Bridging Supply Chain Gap for Exempt High-Reliability OEM's

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RoHS exempt high reliability OEMs breathed a sign of relief for not having to go through the grind of revising their processes and material to be RoHS compliant. However, this was short lived because of supply chain disconnects in the availability of non-RoHS devices. Consumption, in terms of unit volume for Sn/Pb, is small compared to the volume going into the builds of Pb free consumer and commercial product. Many device manufacturers are discontinuing the Sn/Pb option on many part numbers (P/N) when unit volumes fall below a certain threshold.

Bills of materials are being transitioned to obsolete and legacy parts outside the control of the OEMs and at a rapid pace. The life cycle for a military product generally takes over two years for the design and initial deployment, followed by a production life cycle of over 10 years and a repair/warranty cycle of 20 plus years. A redesign to include an alternate part number is no easy task due to redesign review, validation and reliability testing.

In addition, exempt OEMs are exposed to other problems caused by some manufacturers not changing P/Ns once the Sn/Pb is obsolete. The end result too often is mixed reels of RoHS and non-RoHS product. Unfortunately, exempt OEMs are many times left with only one choice and that is Pb-free components. This is clearly not optimal due to some of the reliability concerns associated with Pb-free components. Reflow profiles, thermal stress, MSL, tin whiskers, tin pests, brittleness, voids and thermal mismatch are some of the reliability problems that can't be ignored and can't be managed in the absence of the specific Sn/Pb component.

Test Plan of various Pb free Alloy Compositions

- Perform a limited sample size thermal cycle "screening" test covering different alloys
- Use existing test board design and component (Acceleration Factors Test)
- Single thermal cycle (0-100C, 30 minute dwell
- Single soldering alloy: SAC 305

Pb free Alloy Selection

Packages of 9 different solder alloys were received

- SAC405
- SnAg
- Sn100C
- Sn1.2Ag0.5Cu0.005Ni
- SAC205+Ni
- SAC310 +1%Cu
- SAC105
- SAC108
- SACX

Each Alloy came into 2 different groups

1) Fully populated components
2) Depopulated components

Test Results

Alloy & Pkg Configuration	PCT Fails	Test Status (893 cycles)
SAC405F	56%	
SAC405D	0%	
SnAgF	6%	
SnAgD	25%	
Sn100CF	31%	
Sn100CD	100%	removed from chamber
LF35F	44%	
LF35D	88%	removed from chamber
SAC205NF,	19%	
SAC205ND	88%	removed from chamber
SAC310F	50%	
SAC310D	100%	removed from chamber
SAC105F	19%	
SAC105D	88%	removed from chamber
SAC108F	63%	
SAC108D	88%	removed from chamber
SACXF	81%	removed from chamber
SACXD	100%	removed from chamber

Test concluded a high PCT fail which resulted in removal of test samples & test termination.

Alternative to Pb Free Alloy

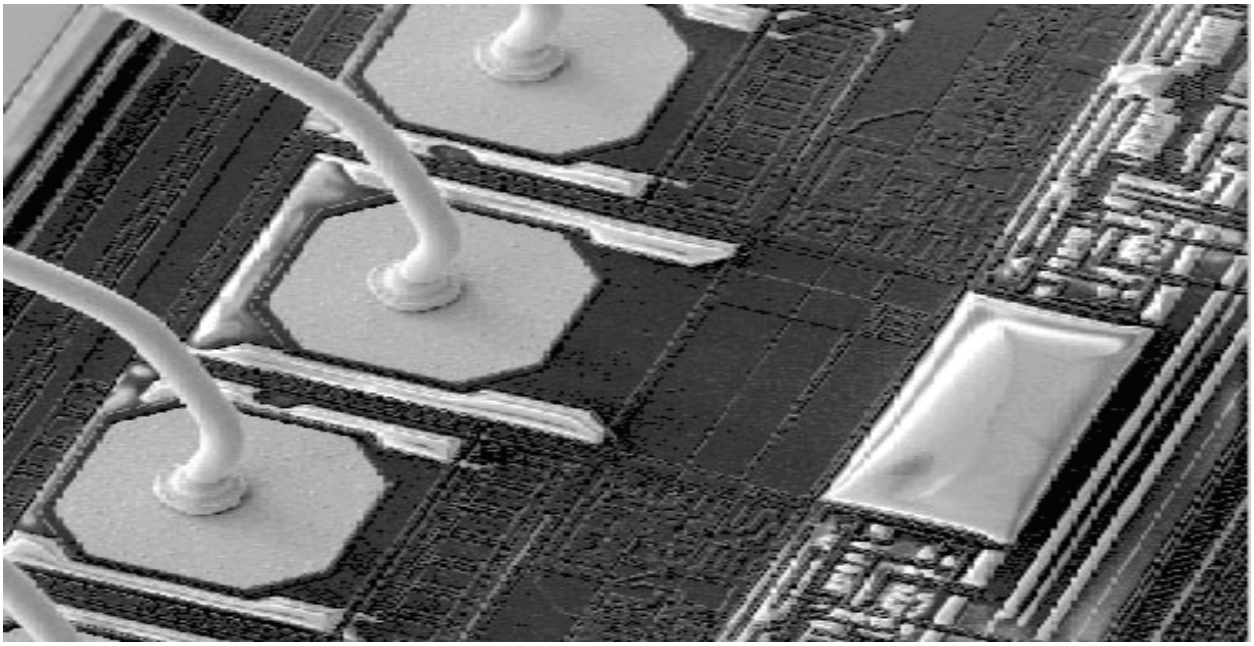
There is hope in bridging this gap. Proprietary processes have been developed for stripping Pb-free BGA's mitigating inter-metallic layers & attaching Sn/Pb spheres utilizing controlled thermal profiles. Similar reliable processes have been demonstrated for the conversion of Pb free parts such as QFP, TSOP, PLCC, resistors & other types to Sn/Pb. This conversion option to Sn/Pb gives device manufacturers and high reliability users real alternatives on how to deal with the availability of Sn/Pb parts and be able to put the Sn/Pb proven reliability back into production builds.

The conversion process for BGA's is more complex to control compared to other device types. RoHS initiatives to remove lead from electronic equipment have resulted in challenges for manufacturers. Due to known reliability issues with tin solder alloys companies building high-reliability equipment must approach lead-free soldering with care. The technique considered for BGA devices involves the removal of lead-free solder and replacement by tin-lead spheres.

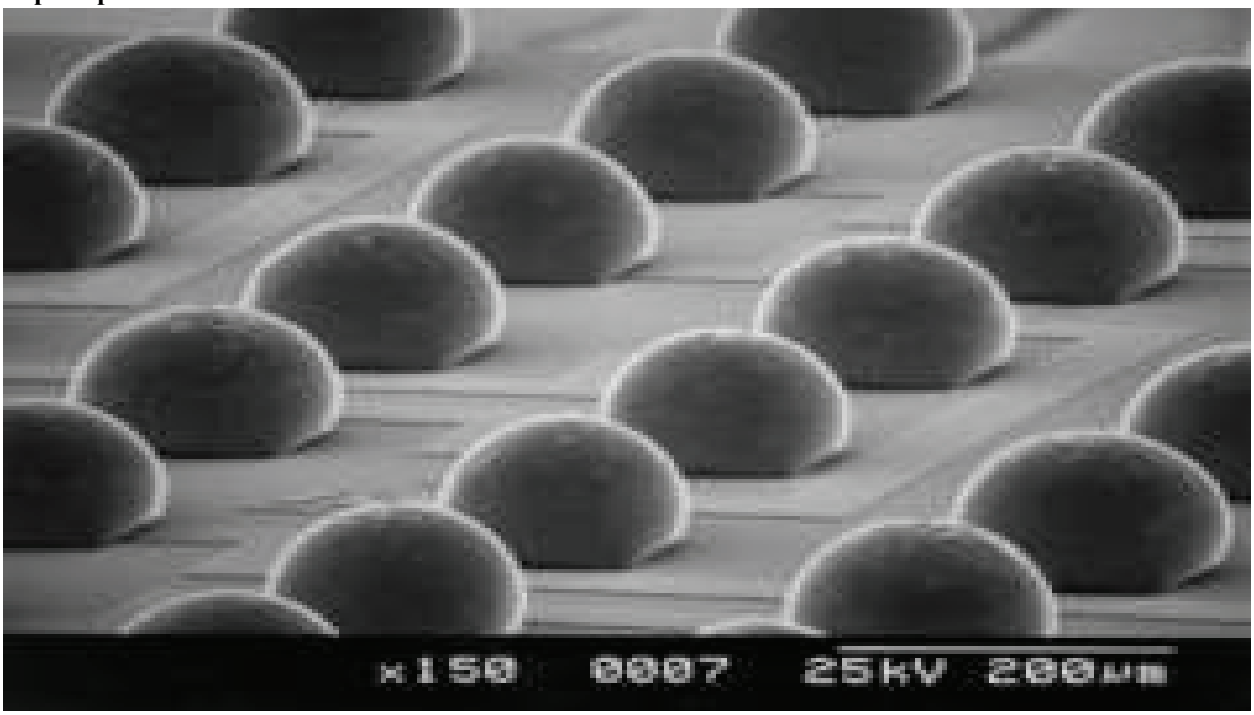
Reliability Concerns with the Reballing Process

Additional Thermal Exposure (Silicon to Package Interface)

