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

Hal Rotchadl
hrotchadl@premiers2.com
www.premiers2.com
Premier Semiconductor Services
Tempe, AZ

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In addition, exempt OEMs are exposed to other problems caused by some manufacturers not changing P/Ns once the Sn/Pb is obsolete.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

**Table 1 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 & termination of test.

**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)

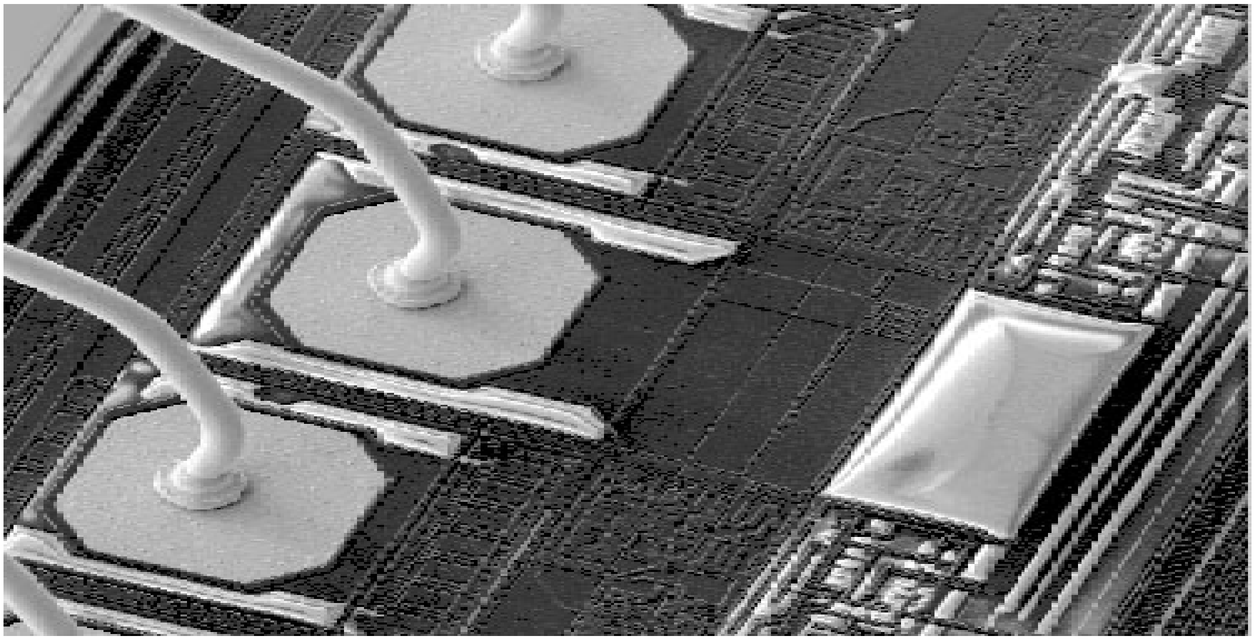

**Figure 1 Wire Bond Device**

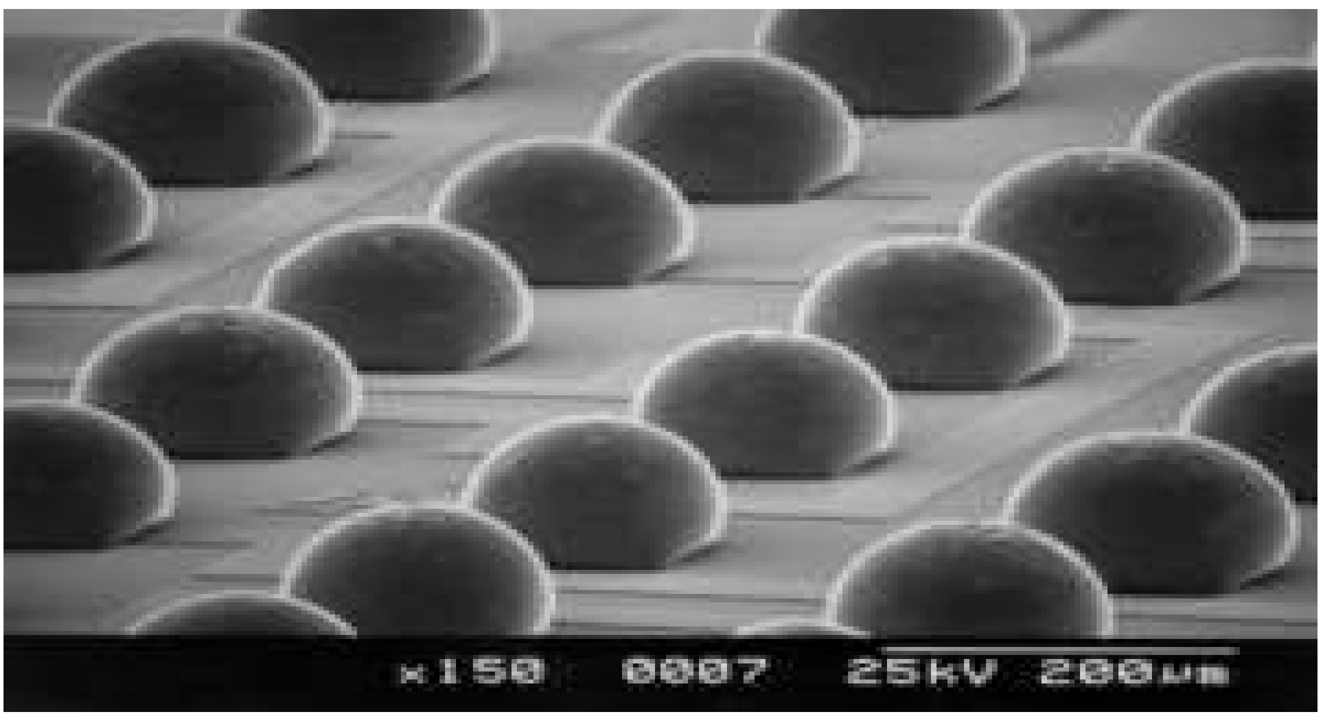


**Figure 2 Flip Chip Device**

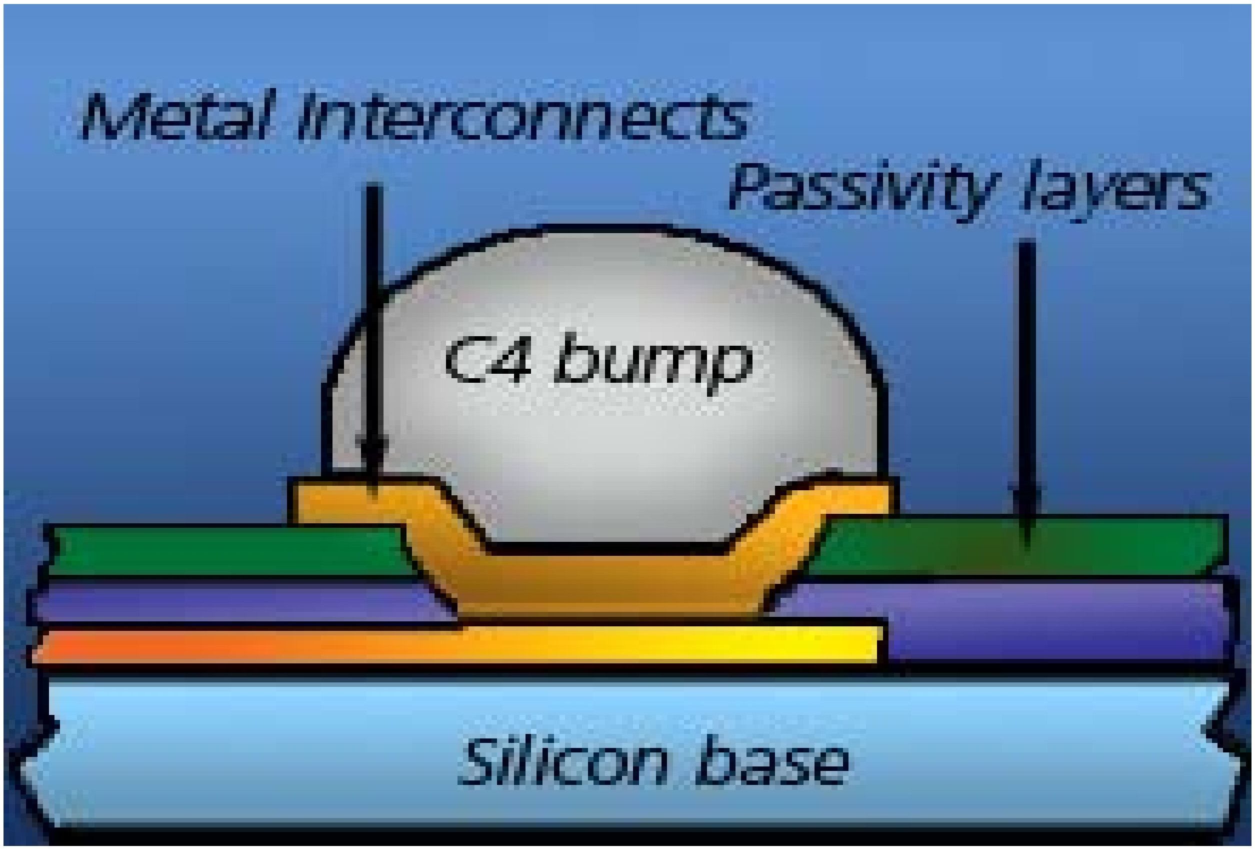


