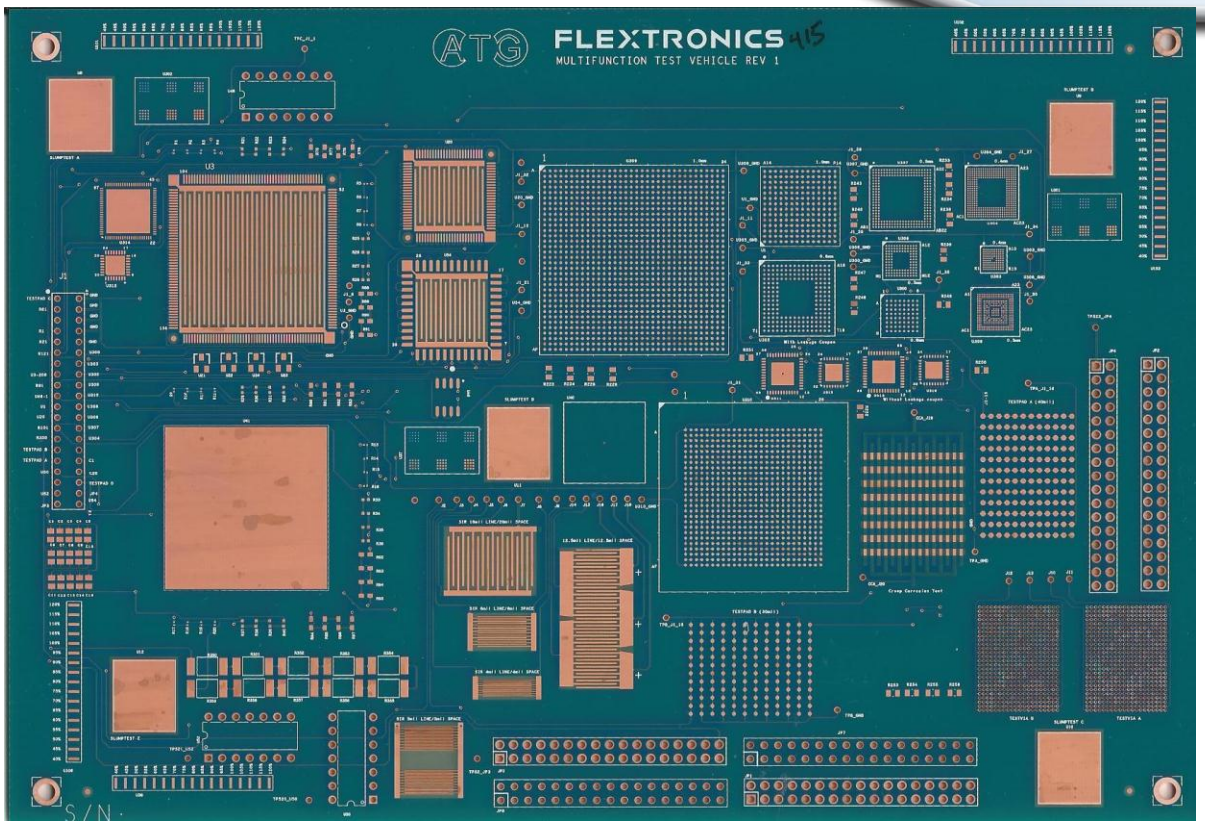
No	Alloy Name	Alloy Composition	Supplier	Liquidus Temp (° C)
1	SAC305	Sn3.0%Ag0.5%Cu	Indium	217
2	SAC105	Sn1.0%Ag0.5%Cu	Senju	225
3	SAC0807	Sn0.8%Ag0.7%Cu	Indium	227
4	SAC0307	Sn0.3%Ag0.7%Cu	Senju	227
5	SN100C	SnCuNi	Nihon Superior	227
6	SACM	98.5Sn0.5Ag1Cu,	Indium	226
7	SACX0307	Sn0.3%Ag0.7%Cu + Bi,Sb,etc...	Alpha	227
8	SAC107+	Sn1%Ag0.7%Cu+Bi+In+Sb	Senju	225
9	SN99CN	Sn1.1%Ag0.7%Cu+Ni+Ga	Nihon Superior	225