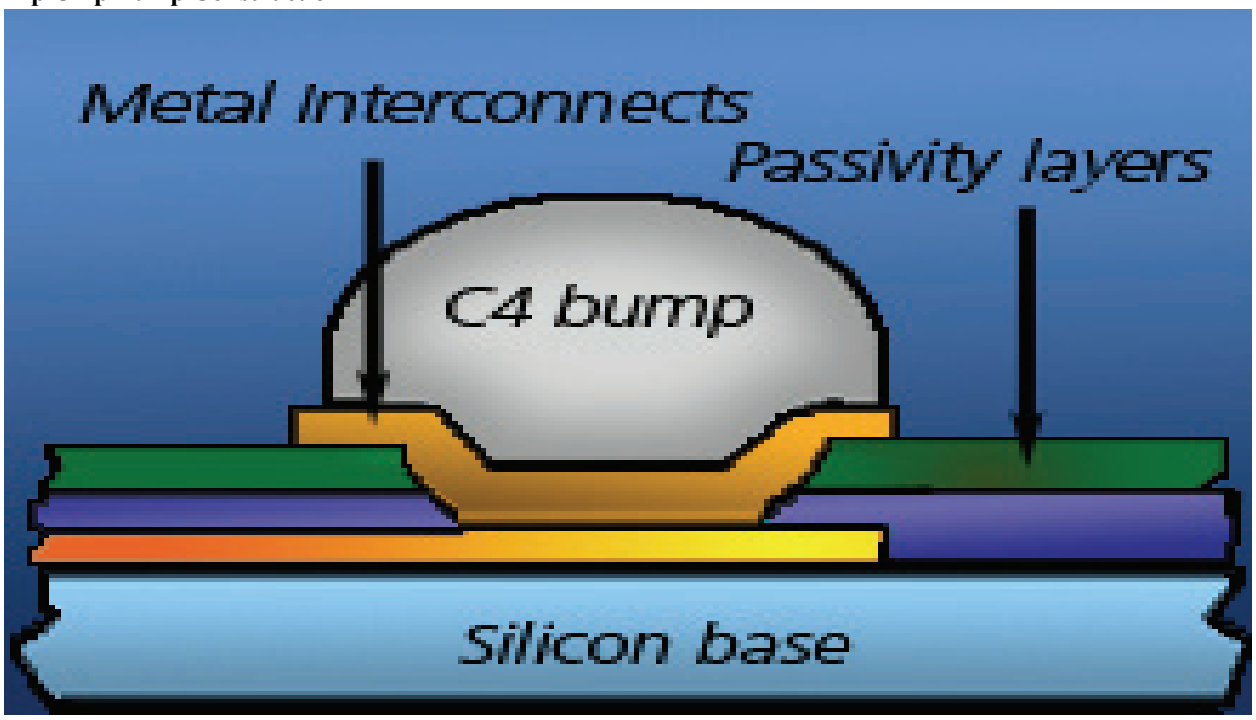
Wire Bond Device



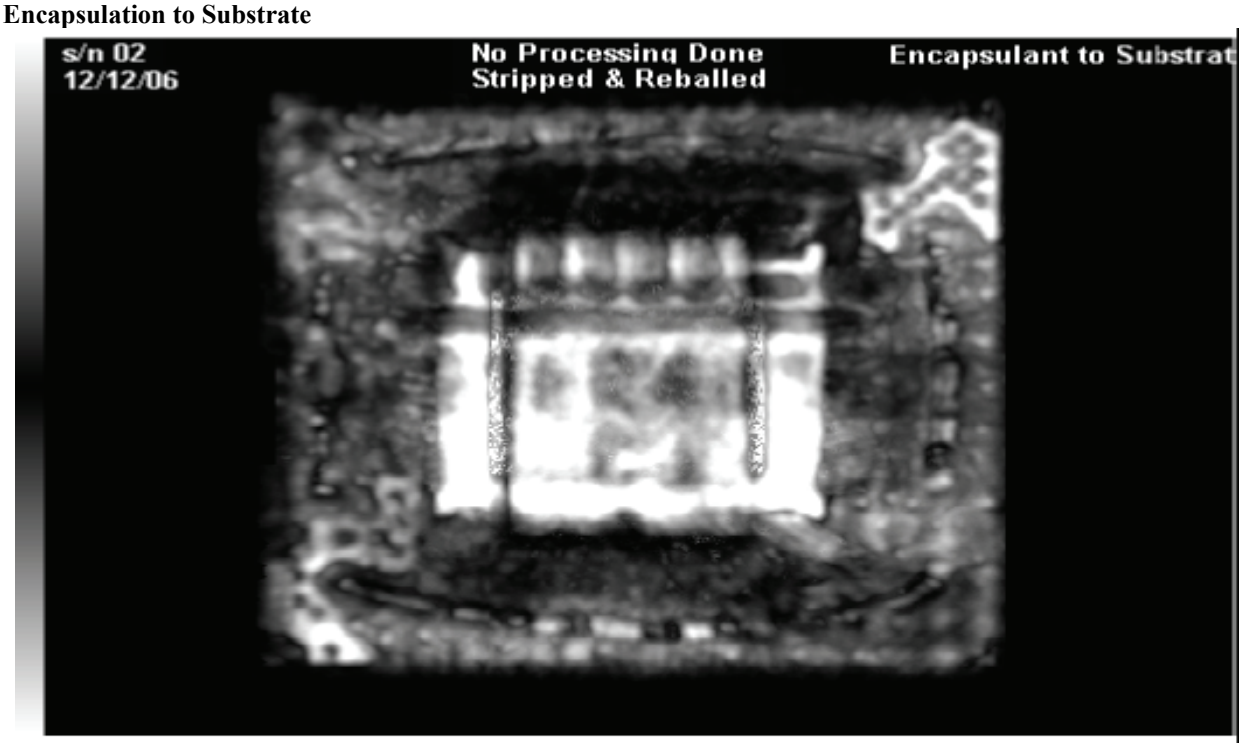
Flip Chip Device



Flip Chip Bump Construction



Encapsulation to Substrate

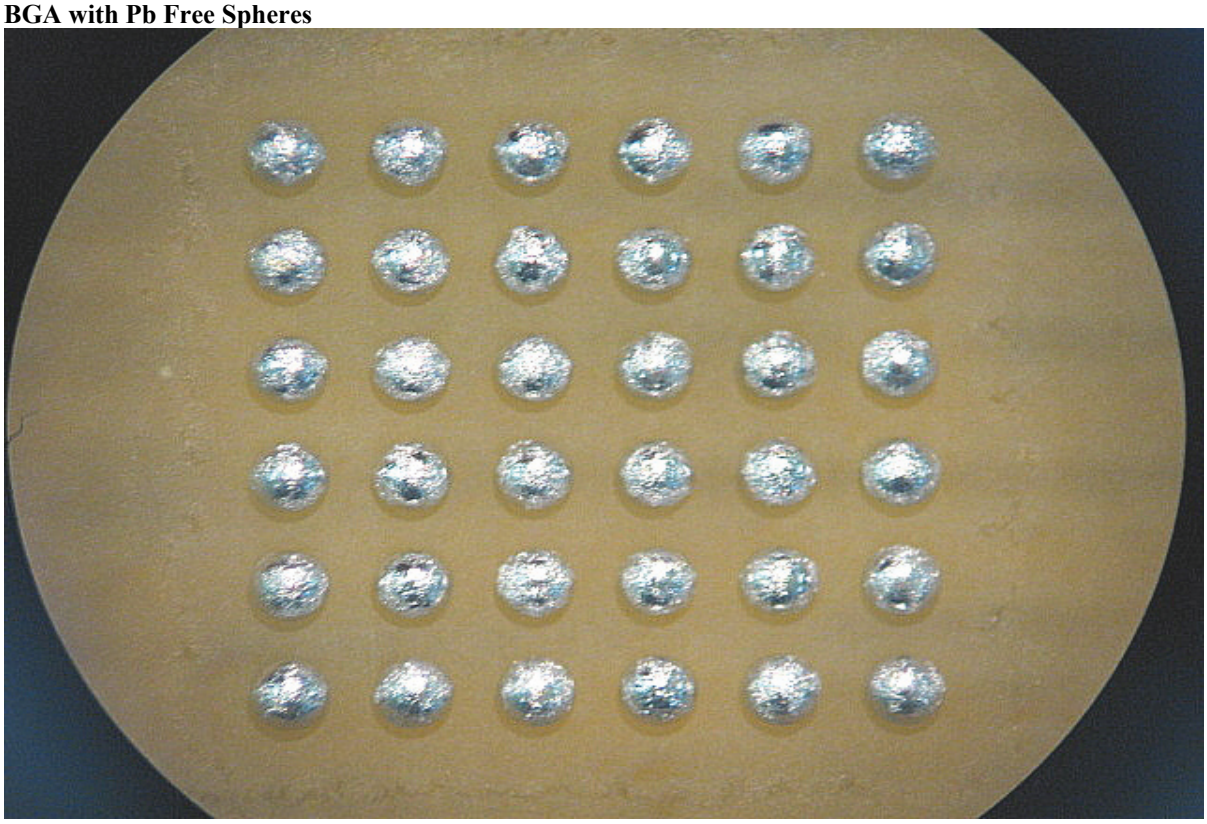


Thermal Exposure Control by controlling the Profile Features:

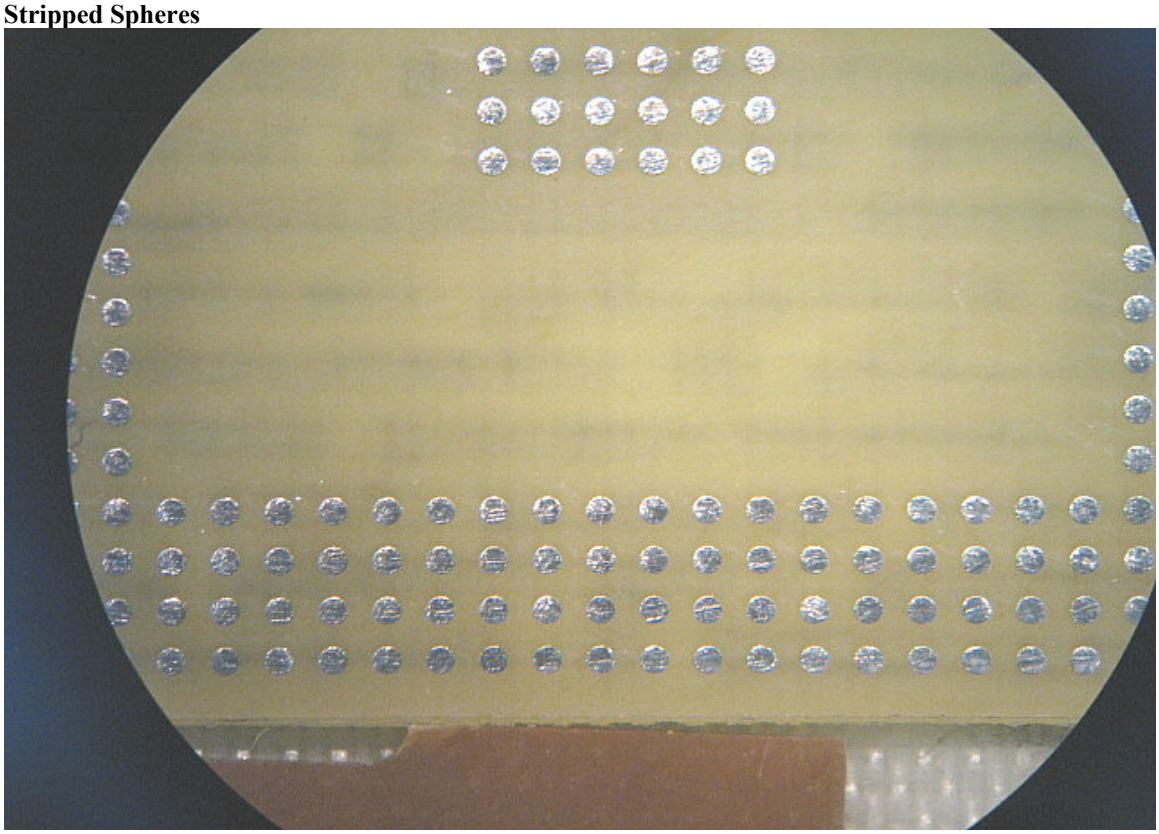
- Ramp up rate
- Preheat temperature
- Peak temperature range
- Cool down rate
- Do not approach the specific Pb free alloy re-flow temperature.

Intermetallic Interaction (Package to PWB Interface)

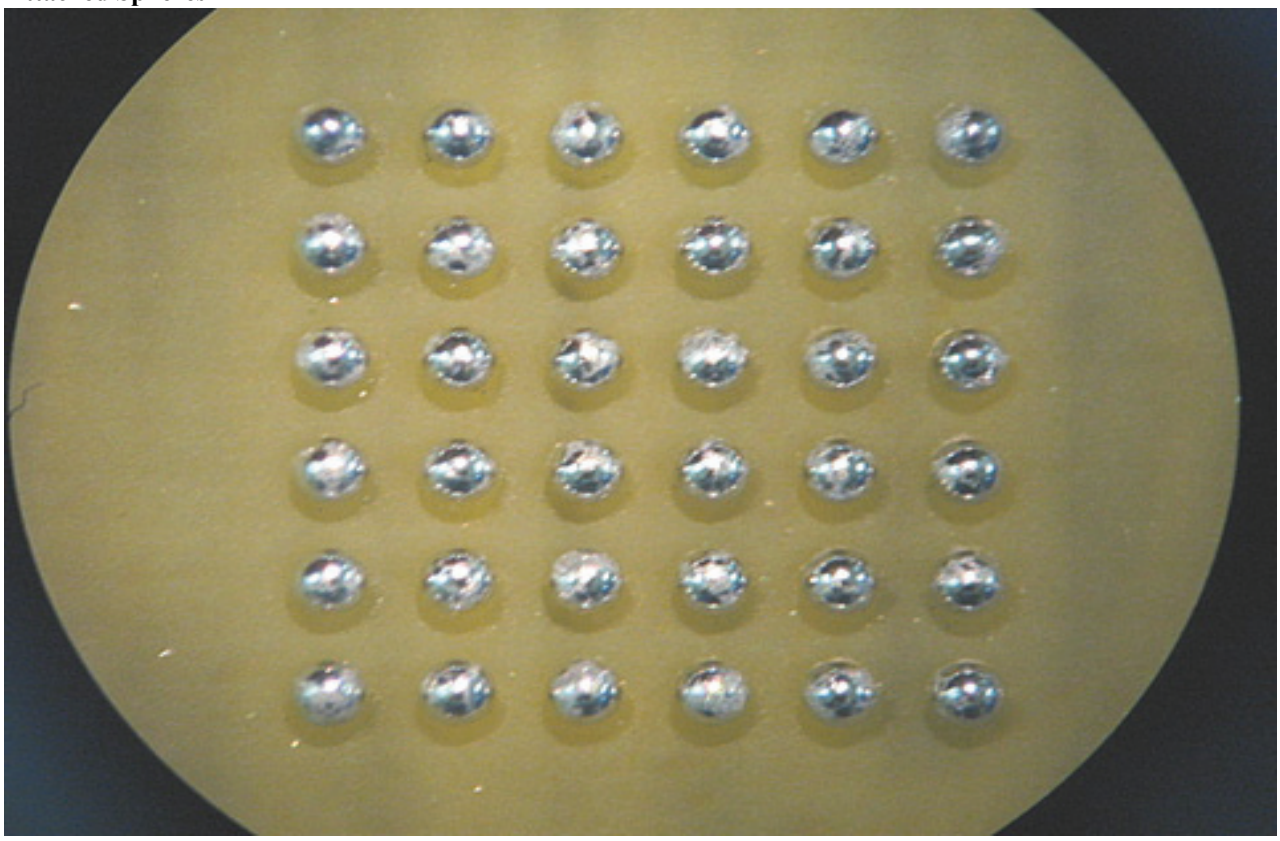
BGA with Pb Free Spheres



Stripped Spheres



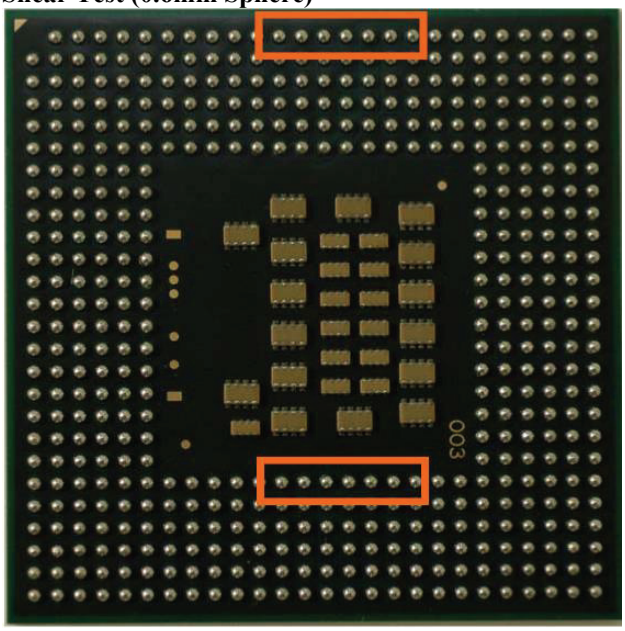
Attached Spheres

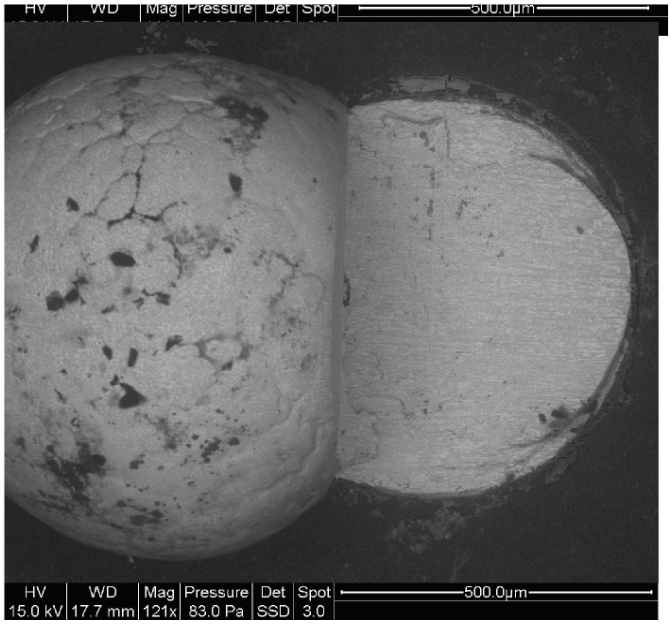


Tests performed to validate the solder ball attachment process

- Shear testing
- C-Sam for Substrate delamination
- SEM Inspection of Solder Joint

Shear Test (0.6mm Sphere)

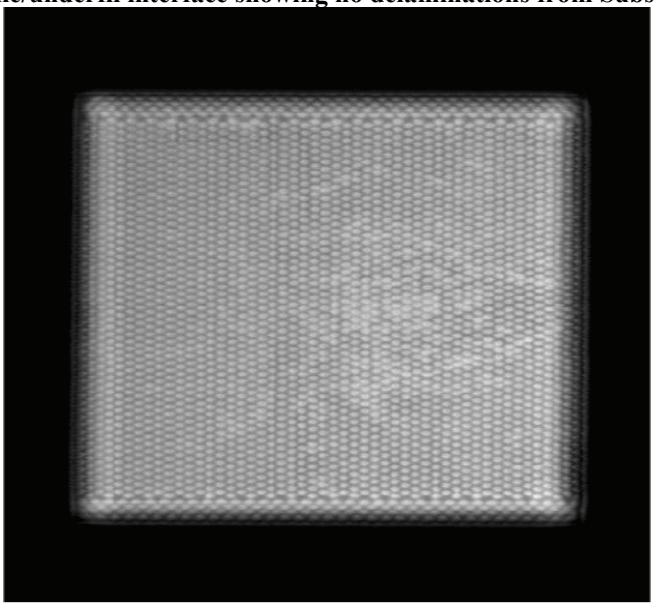




Shear Strength Data

Ball Dia.	Test #	Force (g)	Description	Platform	Load Cell
0.3mm	1	241.58	Pass	Dage 4000	BS5Kg
0.3mm	2	237.18	Pass	Dage 4000	BS5Kg
0.3mm	3	230.50	Pass	Dage 4000	BS5Kg
0.3mm	4	238.53	Pass	Dage 4000	BS5Kg
0.3mm	5	235.77	Pass	Dage 4000	BS5Kg
0.6mm	1	1538	Pass	Dage 2400	BS2Kg
0.6mm	2	1480	Pass	Dage 2400	BS2Kg
0.6mm	3	1701	Pass	Dage 2400	BS2Kg
0.6mm	4	1591	Pass	Dage 2400	BS2Kg
0.6mm	5	1427	Pass	Dage 2400	BS2Kg

