Oxide Thickness and Solderability Methodology to Determine Long Term Storage of BGAs and QFPs

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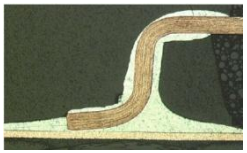
Agenda

- Background and Motivation
- Dry Pack Storage
- Sample (BGAs and QFPs) History
- Component Aging
- Oxide Thickness Measurement
- Solderability Methodology
- Testing Results
- Conclusions
- Recommendations

Background and Motivation

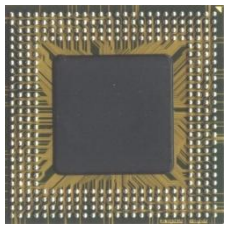
- **Long-term storage of BGA & QFP products may be required due to:**
  - **Fab and assembly factory transfers**
  - **Product obsolescence requiring customers make lifetime/EOL purchases**
  - **Providing extended service (10+ years) on vehicles**
  - **Other program needs**
- **Integrity of EOL products in terms of solderability needs to be verified**
- **Per customer queries a study was performed on various packages to assess oxide growth and solderability**
- **To support customers with data on use of EOL products beyond 2 years**

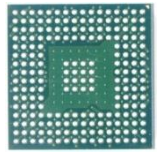
QFPs



Leaded
(All Wire-Bond)