**Figure 3 Flip Chip Bump Construction**

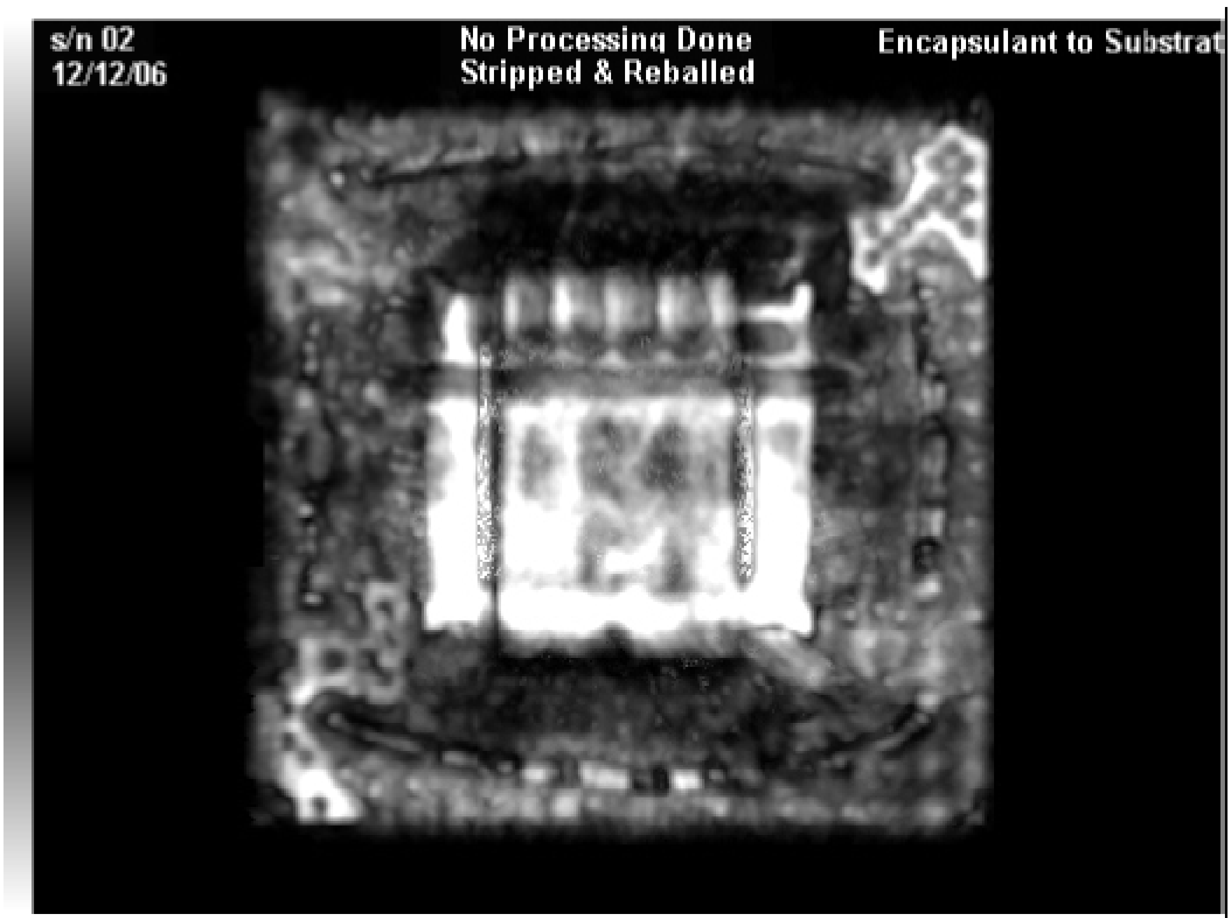


**Figure 4 Encapsulation to Substrate**

**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)

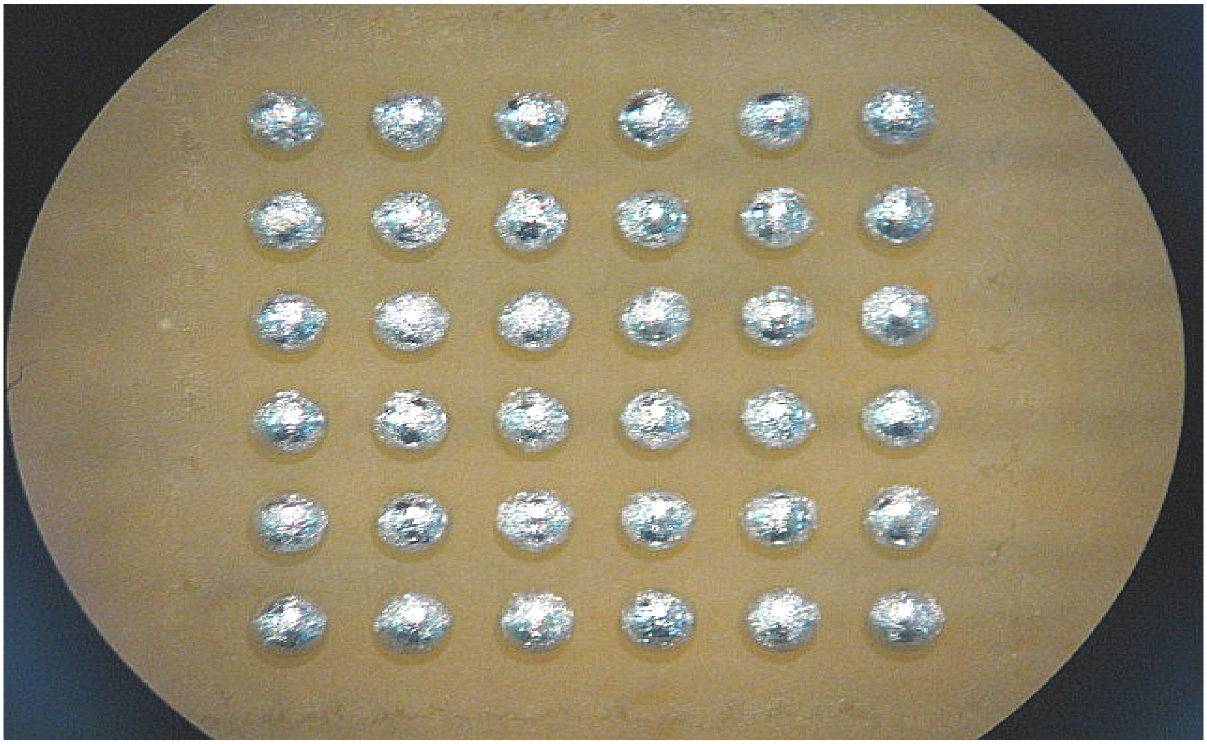