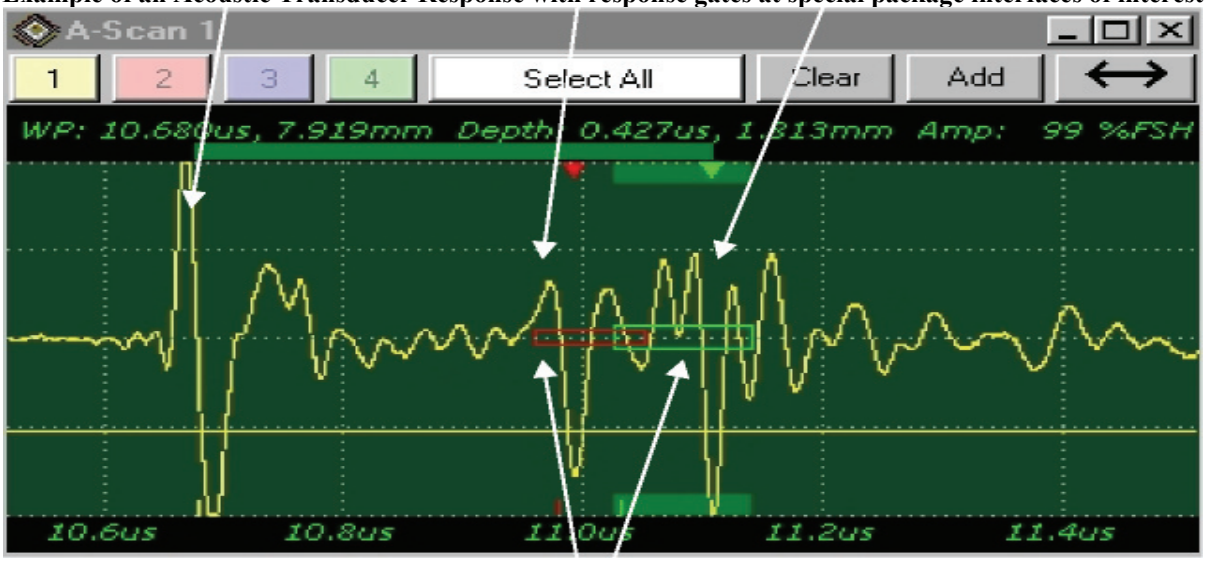
FC die/underfil interface showing no delaminations from Substrate



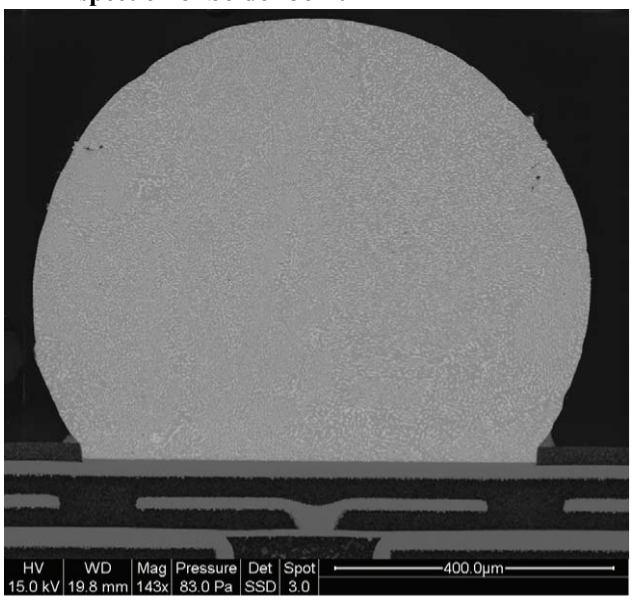
Twenty four (24) of the forty one (41) packages were subjected to CSAM analysis. The purpose of this evaluation is to make sure that multiple re-flow temperature profiles subjected to the packages during the lead free ball removal and the subsequent re-balling process did not initiate or cause underfil delaminations at the flip chip die interface.

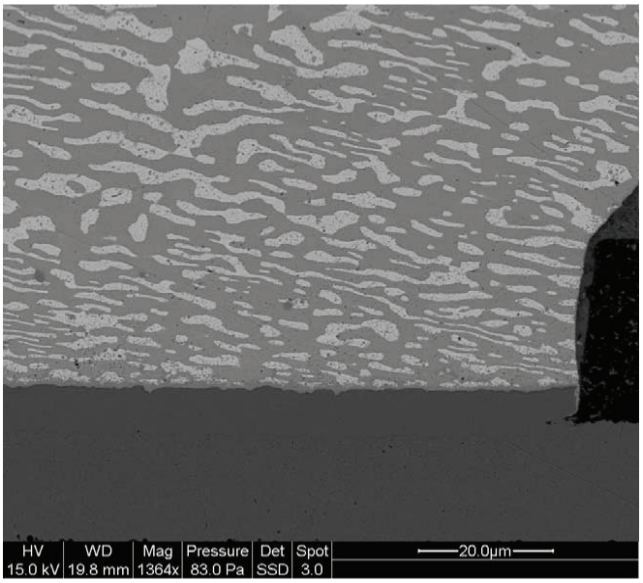
This type of evaluation is normally recommended to be performed when Flip Chip (FC) packages are exposed to temperature excursion or profiles. Underfil delaminations can either failures or compromise the integrity and reliability of the package solder bump interconnects.

Example of an Acoustic Transducer Response with response gates at special package interfaces of interest

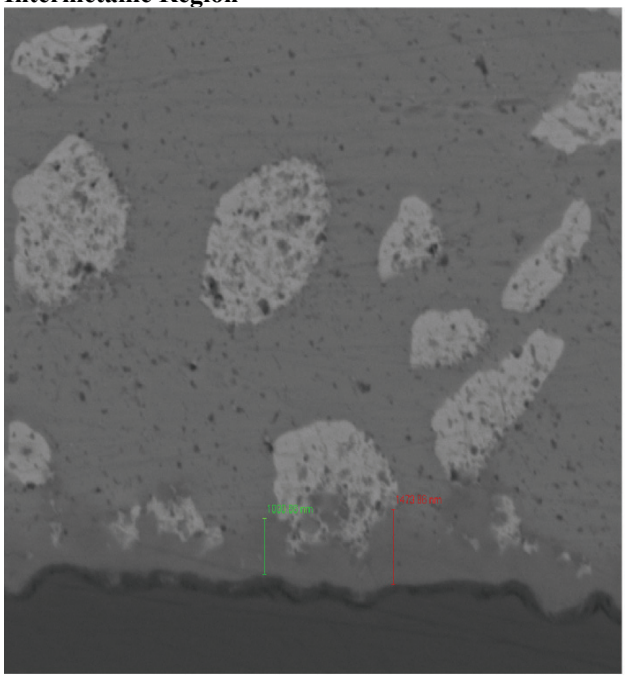


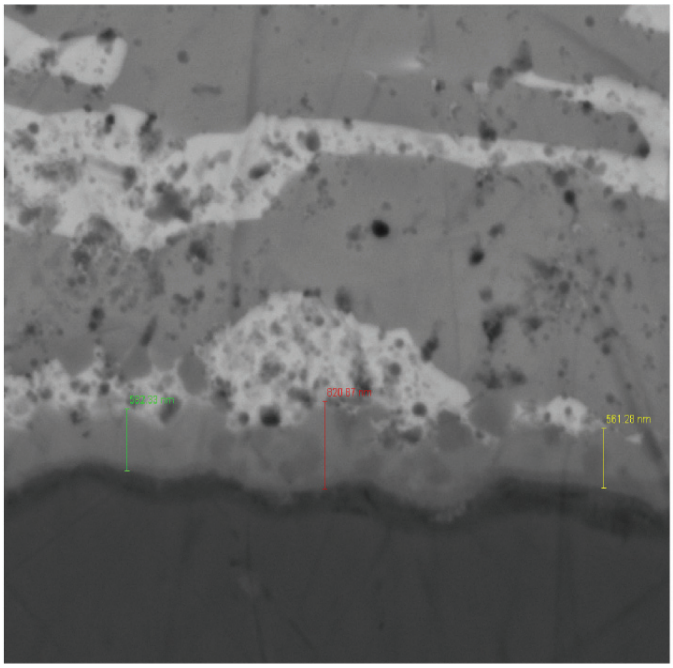
EM Inspection of Solder Joint





Intermetallic Region





Analytic Conclusion

- X-ray inspection showed no voiding
- Cross sections showed good metallurgical ball attachment
- CSAM analysis - no FC/underfil interface delamination
- Extensive solder ball shear performed showed good BGA to substrate solder joints with tight shear force range all above the industry acceptable level. The shear failure was always in the bulk solder indicating strong solder joint to the substrate pads.

Summary

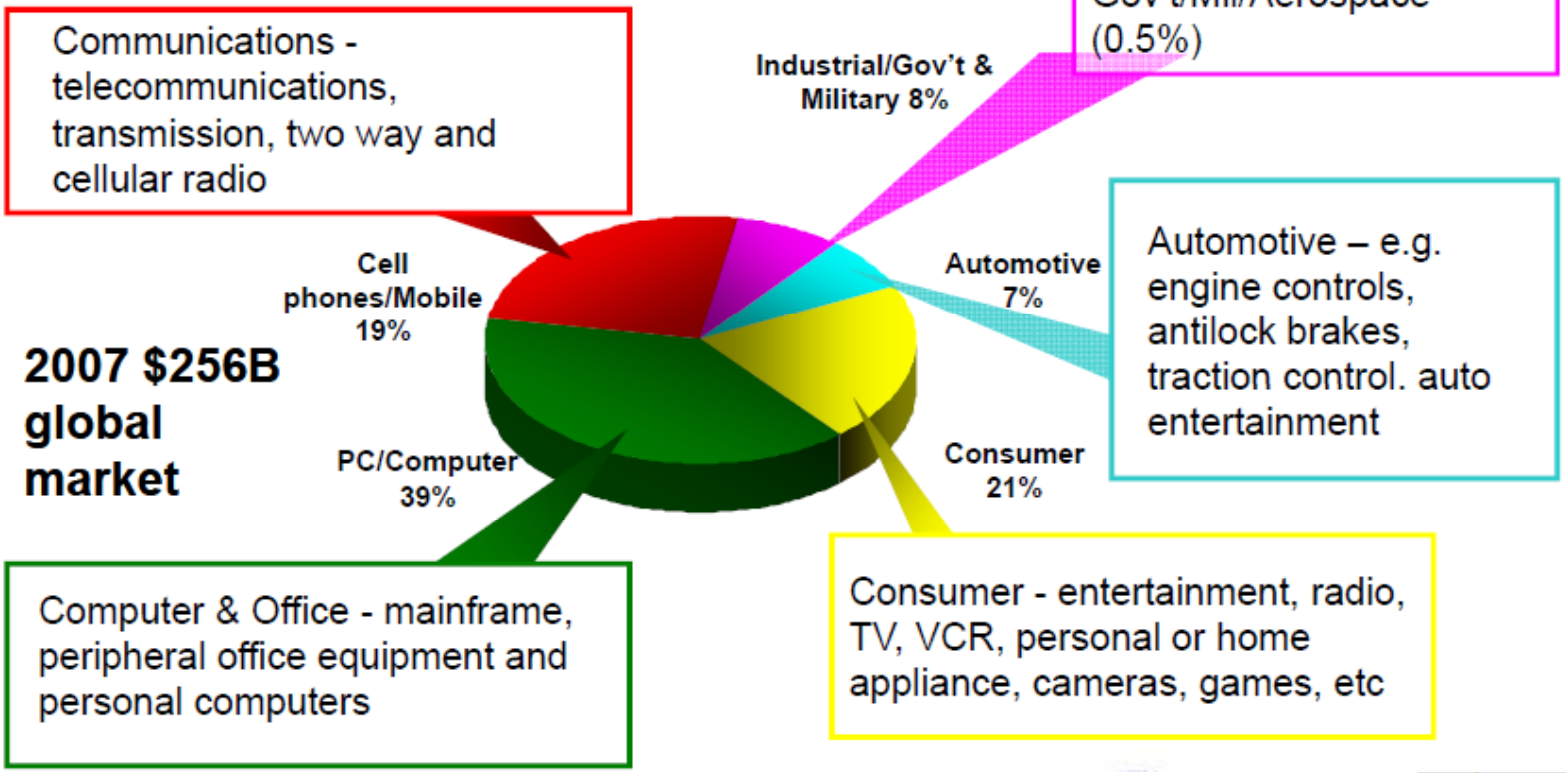
Proprietary processes have been developed for stripping Pb-free BGA's mitigating inter-metallic layers & attaching Sn/Pb spheres utilizing controlled thermal profiles. Similar reliable processes have been demonstrated for the conversion of Pb free parts such as QFP, TSOP, PLCC, resistors & other types to Sn/Pb. This conversion option to Sn/Pb gives device manufacturers and high reliability users real alternatives on how to deal with the availability of Sn/Pb parts & granting the OEMs their freedom back to choose and be able to put the Sn/Pb proven reliability back in their builds.