BGAs

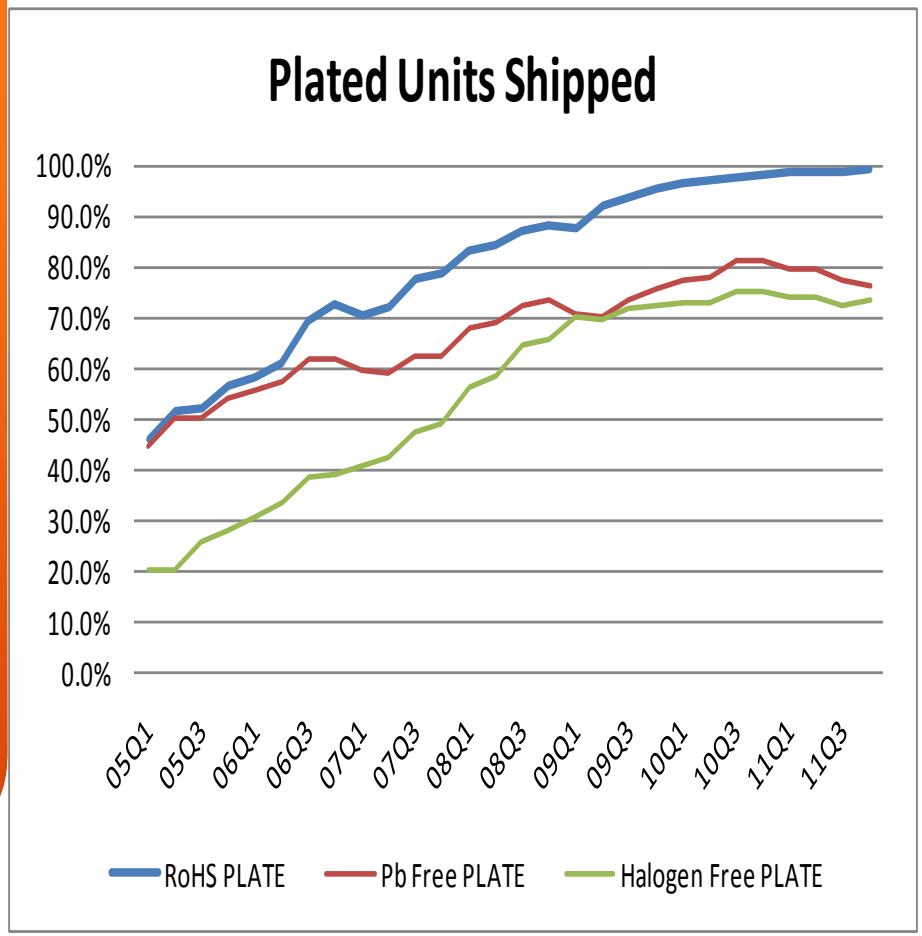


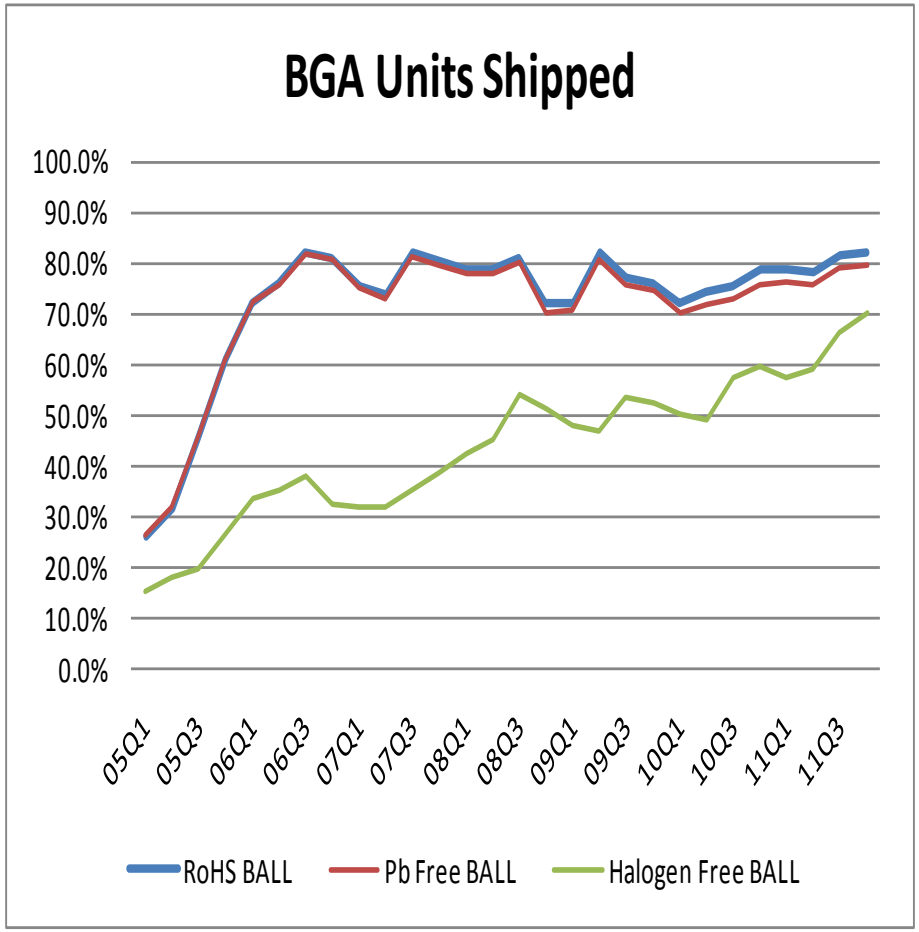


Ball Grid Array
(Wire-Bond or Flip Chip)

Background and Motivation (Cont.)

- As part of the 2006 WEEE Directive, Freescale transitioned most products to Pb-free, Sn-based finishes in 2006
- As of Q3 2011, 70-80% of packages are Pb-free
- Pb-containing products shipping to customer with exemptions





Dry Pack Storage

- Freescale products generally shipped in ESD dry pack bags
- Examples of JEDEC trays and reels in dry pack bags

JEDEC Trays in Tightly Sealed Dry Pack

Product Reel with Potentially Compromised Dry Pack

Sample History for BGAs and QFPs

- **Samples of multiple package types and lead finishes with history were obtained from various sources and storage conditions**
  - **BGAs with SnPb and Pb-free spheres**
  - **LQFPs with Pb-free plating**
  - **Assembly years ranging from 1996 through 2005**
- **Samples were still in original packaging in most cases**
- **All samples processed through MSL bake (125°C/16hrs) prior to testing to ensure parts were dry**
- **Additional component aging carried out using:**
  - **Baking => 150ºC/16hrs**
  - **Steam Aging => 8hrs (97ºC/100% humidity)**
- **Oxide thickness measurements using Auger (AES) and solderability testing were performed on all samples**