**Figure 5 BGA with Pb Free Spheres**

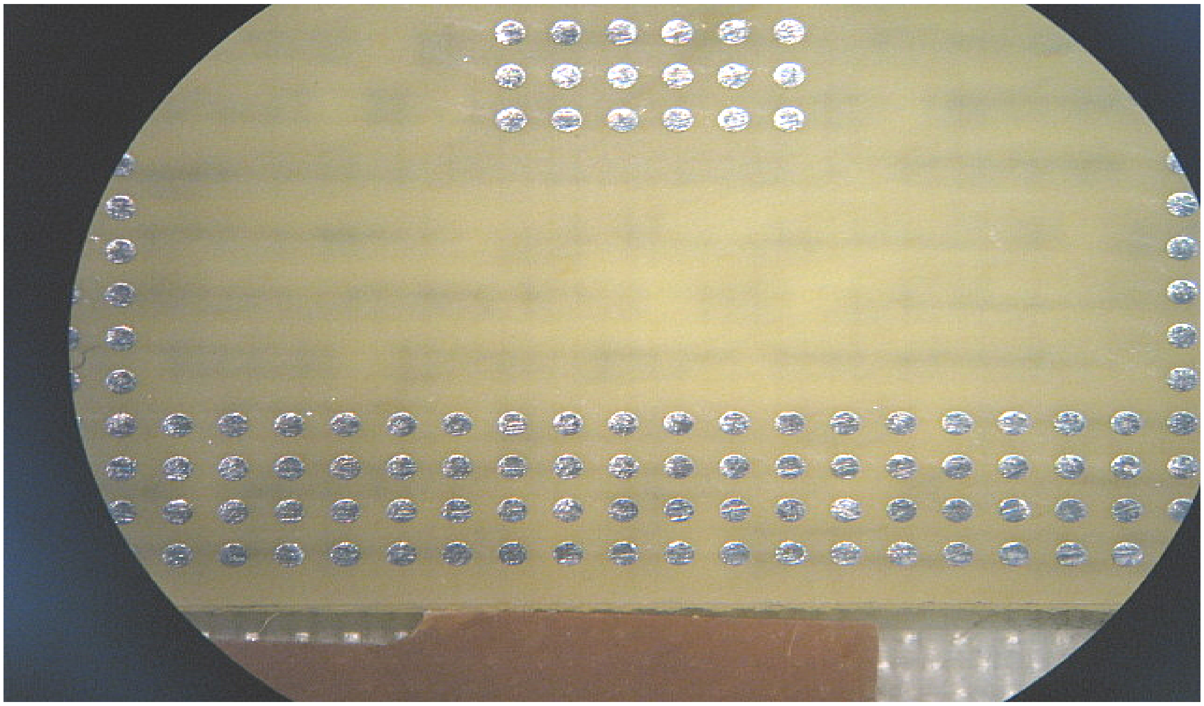

**Figure 5 BGA with Pb Free Stripped Spheres**

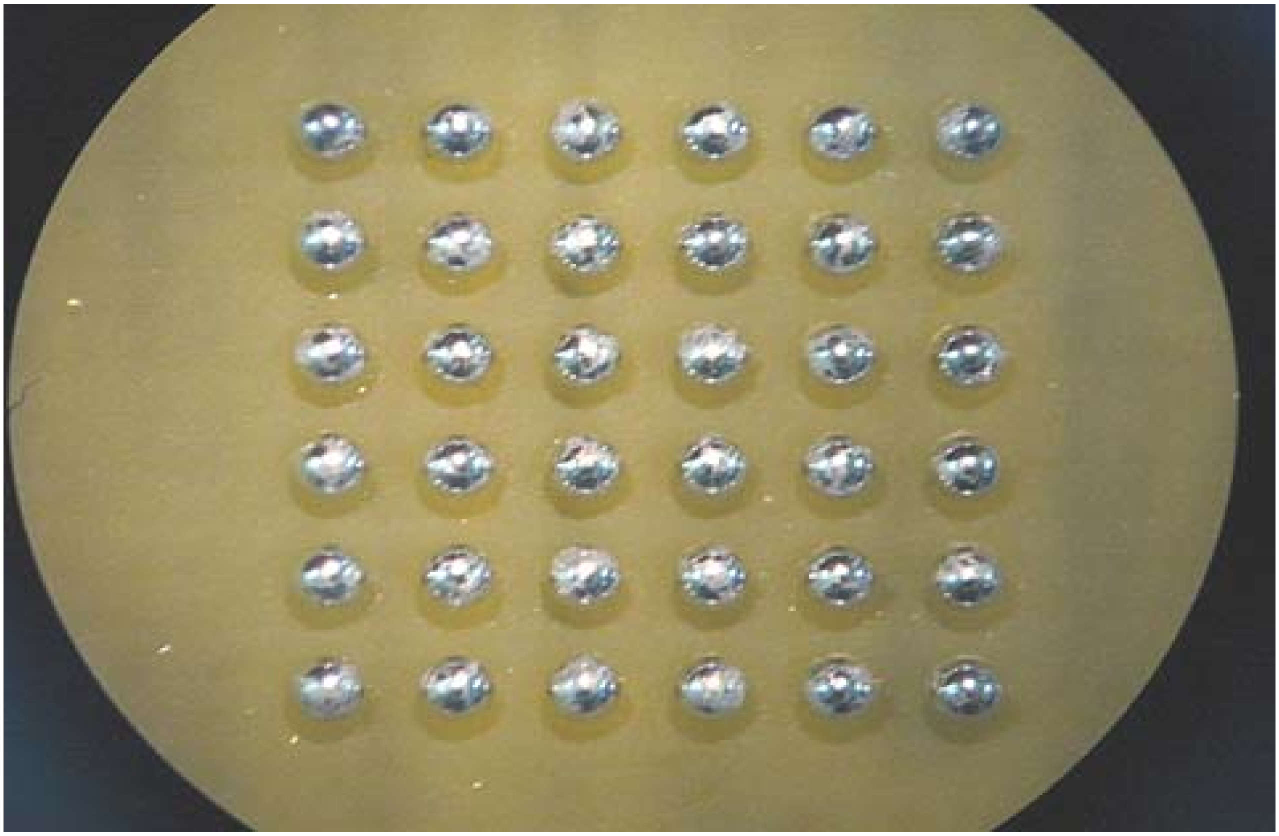

**Figure 6 Attached Spheres**

**Tests performed