Bridging Supply Chain Gap for Exempt High-Reliability OEM's

Hal Rotchadl, President

OEM Applications of

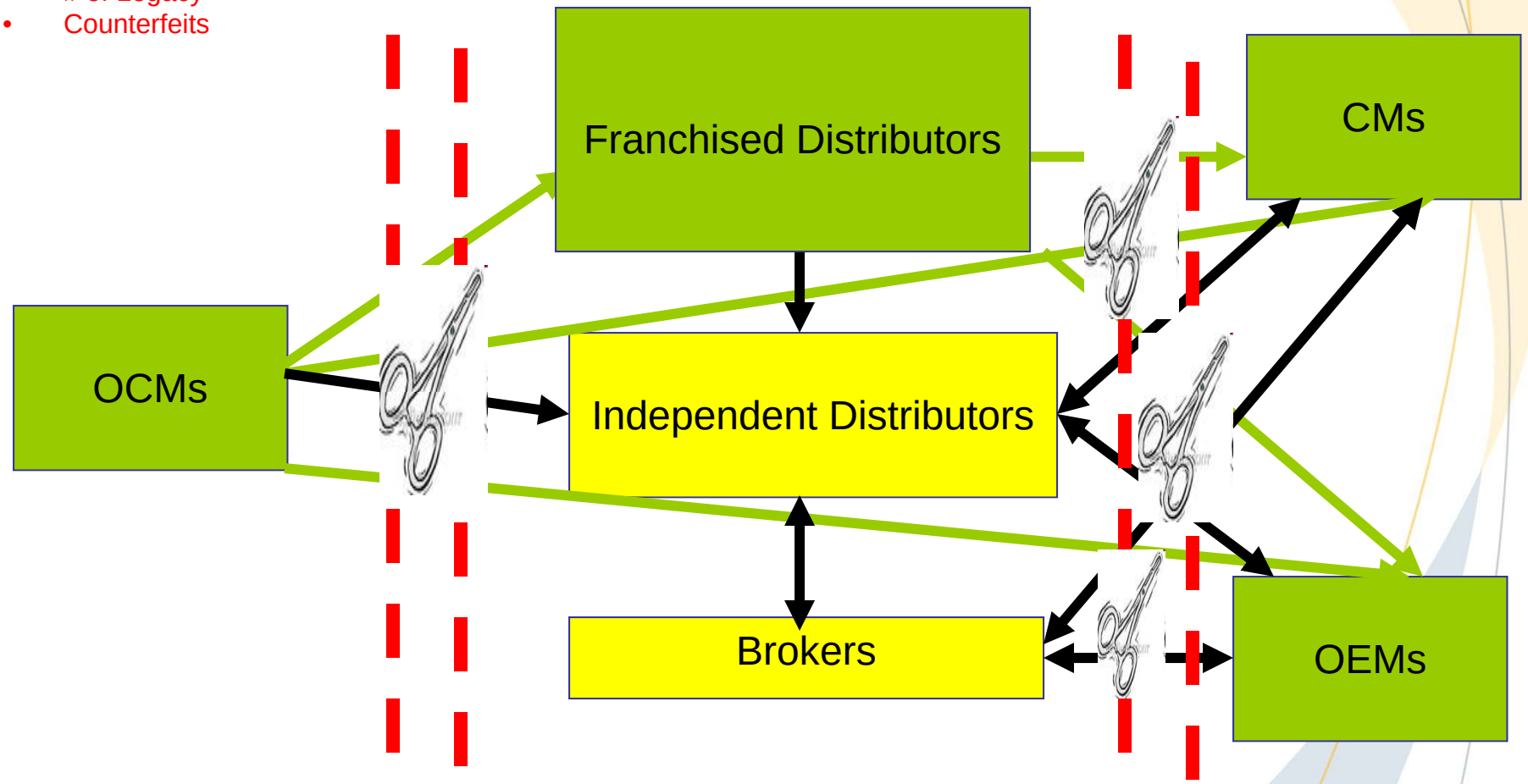
- **Semiconductors are Everywhere – including health and safety applications.**



Supply Chain - Disconnects

Disconnects in Supply Chain

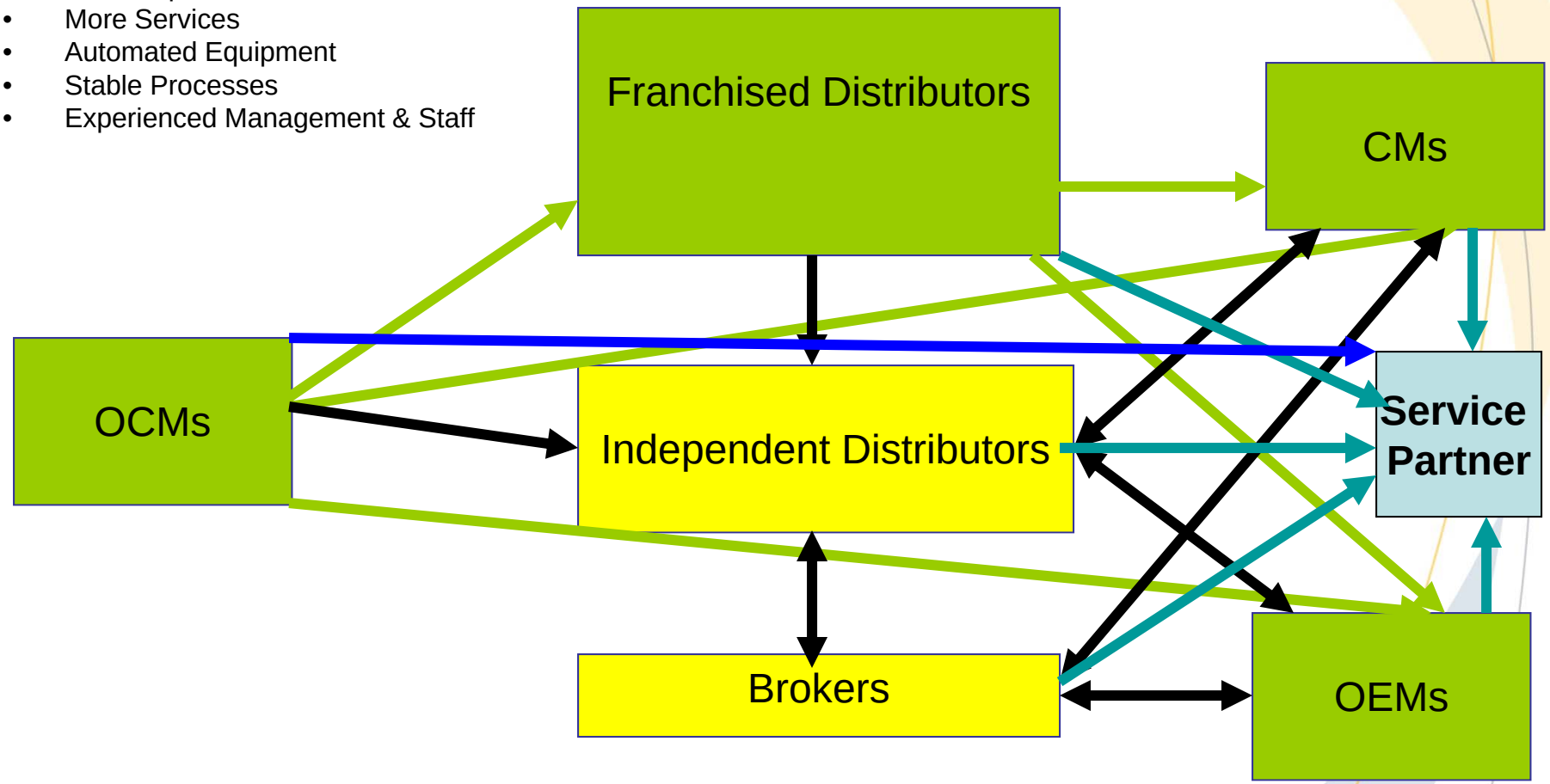
- RoHS adoption
- # of Legacy
- Counterfeits



Supply Chain – Bridged Gap

Greater Inclusion of Service Partner

- More Sophistication
- More Services
- Automated Equipment
- Stable Processes
- Experienced Management & Staff



RoHS & Pb Free Conversion

– What are the issues here?

– What industries are impacted?

– Are there good solutions for RoHS related issues for these industries?

RoHS/REACH

Recent Restricted Substance Regulations

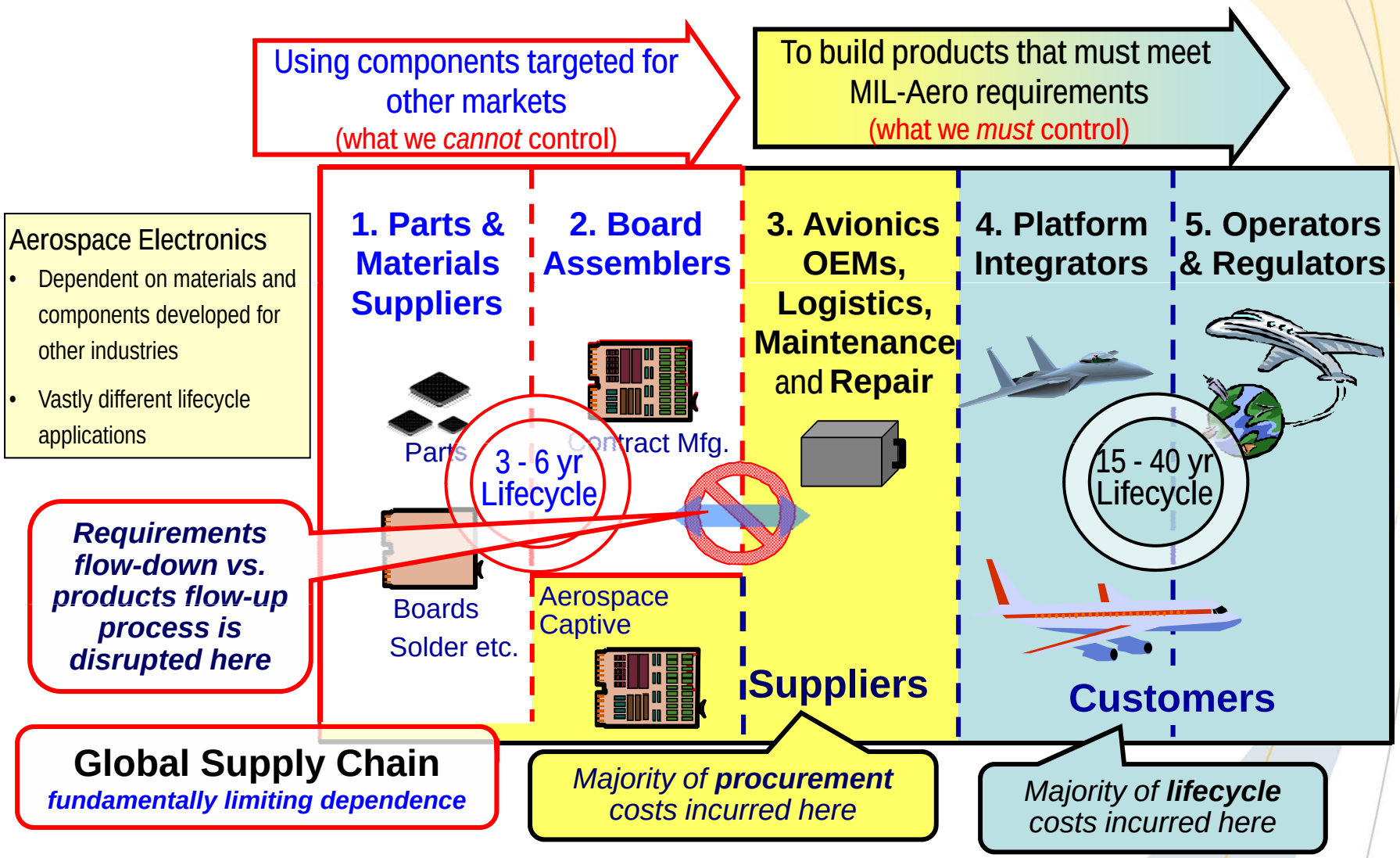
- EU RoHS (Restriction of Hazardous Substances)
  - From July 1st 2006, RoHS restricted the use of six substances in most electrical and electronic products
    - Lead (Pb), Mercury (Hg), Cadmium (Cd), Hexavalent Chromium (Cr6+), PBB and PBDE
  - California, China, and Korea have added similar regulations
- EU REACH Regulation
  - Requires Registration, Evaluation, and Authorization of Chemicals (including some chemicals in products)
    - Initial requirements came into effect starting June 1, 2008 and new requirements will continue to roll-out through 2018 and beyond
- RoHS II proposal
  - The EU Commission announced its proposal for RoHS2 in December 2008 – increasing the scope of products, adding conformity assessment, increased enforcement and hinting at new substances.
- .... and environmental NGOs keep pushing for more

Exempt Industries

- Exempt Industries account for an estimated 13% - 18% of the total electronics components activity:
  - Military
  - Aerospace
  - Medical
  - Telecommunications – Infrastructure
  - Automotive – Engines, ABS

- Long product life cycle & warranty support
- Products that impact human life
- Impact on national security
- Heavily regulated – FDA for medical,…..

The Electronics Supply Chain According to a Mil/Aero OEM



Courtesy of PERM

High Reliability OEM Concerns

- Most of the High-Reliability (Exempt) industries were caught off guard by the lack of available leaded components
- Leaded components are being transitioned to obsolete and legacy parts outside the control of the OEMs and at a rapid pace
- A redesign to include an alternate part number is no easy task due to redesign review, validation and reliability testing

High Reliability OEM's Concerns

- Some manufacturers are not changing P/Ns once the Sn/Pb is obsolete. The end result too often is mixed reels of RoHS and non-RoHS product
- Reliability concerns associated with Pb-free components. Reflow profiles, thermal stress, MSL, tin whiskers, tin pests, brittleness, voids and thermal mismatch,…
- Exempt OEMs are many times left with only one choice and that is Pb-free components

Tin Whiskers – Pb Free

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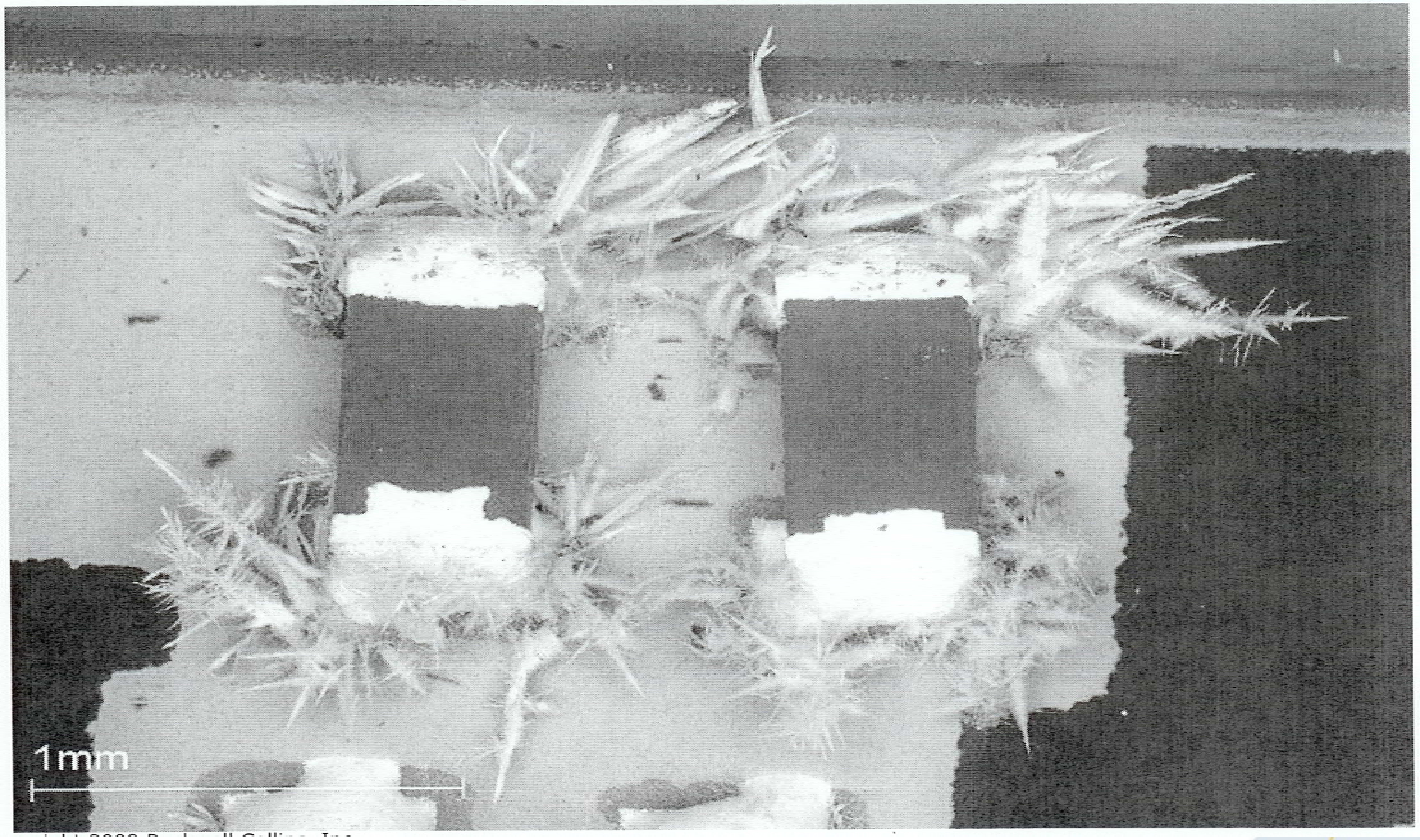
Rockwell Collins