2. Low Silver Low Temperature Alloy Candidates

No	Alloy Composistion	Alloy Composition	Supplier	Liquidus Temp (° C)
1	SnBi	Sn42/Bi58	Any	138
2	SnAgBi	Sn42/Bi57/Ag1	Any	138
3	SnAgBi	Sn42/Bi57.6/Ag0.4	Alpha	138
4	SnAgCuBi	Sn2.25%Ag0.5%Cu6.0 %Bi	Indium	205
5	SnAgCuBi	Sn1%Ag0.7%Cu7Bi	Indium	199
6	SnAgCuBi	Sn2%Ag0.75%Cu3%Bi	Indium	207
7	SnCuBi	Sn0.7%Cu7%Bi	Indium	209
8	SnBiCuNi	Sn42/Bi40/Cu/Ni	Senju	174

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1 _ Test Vehicle



- Flextronics Multifunction Test Vehicle, Rev 1.0
- Board Dimension: 225mm x 150mm x 1.67mm
- Board S.F = OSP, I-Ag, ENIG

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1 _ Components

No.	Description	Designator	Qty	MPN	Mfr
1	Resistors,0201, lead-free, 0 ohm	R1-R20	20	TBD	TBD
2	Resistors, 0603, lead-free, 0 ohm	R61-R100	40	TBD	TBD
3	Resistors, 2512, lead-free, 0 ohm	R350-R359	10	TBD	TBD
4	BGA196 pin, 1.0mm pitch	U1	1	A- CABGA196-1.0mm-15mm-DC-LF305	Practical Components
5	QFP208, 28x28mm, 0.5 mm pitch	U3	1	A-QFP208-28mm-.5mm-2.6-DC-Sn	Practical Components
6	BGA,1156 pins,35x35mm, 1mm pitch, LF	U309	1	A-PBGA1156-1.0mm-35-DC-LF-305	Practical Components
7	BGA,676 pins,27x27mm, 1mm pitch, LF	U310	1	A-PBGA676-1.0mm-27-DC-LF-305	Practical Components
8	QFN, 88 pins, 10x10mm, .4mm, LF	U314	1	A-MLF88-10mm-.4mm-DC-Sn	Practical Components
9	BGA,360 pins,5x5mm, 0.4mm pitch, LF	U304	1	A-CVBGA360-.4mm-10mm-DC-LF-305	Practical Components

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ DOE 1 Matrix

DOE 1 tests different solder paste materials and reflow temperature conditions

Low Ag / High Temperature

- Factor (level)
  - Paste type (9)
  - Reflow Condition (3)
- Board qty: 9 boards/ alloy
- Total qty = 9 boards x 9 alloys = 81 boards
- Reflow condition: Air

Low Ag / Low Temperature

- Factor (level)
  - Paste type (9)
  - Reflow Condition (3)
- Board qty = 9 boards/ alloy
- Total qty: 9 boards x (8 alloys + 1 control)= 81 boards
- Reflow condition: Air

Total Quantity for DOE 1 = 81+81= 162 boards

© 2013 HDP User Group International, Inc. All rights reserved

Phase 1_ DOE 2 Matrix

DOE 2 tests for different board surface finish and reflow atmosphere

Board Surface Finish (1 reflow condition)

- OSP (from DOE1)
- I-Ag
- ENIG
- 3 boards / alloy
- High Temp Qty = 3 boards x 9 alloys x 2 S.Fs = 54 boards
- Low Temp Qty = 3 boards x 8 alloys x 2 S.Fs = 48 boards

Reflow Atmosphere (1 reflow condition)

- Air (from DOE 1)
- N2
- High Temp Qty = 3 boards x 9 alloys x 1 add. Reflow (N2) = 27 boards
- Low Temp Qty = 3 boards x 8 alloys x1 add. Reflow (N2)= 24 boards

Total Qty for DOE 2: 54+48+ 27+24=153 boards

© 2013 HDP User Group International, Inc. All rights reserved

Resources Needed/Committed

Task	Resource	Complete Date	
Solder Materials for DOE's	Indium, Tim Jensen Senju, Derek Daily Nihon Superior, Keith Howell	Q2"14	
Component Acquisition	Juniper, Helen Turner	Q1"14	
Test Vehicle Design/Files	Flextronics, Jennifer Nguyen	Q1"14	
Test Vehicle Fabrication	Chris Katzko, TTM	Q2'14	
Assembly Low Temperature DOE1 DOE2	Thilo Sack /Simin Bagheri, Celestica	Q4"14	
Assembly High Temperature DOE1 DOE2	Flextronics, Jennifer Nguyen Sanmina, Iulia Muntele	Q4"14	
Cross Section & Failure Analysis	Alcatel Lucent, Richard Coyle Nihon Superior, Keith Howell	Q1"15	
Report Writing/Correlation	Flextronics, Jennifer Nguyen Team inputs	Q2"15	