Sample History for BGAs and QFPs

FSL Product Type	Package Type	Year Assembled	Storage History	Sphere / Plating Comp	Aging Performed
Memory	119 PBGA	1996	Non-dry Packed Trays / FSL Office Environment	SnPbAg	MSL Bake Steam Age
Automotive Microcontroller	272 PBGA	2003	Dry Packed / 3rd Party Storage	SnPbAg	MSL Bake Steam Age
Network Processor	516 PBGA	2003	Dry Packed / 3rd Party Storage	SAC387	MSL Bake 150ºC Bake Steam Age
Multimedia Apps Processor	280 MAP	2005	Non-dry Packed Trays / FSL Office Environment	SAC105	MSL Bake Steam Age
Network Processor	357 PBGA	2002	Dry Packed / FSL	SAC405	MSL Bake 150ºC Bake Steam Age
DSP	144 LQFP	2003	Dry Packed / 3rd Party Storage	Matte Sn	MSL Bake Steam Age
DSP	80 LQFP	2004	Dry Packed / 3rd Party Storage	Matte Sn	MSL Bake Steam Age
Automotive Microcontroller	64 LQFP	2004	Dry Packed / 3rd Party Storage	Matte Sn	MSL Bake Steam Age

Component Aging

Two ways to age:

Baking = 150ºC/16hrs in air

Steam Age = 8hrs (97ºC/100% humidity)

MSL Bake (125ºC/16hrs) => moisture removal bake not part of aging, but included in this study on all parts

Bake Oven

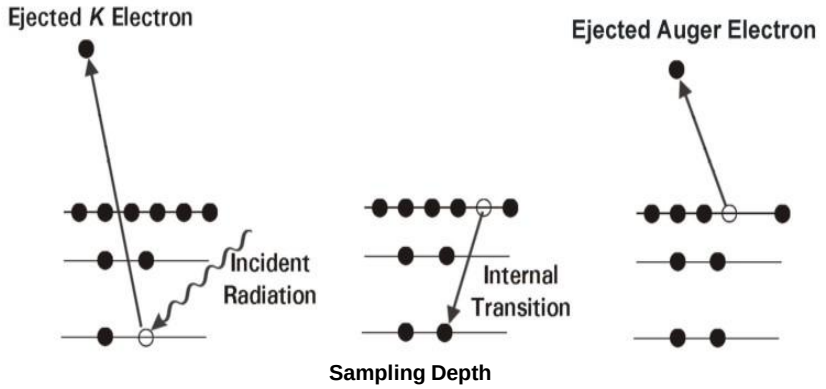
Steam Ager

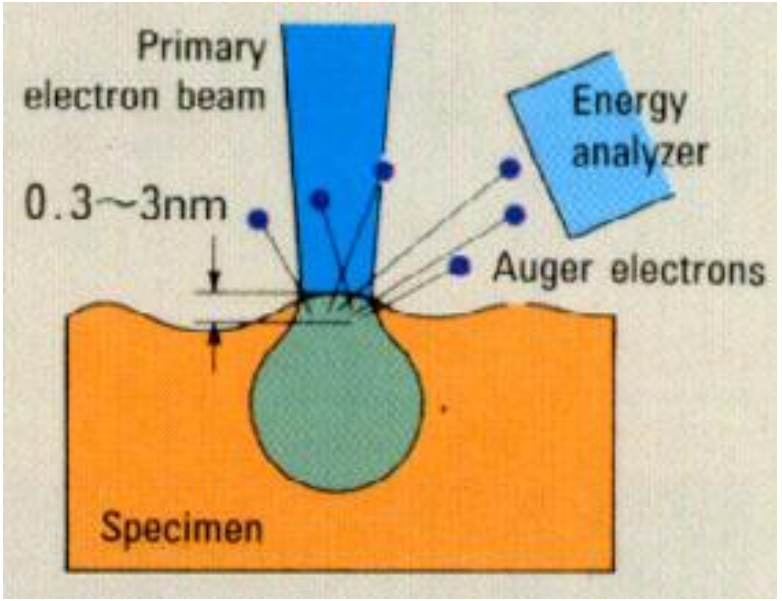
Oxide Thickness Measurement by AES Depth Profiling

Background:

- AES (Auger Electron Spectroscopy)
- AES is sensitive to top most surface layers of sample due to low electron mean free path in solids
- Elemental identification of top 3-5 atomic layers on samples
- Depth Profile Analysis can be used to measure thickness and stoichiometry of surface films
- Focused electron beam allows analysis of areas as small as 100 nm
- SEM imaging capability

Auger Electron Process





Oxide Thickness Measurement (Cont.)