to validate the solder ball attachment process**

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

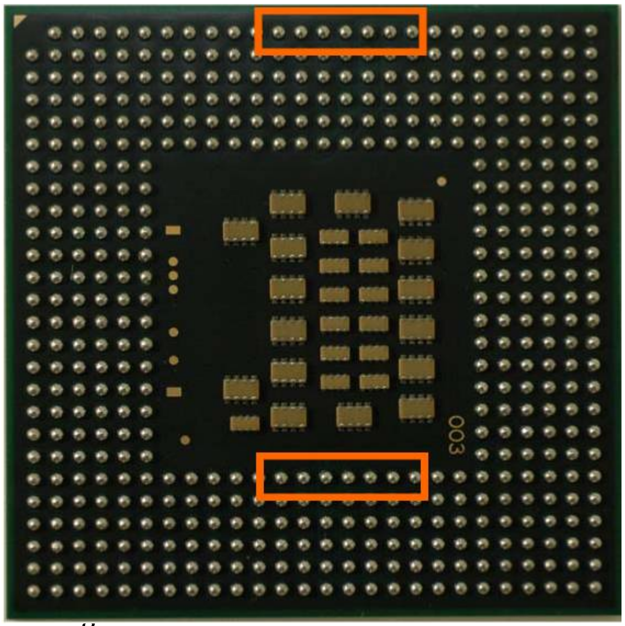





**Figure 7 Shear Test (0.6mm Sphere)**

**Shear Strength Data**

**Table 2**

| 