© 2013 HDP User Group International, Inc. All rights reserved

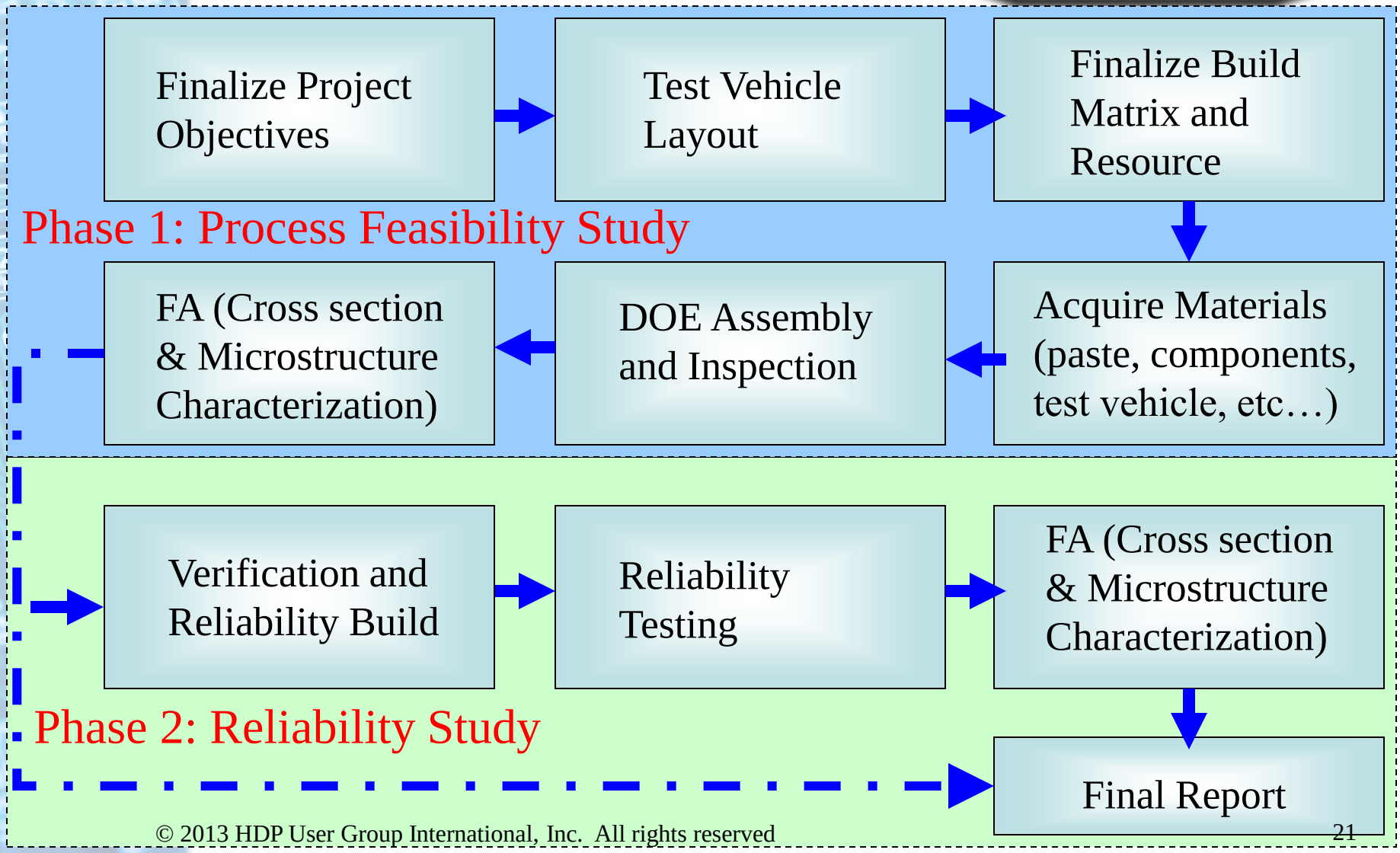
Project Definition Participants

- Jennifer Nguyen, Flextronics (Project Lead)
- Richard Coyle, Alcatel-Lucent
- Joe Smetana, Alcatel-Lucent
- Karl Seelig, AIM Solder
- Alan Dolan, AIM Solder
- Thilo Sack, Celestica
- Simin Bagheri, Celestica
- Brice Achkir, Cisco
- Steven Perng, Cisco
- Sean Mirshafiei, Cookson
- Bo Song, Draeger
- Igor Perez-Uria, Ericsson
- Al Ortiz, Ericsson
- David Geiger, Flextronics
- Shunichi Kikuchi, Fujitsu
- John Davignon, HDPUG
- Marshall Andrews, HDPUG
- Marie Cole, IBM
- Tim Jensen, Indium
- Ning-Cheng Lee, Indium
- Weiping Liu, Indium
- Arnab Dasgupta, Indium
- Andy Mackie, Indium