AES Depth Profiling of Plated Lead:

Involves analyzing the surface, sputtering away material & then re-analyzing

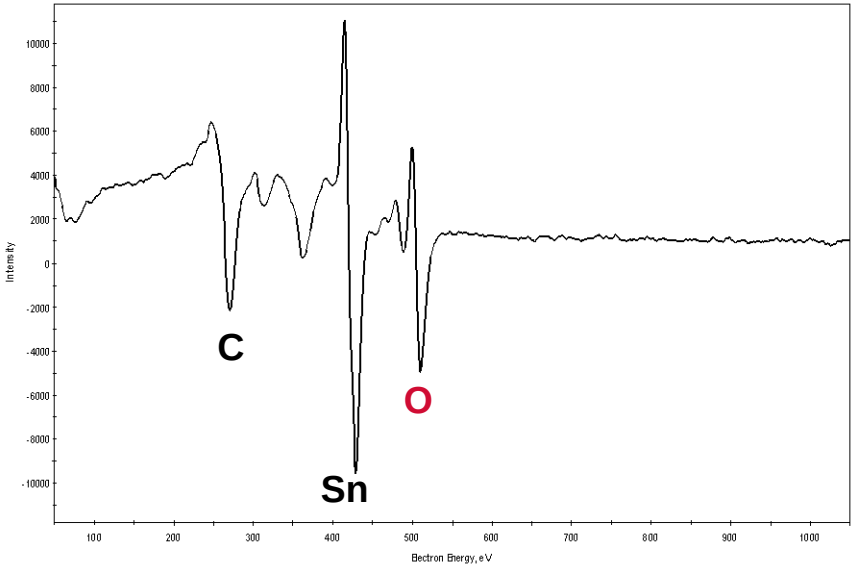
Example with ~ 50Å SnO_x on the Lead

(Oxide thickness number based on SiO_2 sputter rate)