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 |

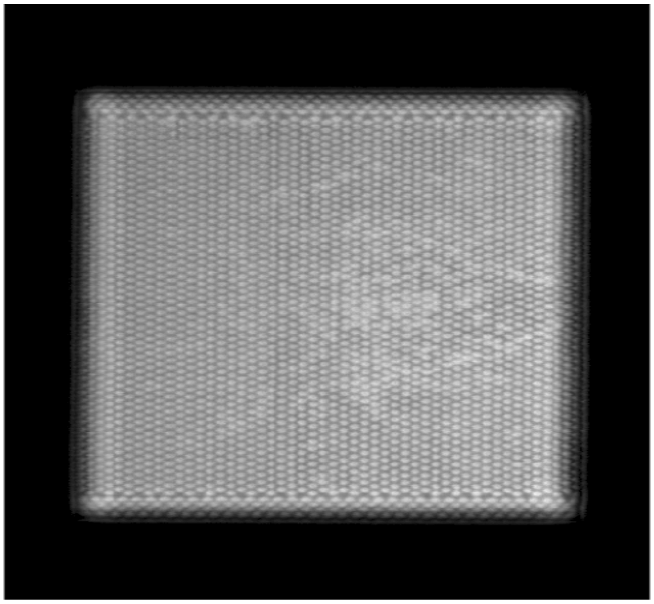

**Figure 8 FC die/underfil interface showing no delaminations from Substrate**

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.