- Raiyo Aspandiar, Intel
- Jeffrey Lee, ISTgroup
- Helen Turner, Juniper Networks
- Po Tse, Phillips
- Mark Kolenik, Philips
- Manas Dash, Philips
- Kirk VanDreel, Plexus
- Mulugeta Abtew, Sanmina
- Iulia Muntele, Sanmina
- Derek Daily,Senju
- Keith Howell, Nihon Superior
- Jim Wilcox

© 2013 HDP User Group International, Inc. All rights reserved

Back-up Slides

Project Flow Chart

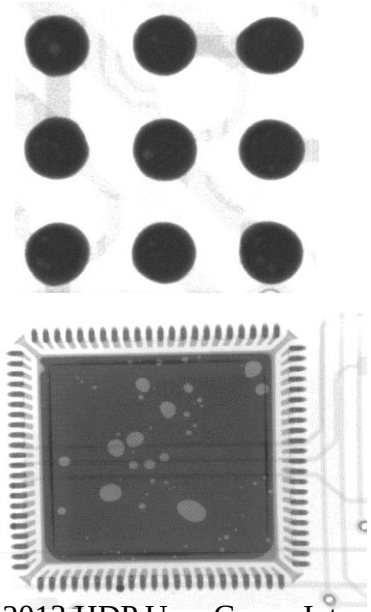


© 2013 HDP User Group International, Inc. All rights reserved

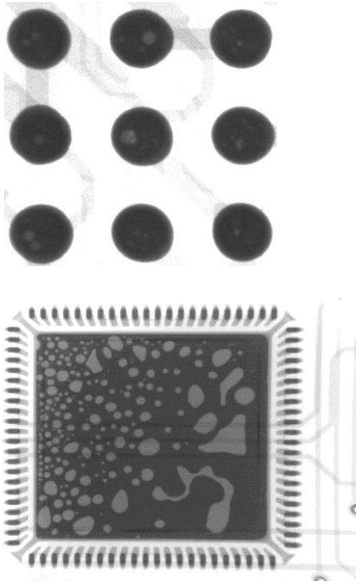
Challenges

- Low/no silver alloy solder pastes may result in more defects such as solder balling, voiding (especially on QFN components) and solder bridging, etc... However, data is very limited.