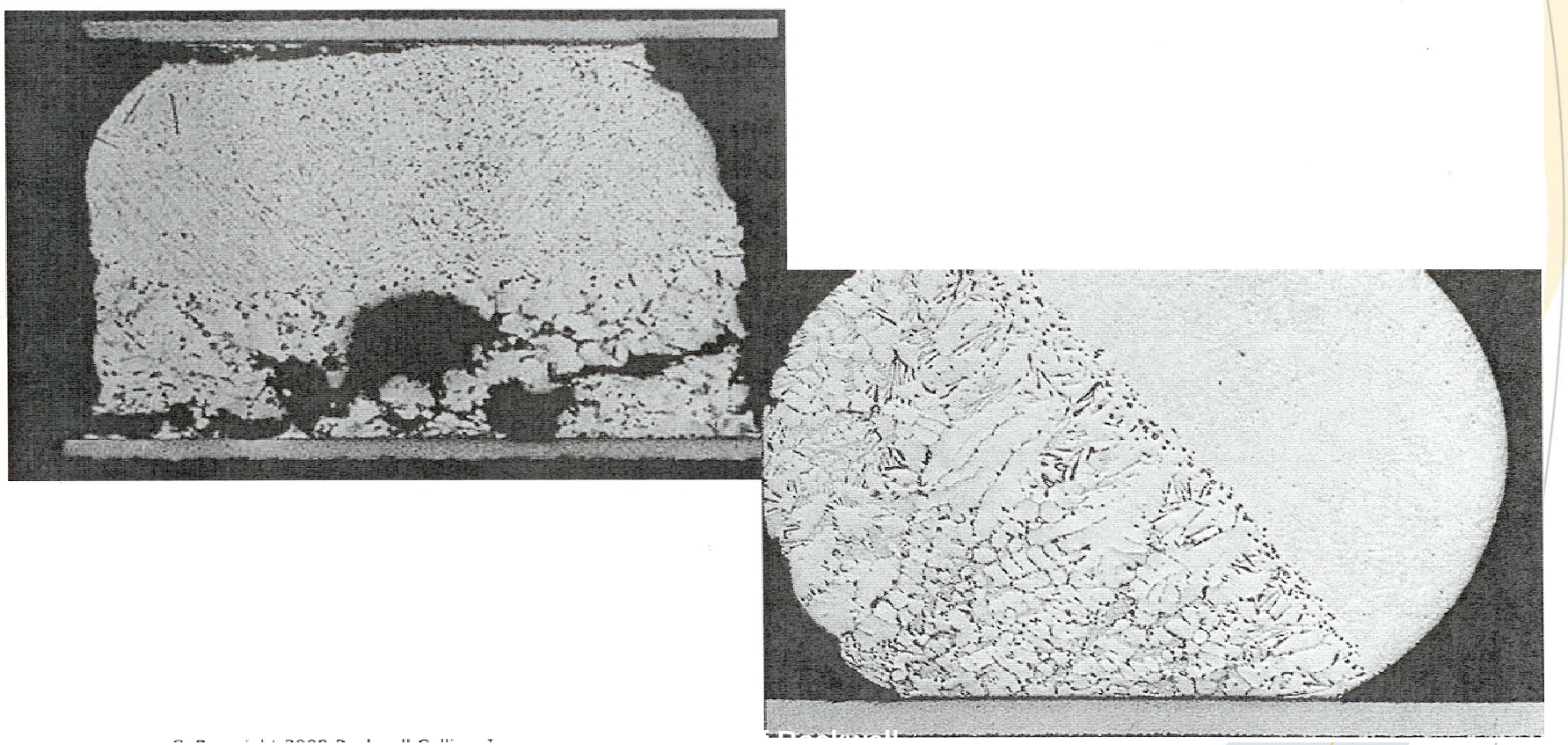
Lead-free Soldering Process & Component Surface Finishes Interactions



Mixed Metallurgy – BGA's – Pb Free Issues

Rockwell Collins

Mixed Metallurgy Concerns



Can You Trust Pb-Free with this?

Options For The Exempt Industries

- Find legacy product in gray market
- Transition to lead free
- Develop new alloy
- Buy lead free product & convert to leaded

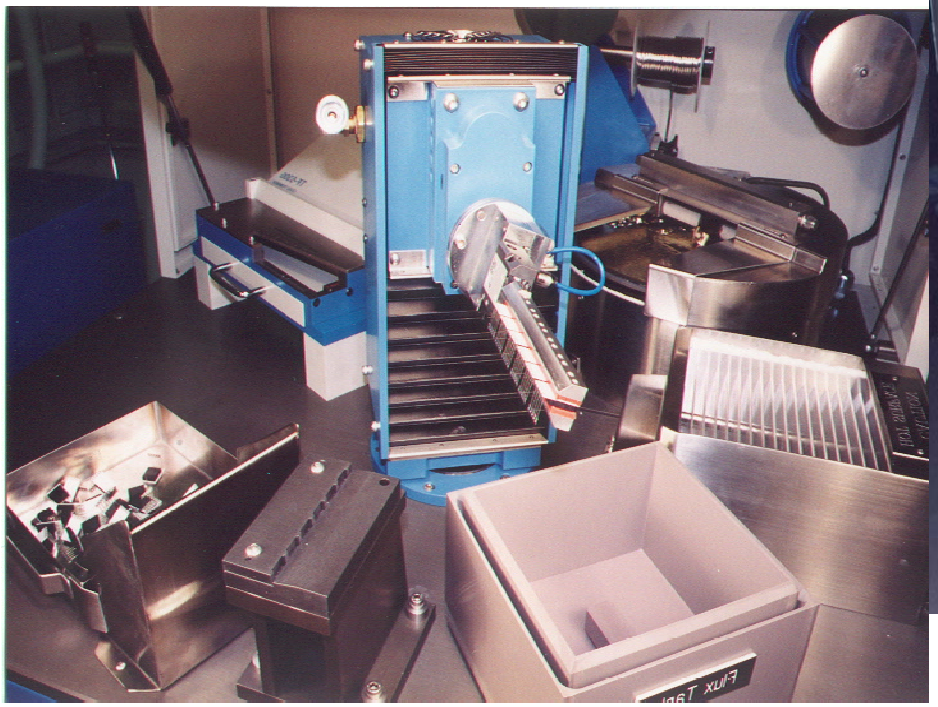
Finding a Conversion Partner

- The key is to find a good conversion partner that truly understands the process & has equipment to properly deal with reliability concerns such as:
  - Tin whisker/pest mitigation
  - Thermal stress
  - Intermetalic layers
  - Mechanical aspects
  - Visit & audit potential service partner

Solder dipping and Solder Conversion

- Historical - process was fairly basic
  - Restore finish
  - Reball
- Currently – much more technical
  - Add/take out Pb
  - More alloys
  - Complex package types
  - Small foot print parts – CSP & die level
  - Stripping of alloys
- Reliable processes have been demonstrated for the conversion of Pb free parts such as QFP, TSOP, PLCC, resistors & other types to Sn/Pb

Automated Solder Dip



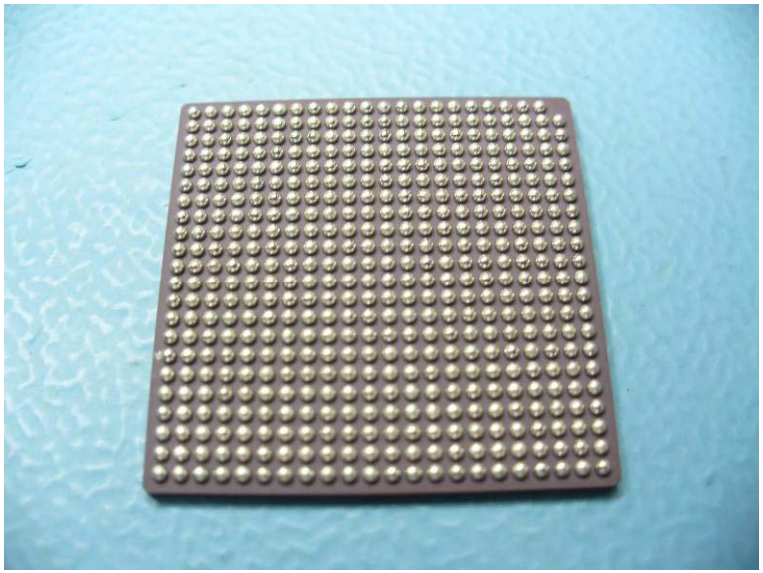
OEM Statement (Lead-free/BGA Reball)

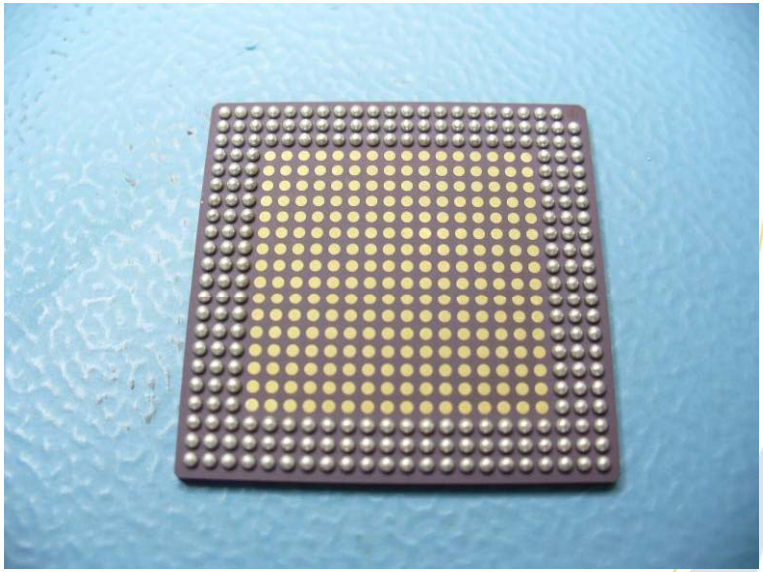
"Lead-free" RoHS initiatives to remove lead from electronic equipment have resulted in challenges for manufacturers. Due to known reliability issues with tin solder alloys (e.g., tin whiskers & voids), companies building high-reliability equipment **must approach lead-free soldering with care**. A technique being considered for BGA devices is that of re-balling, that is, **removal of lead-free solder and replacement by tin-lead spheres**. The question is whether this procedure is advisable or if there are other options."

Pb Free Alloy Test Plan

- Overview:
  - Perform a limited sample size thermal cycle “screening” test covering/comparing multiple different alloys
  - Use existing test board design and component (Acceleration Factors Test)
  - Single thermal cycle (0-100C, 30 minute dwell
  - Single soldering alloy: SAC 305

Pb Free Alloy - Test Devices





Pb Free Alloy Test - Compositions

Packages of 9 different solder alloys were received

SAC405,

SnAg,

Sn100C,

Sn1.2Ag0.5Cu0.005Ni,

SAC205+Ni,

SAC310 +1%Cu,

SAC105,

SAC108,

SACX.