**Figure 9 Example of an Acoustic Transducer Response with response gates at special package interfaces of interest**

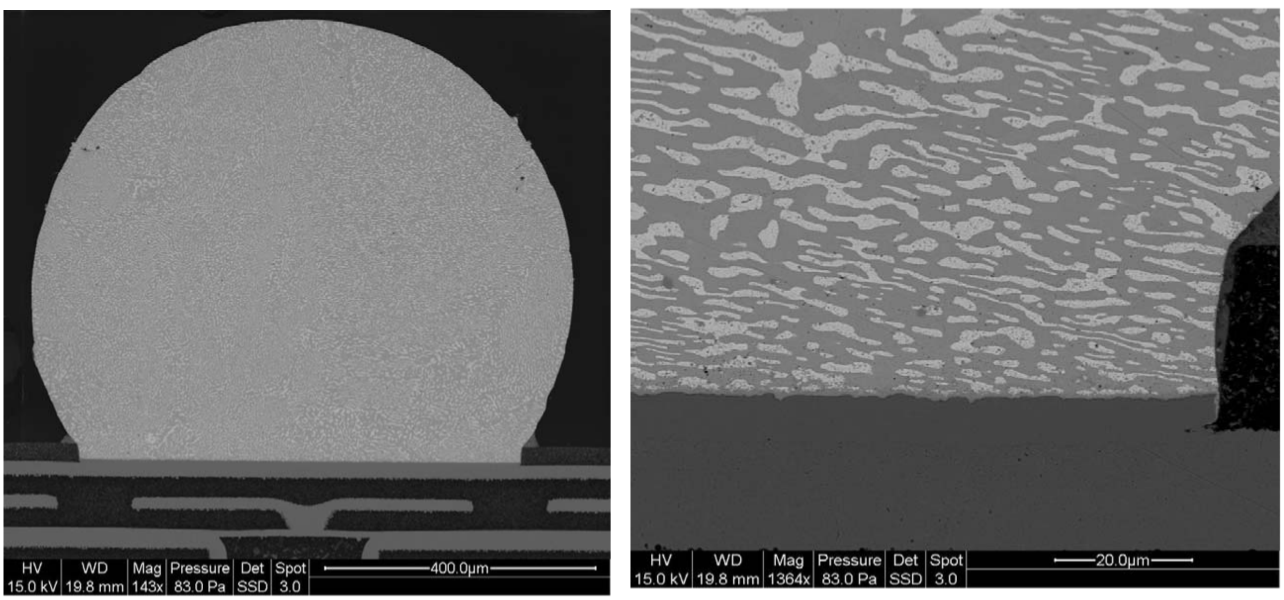


**Figure 10 SEM Inspection of Solder Joint**

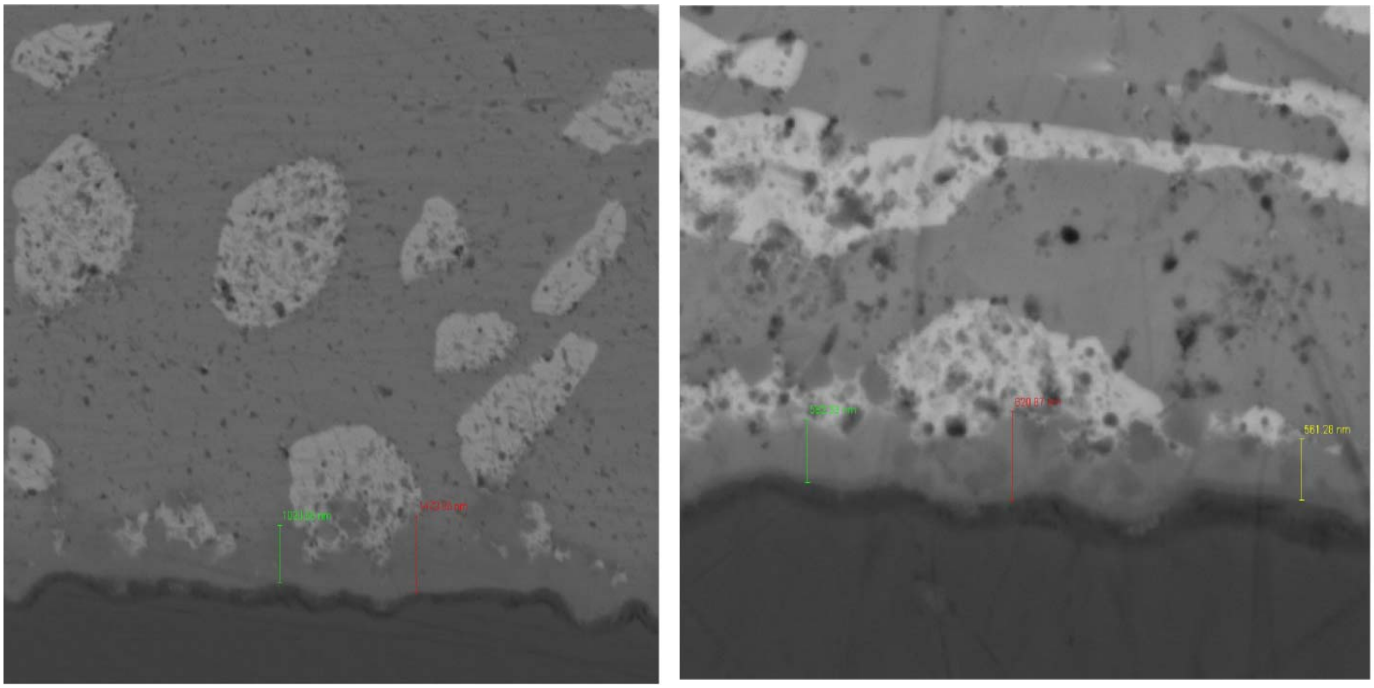

**Figure 11 Intermetallic Region**

**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.