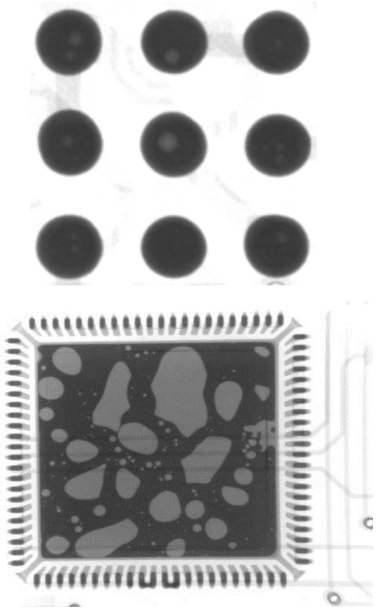
SAC305



SAC0307



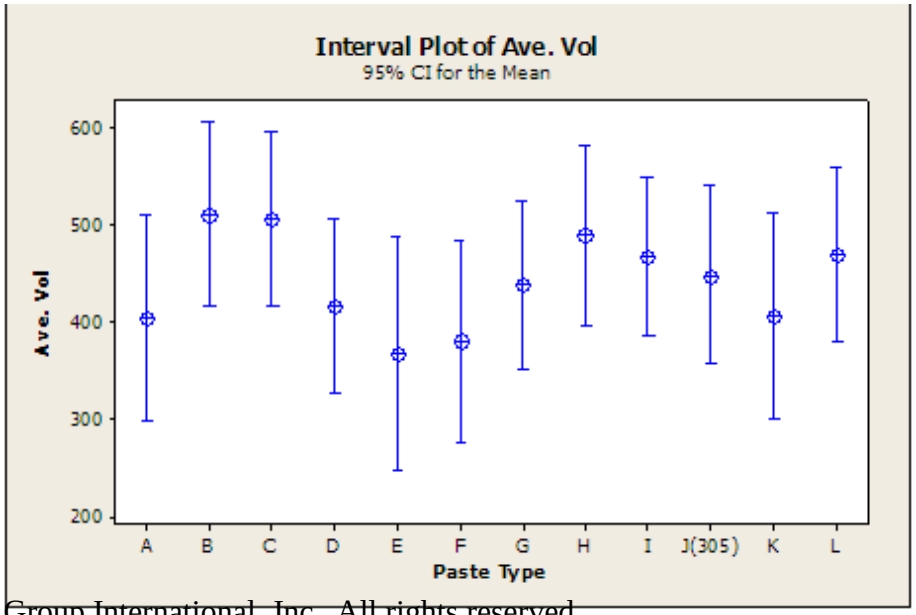
SN100C



© 2013 HDP User Group International, Inc. All rights reserved

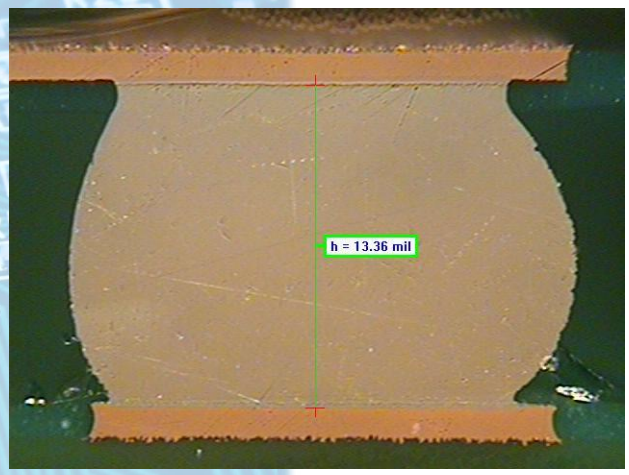
Process Feasibility

- Some low/no silver alloys can have the good printability and wetting characteristics.
- It's feasible that alternative alloy solder paste can be used for some products.

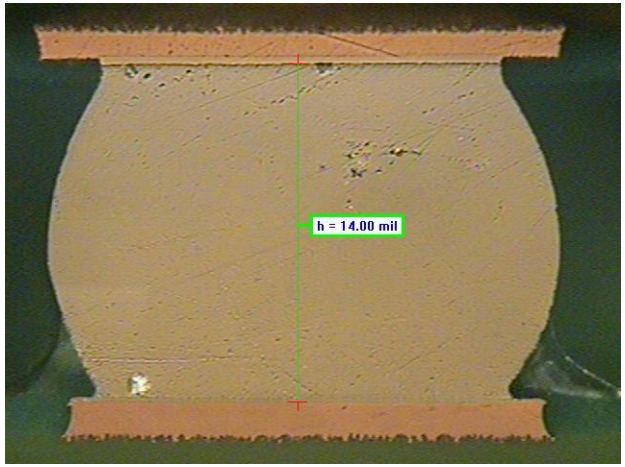


© 2013 HDP User Group International, Inc. All rights reserved

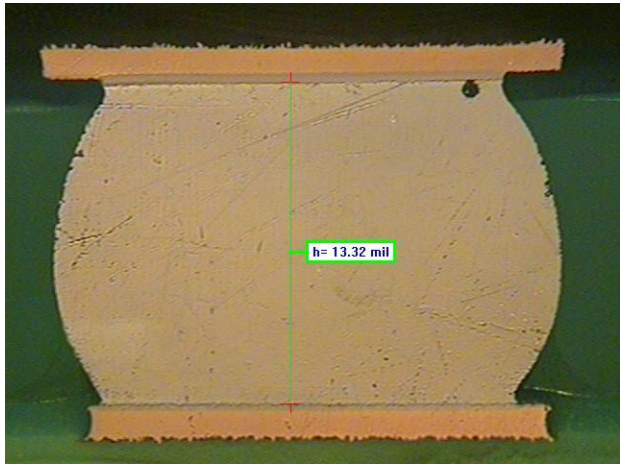
Process Feasibility



SAC305



SAC0307



SN100C

- No abnormality was seen on the BGA solder joint reflowed with alternative alloy solder pastes.

© 2013 HDP User Group International, Inc. All rights reserved