Each Alloys came into 2 different groups

1) Fully populated components
2) Depopulated components

Pb Free Alloy Test - Early Results

Alloy & Pkg Configuration	PCT Fails	Test Status (893 cycles)
SAC405F	56%	
SAC405D	0%	
SnAgF	6%	
SnAgD	25%	
Sn100CF	31%	
Sn100CD	100%	removed from chamber
LF35F	44%	
LF35D	88%	removed from chamber
SAC205NF,	19%	
SAC205ND	88%	removed from chamber
SAC310F	50%	
SAC310D	100%	removed from chamber
SAC105F	19%	
SAC105D	88%	removed from chamber
SAC108F	63%	
SAC108D	88%	removed from chamber
SACXF	81%	removed from chamber
SACXD	100%	removed from chamber

BGA Re-ball Options/Technology

I. Device removal and refurbishment
   For revisions, board rework, PWBA failures, etc

II. Pb Free to Sn/Pb Conversion
   For High reliability products with RoHS exemptions

III. Sphere attach to Land Grid Array (LGA)
   For High reliability products with RoHS exemptions

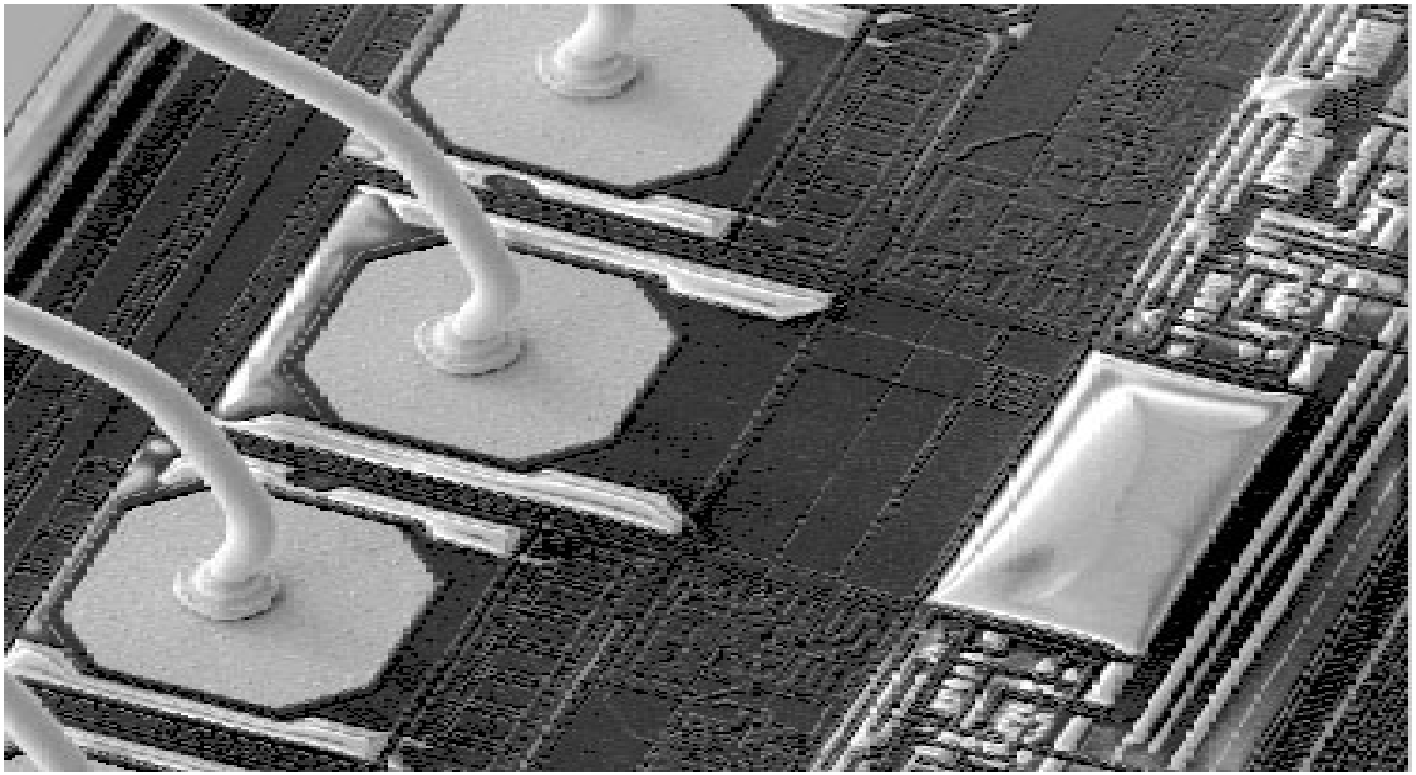
IV. Sn/Pb to Pb Free Conversion
   For legacy products requiring RoHS Compliance

Proprietary processes have now been developed for stripping

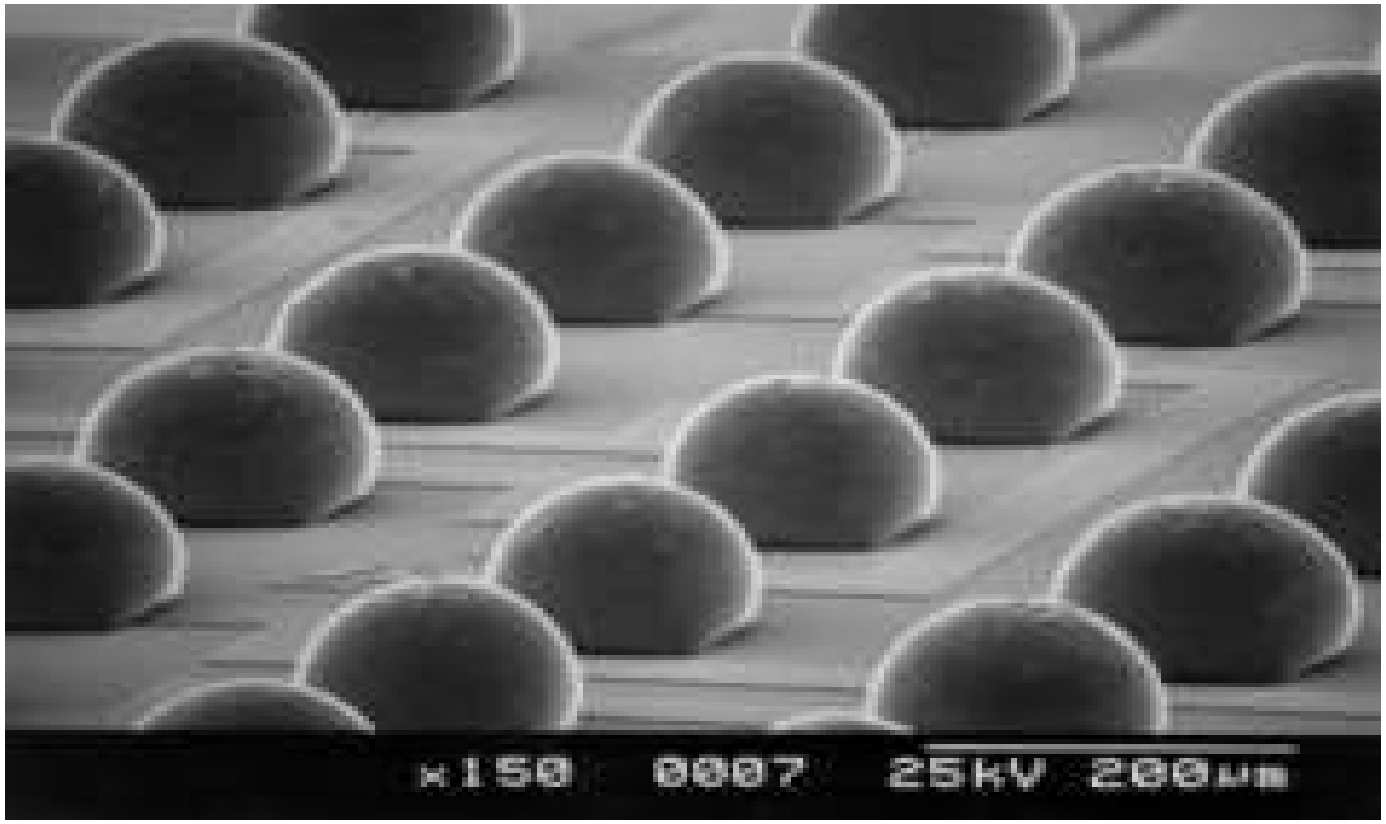
Pb-free BGA's mitigating inter-metallic layers & attaching Sn/Pb

spheres utilizing controlled thermal profiles

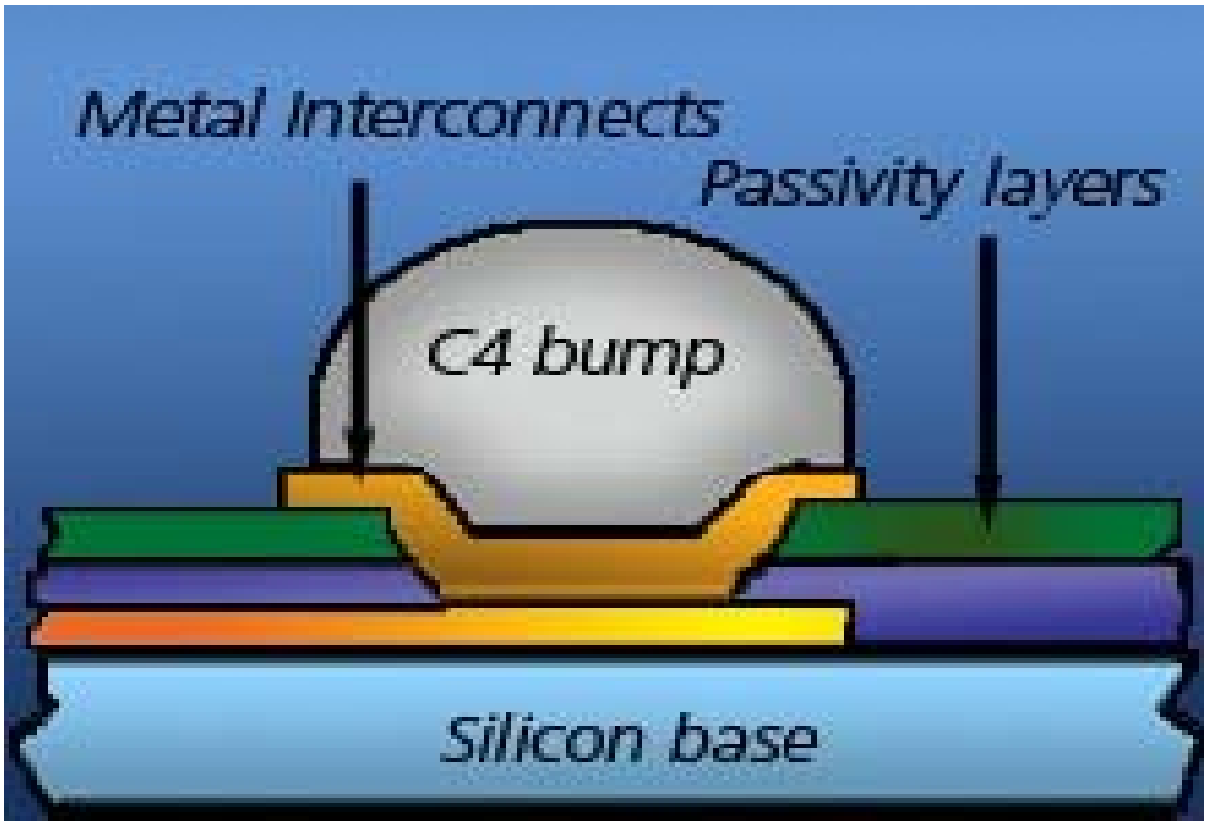
Wirebond Device



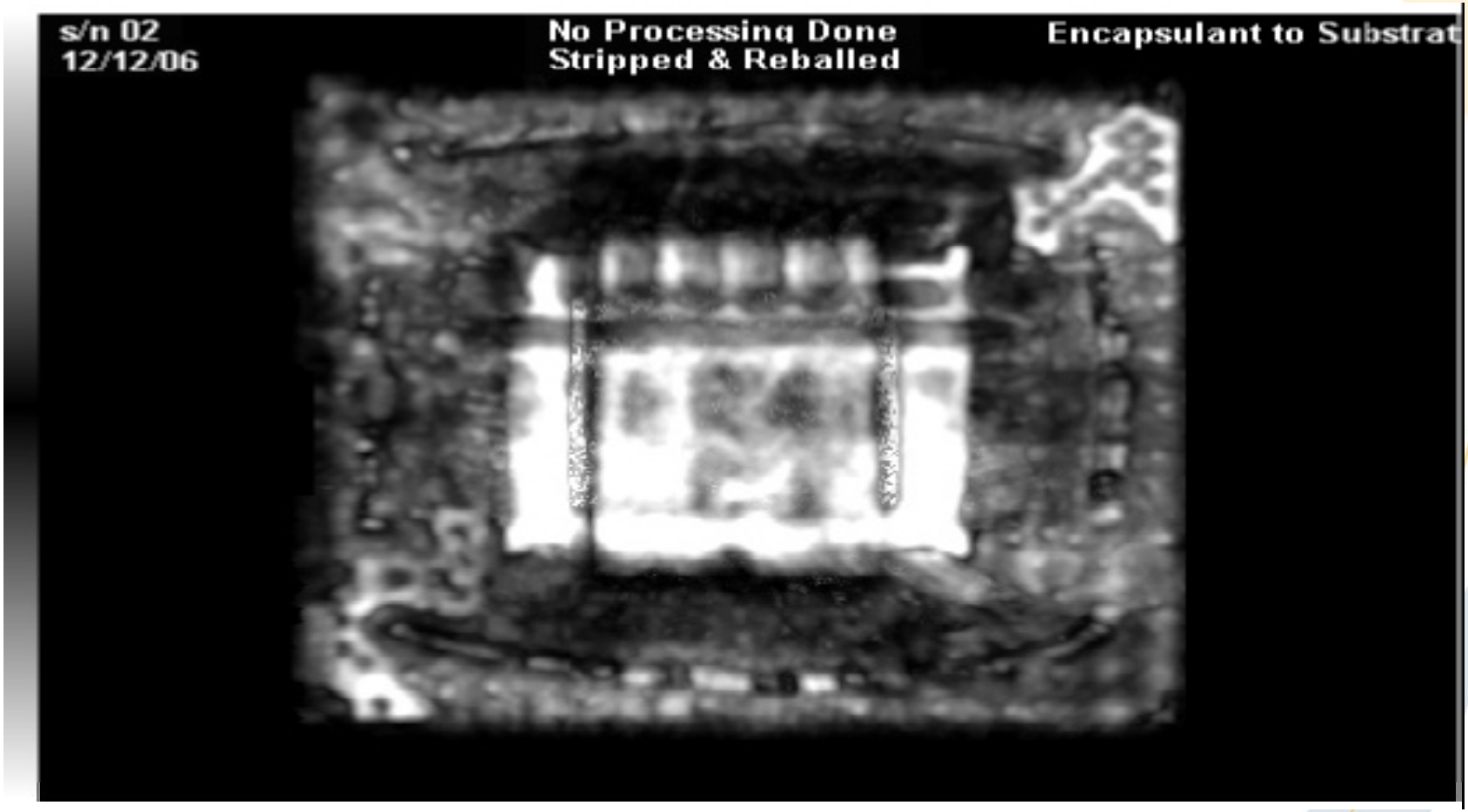
Flip Chip Device



Flip Chip Bump Construction



Encapsulant to Substrate



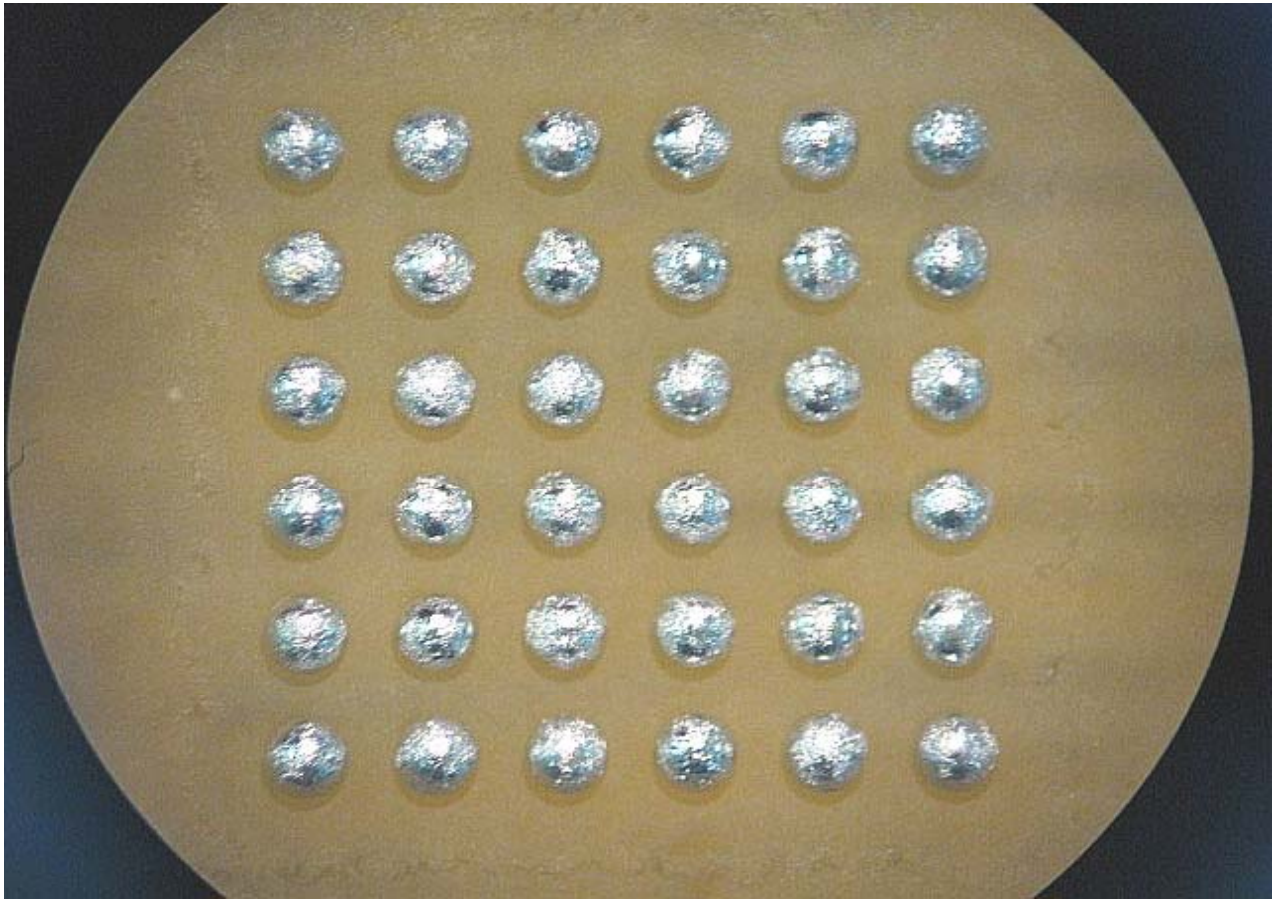
Thermal Exposure Control

Profile Feature

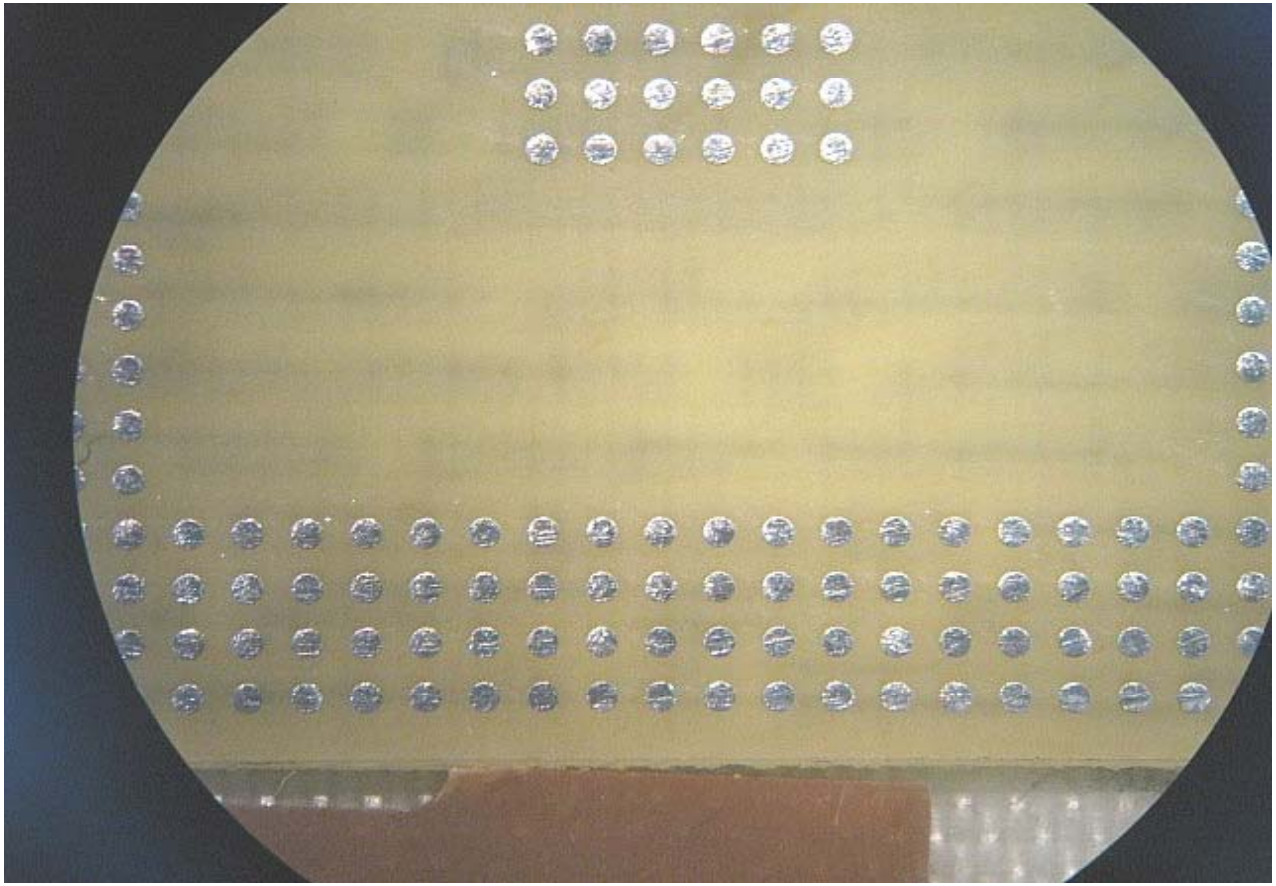
- Ramp up rate
- Preheat temperature
- Peak temperature range
- Cool down rate
- Do not approach the specific Pb free alloy re-flow temperature.

* Profile feature data is device specific

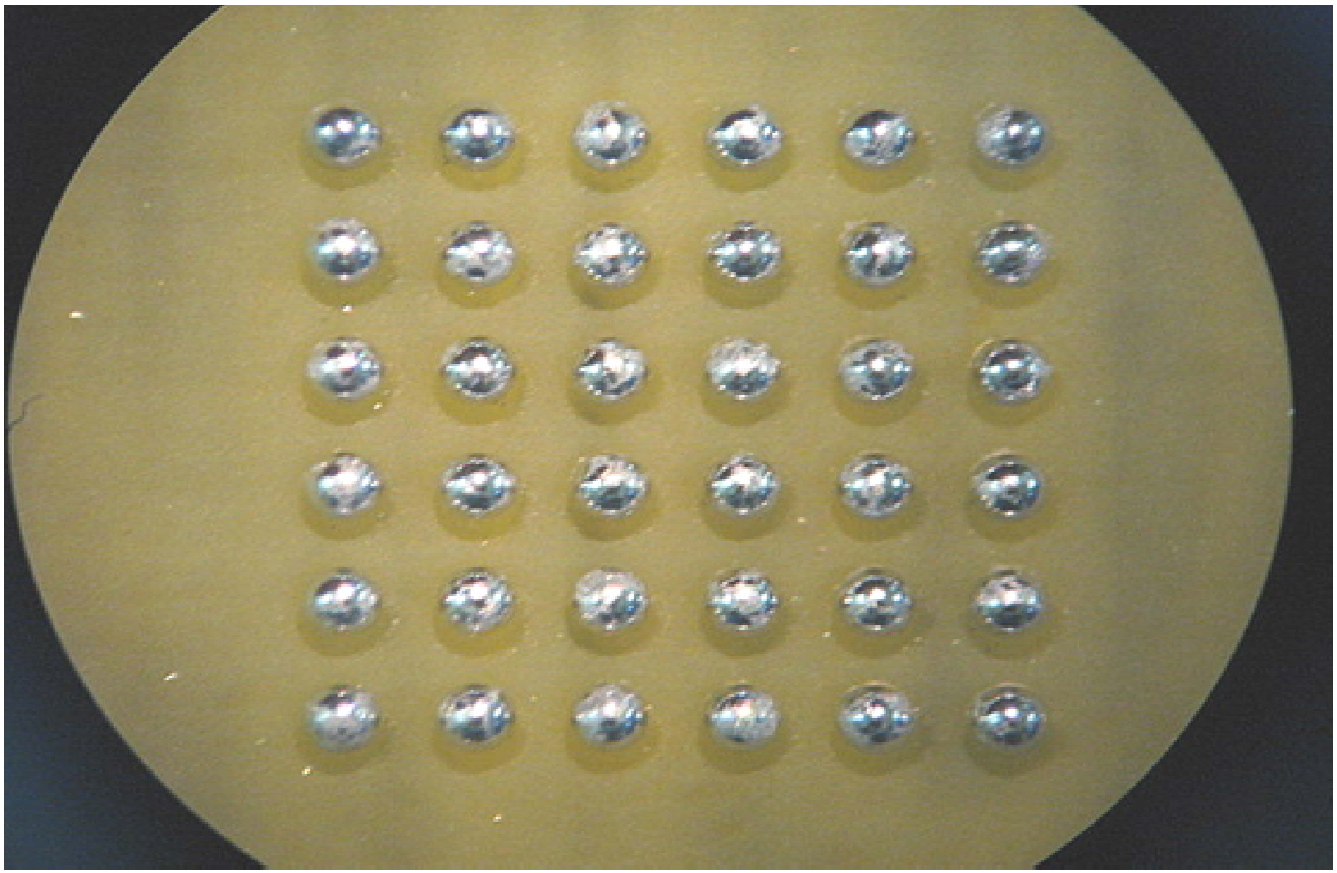
Pb Free Spheres



Strip Process



Sphere Attach



BGA Re-ball & Ball Attach

3D Ball Scan, Tape & Reel

Electrical Test Capabilities

Ball Attach Integrity Testing

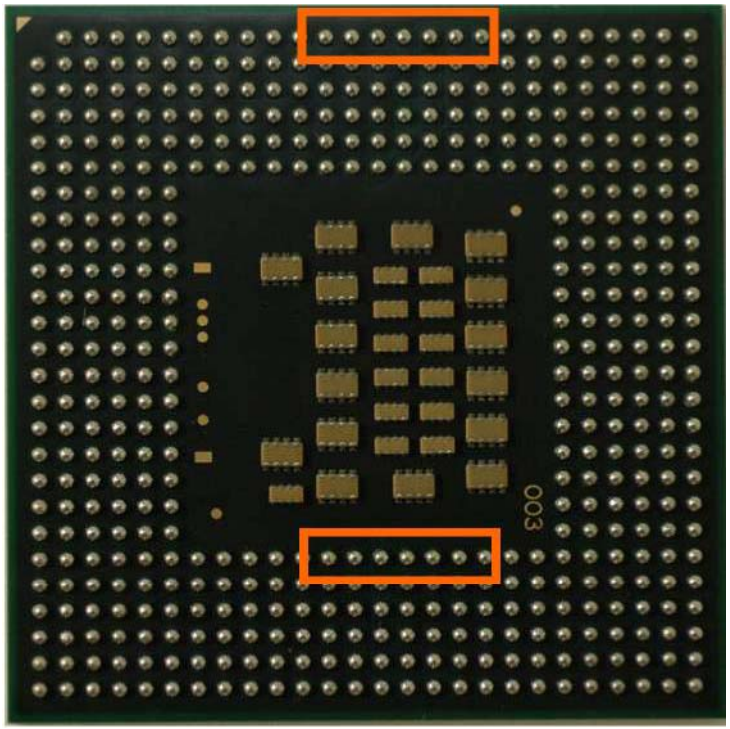
Tests performed to validate the solder ball attachment process

- Shear testing
- C-Sam for Substrate delamination
- SEM Inspection of Solder Joint

Pb Free to Eutectic – Case Study

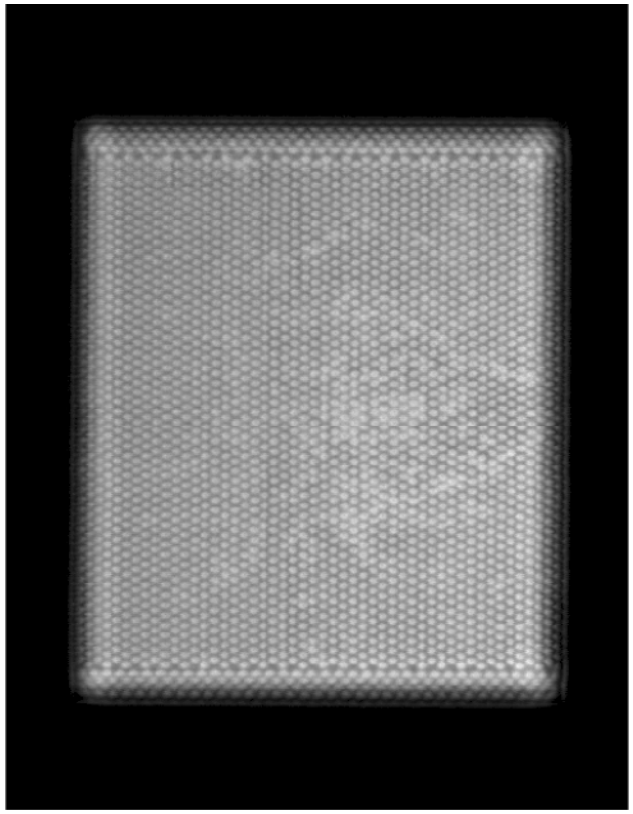
- The following series of photos reflect results of a specific proprietary process.
- The requirement was to convert a series of devices from a SAC405 interconnect structure to a eutectic structure.
- The devices were sent by the customer to an independent laboratory for evaluation.

Intel U2500 Duo-Core Processor



C-SAM of Flip Chip Bumps

FC die/underfil interface showing no delaminations from Substrate



Acoustic Analysis

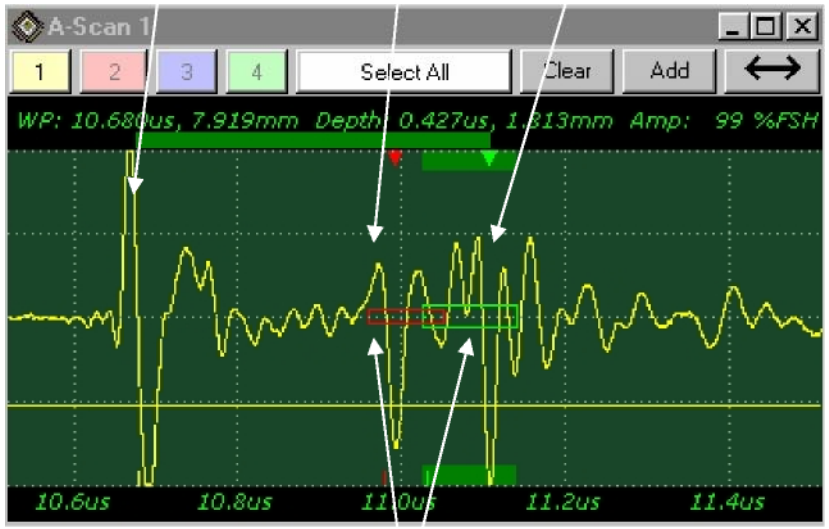
Example of an **Acoustic Transducer Response** with response gates at special package interfaces of interest.

Twenty four (24) of the forty one (41) packages were subjected to CSAM analysis. The purpose of this evaluation is to make sure that multiple re-flow temperature profiles subjected to the packages during the lead free ball removal and the subsequent re-balling process did not initiate or cause underfil delaminations at the flip chip die interface.

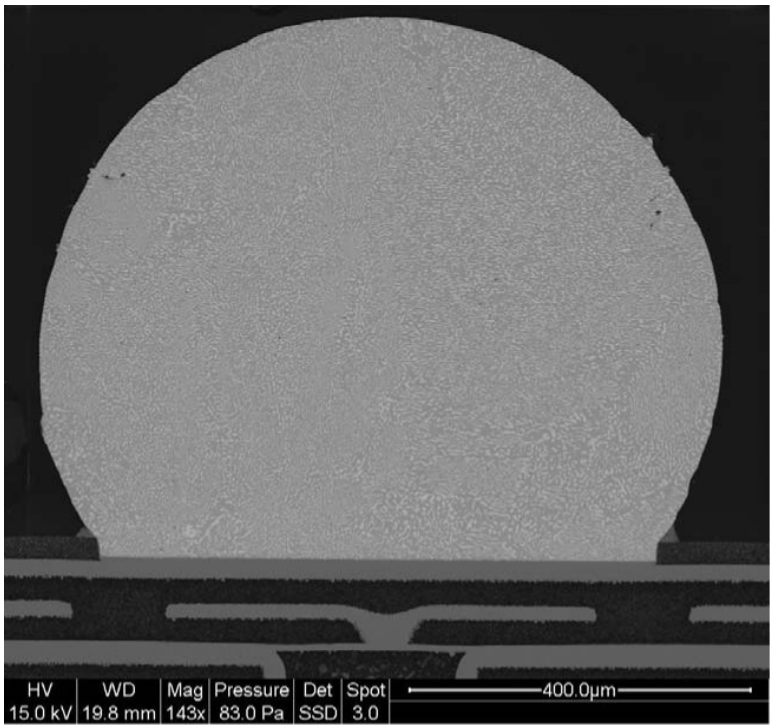
This type of evaluation is normally recommended to be performed when Flip Chip (FC) packages are exposed to temperature excursion or profiles. Underfil delaminations can either failures or compromise the integrity and reliability of the package solder bump interconnects.

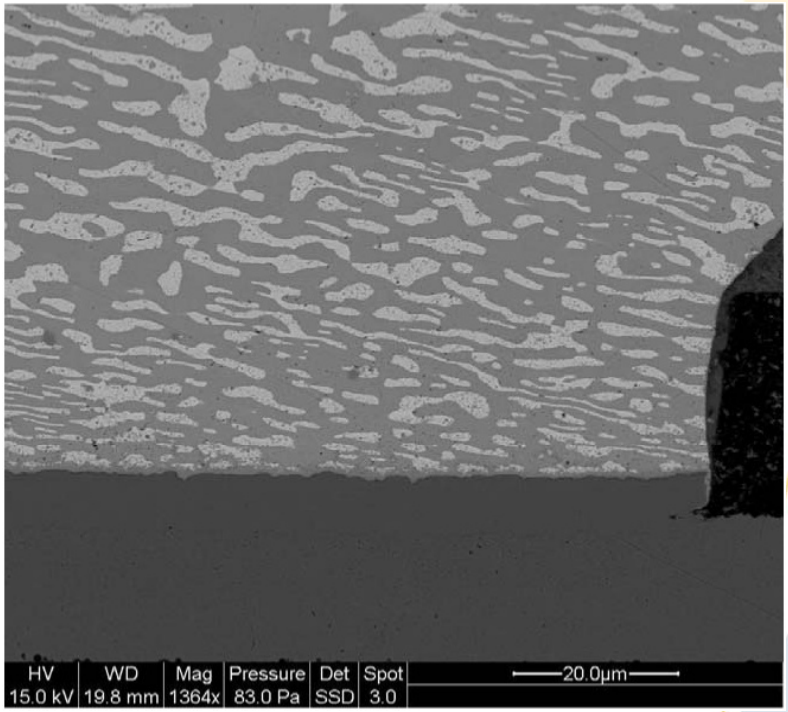
Acoustic Analysis Chart

Illustration of Acoustic Transducer Response Chart

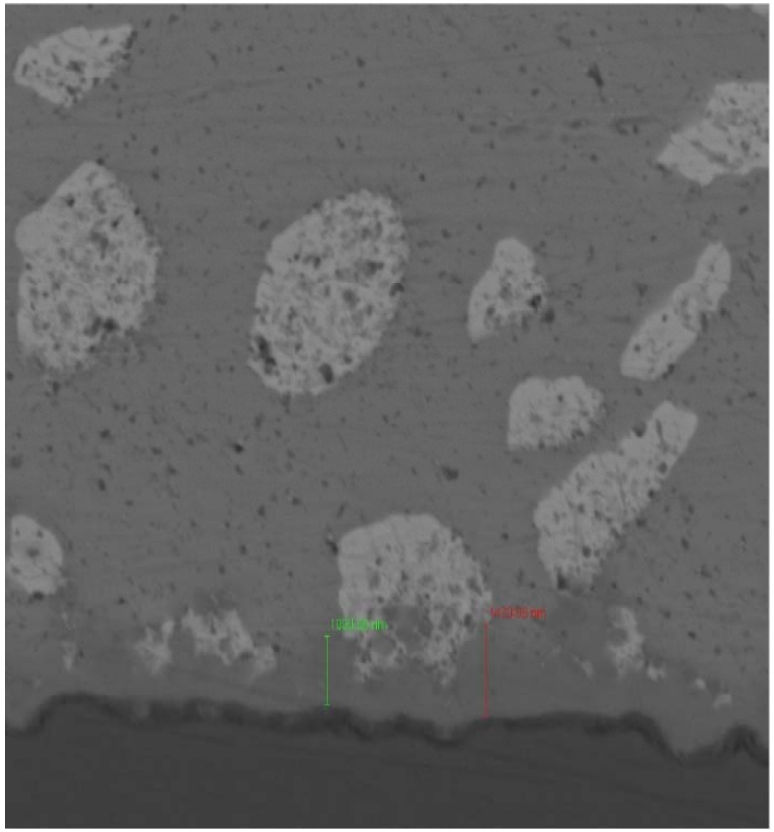


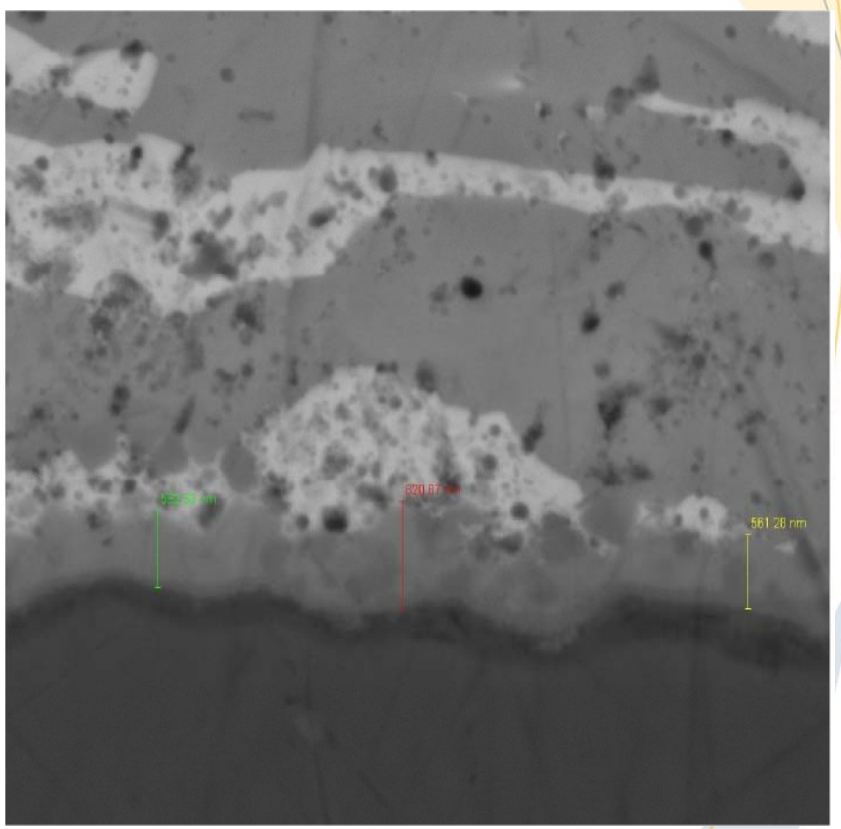
Solder Joint



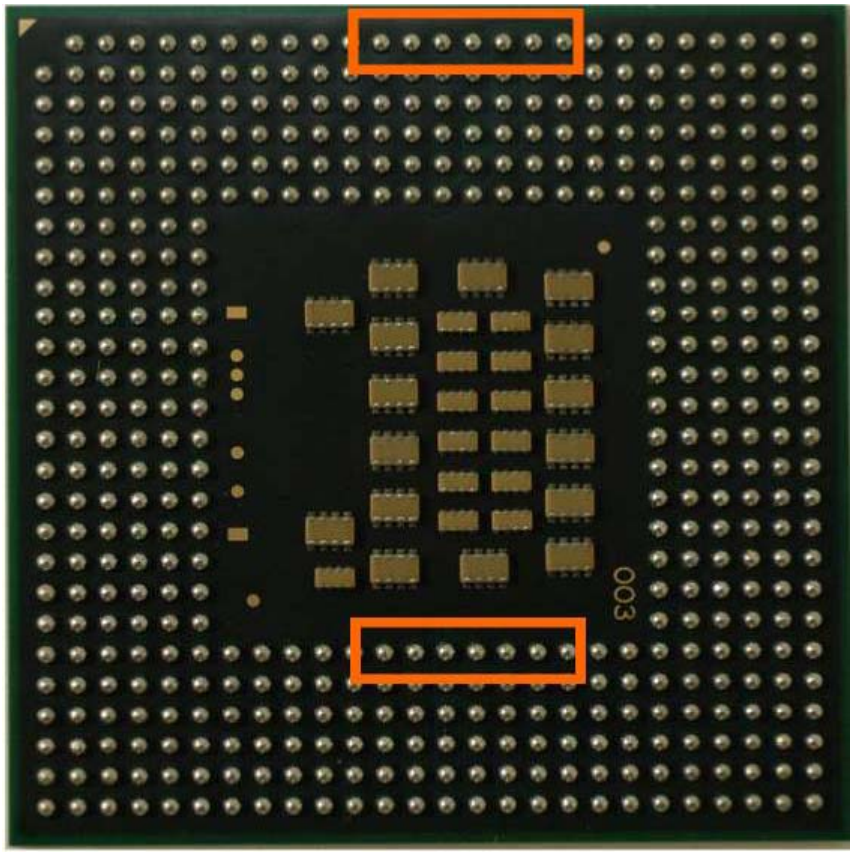


Intermetallic Region





0.6mm Ball Shear



Shear Strength Data

Ball Dia.	Test #	Force (g)	Description	Platform	Load Cell
0.3mm	1	241.58	Pass	Dage 4000	BS5Kg
0.3mm	2	237.18	Pass	Dage 4000	BS5Kg
0.3mm	3	230.50	Pass	Dage 4000	BS5Kg
0.3mm	4	238.53	Pass	Dage 4000	BS5Kg
0.3mm	5	235.77	Pass	Dage 4000	BS5Kg
0.6mm	**1**	**1538**	**Pass**	**Dage 2400**	**BS2Kg**
0.6mm	**2**	**1480**	**Pass**	**Dage 2400**	**BS2Kg**
0.6mm	**3**	**1701**	**Pass**	**Dage 2400**	**BS2Kg**
0.6mm	**4**	**1591**	**Pass**	**Dage 2400**	**BS2Kg**
0.6mm	**5**	**1427**	**Pass**	**Dage 2400**	**BS2Kg**

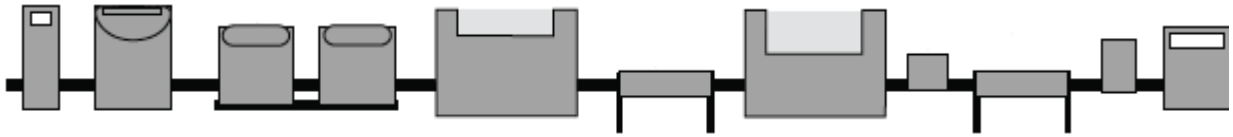
Analytical Conclusions

- X-ray inspection showed no voiding.
- Cross sections showed good metallurgical ball attachment.
- CSAM analysis - no FC/underfil interface delamination
- Extensive solder ball shear performed showed good BGA to substrate solder joints with tight shear force range all above the industry acceptable level. The shear failure was always in the bulk solder indicating strong solder joint to the substrate pads.

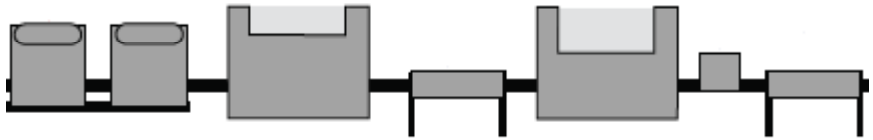
Process Flow

Wafer Dice – Sort – Die Attach / Flip Chip Attach – Underfil – Wire Bond – Encapsulate – Deflash

Inspect – Clean – Flux/Paste Print – Sphere Attach – Inspect – Re-flow – Inspect – Clean – Mark – Inspect – Scan



Singulate - Functional Test – Scan – Final Pack – Inspect - Ship



No Real Choice For The Exempt Industries

Wrap Up

- Supply chain has gotten more complicated in recent years
- There are legitimate options to deal with both counterfeit & RoHS related issues that have served as disconnects
- There are qualified partners to dealing with these disconnect issues
- Do your homework to select a service partner & not settle for just a vendor

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Interconnect PWB Solutions Inc.

Honeywell

HARRIS

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ITB inc.

TT APSCO

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