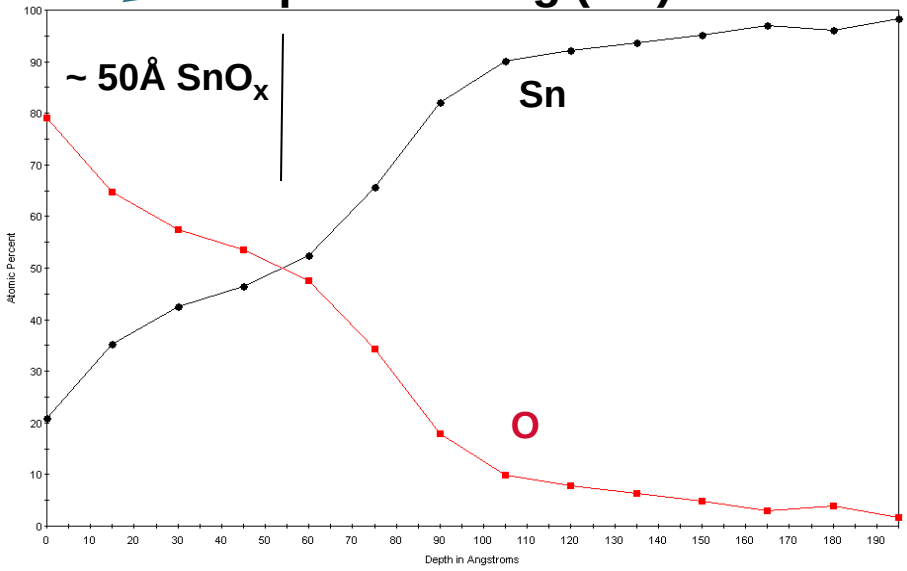
AES

AES DP

Lead Surface



Depth Profiling (DP) of Lead



Results: AES Oxide Thickness Measurements

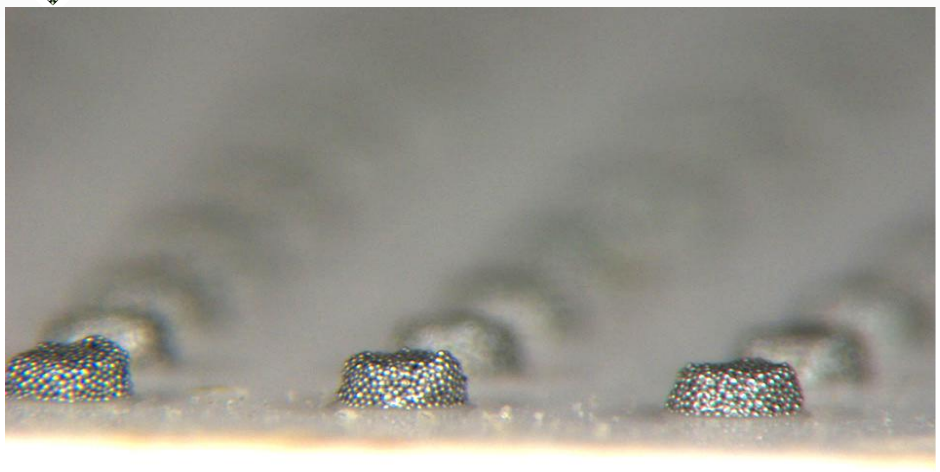
FSL Product Type	Package Type	Year Assembled	Sphere / Plating Comp	Component Aging	Oxide Thickness (Å) by AES DP
Memory	119 PBGA	1996	SnPbAg	MSL Bake	~ 20
				Steam Age	~ 70
Automotive Microcontroller	272 PBGA	2003	SnPbAg	MSL Bake	~ 20
				Steam Age	~ 30
Network Processor	516 PBGA	2003	SAC387	MSL Bake	~ 20
				150ºC Bake	~ 40
				Steam Age	~ 200
Multimedia Apps Processor	280 MAP	2005	SAC105	MSL Bake	~ 40
				Steam Age	~ 70
Network Processor	357 PBGA	2002	SAC405	MSL Bake	~ 20
				150ºC Bake	~ 40
				Steam Age	~ 80
DSP	144 LQFP	2003	Matte Sn	MSL Bake	~ 40
				Steam Age	~ 60
DSP	80 LQFP	2004	Matte Sn	MSL Bake	~ 30
				Steam Age	~ 60
Automotive Microcontroller	64 LQFP	2004	Matte Sn	MSL Bake	~ 30
				Steam Age	~ 60

Solderability Testing Techniques

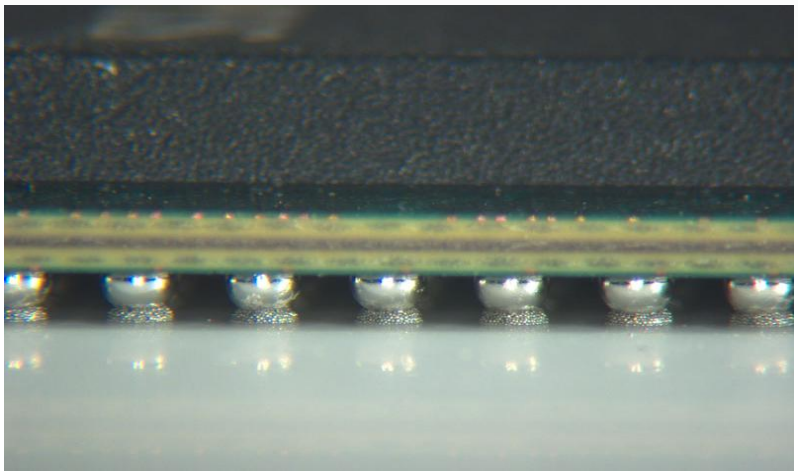
- There are three basic types of solderability testing:
  - Dip and look which uses liquid flux and a solder pot
  - Surface mount simulation (ceramic plate test) which uses a stencil that matches the component, unmetallized ceramic plates and a reflow furnace
  - Wetting balance which uses liquid flux and a specialized solder pot
    - Wetting balance has been a “Test without Established Accept/Reject Criterion” and is for “evaluation purposes only”
- Industry specs that cover solderability testing are:
  - JESD22-B102D – “Solderability”
  - IPC/EIA J-STD-002B – “Solderability Tests for Component Leads, Terminations, Lugs, Terminals and Wires”
- Of the three types, the surface mount ceramic plate test is the only appropriate test for BGAs
  - Also recommended as an alternative to dip and look for fine pitch gull wing lead spacing <0.51 mm

Solderability Test for BGAs

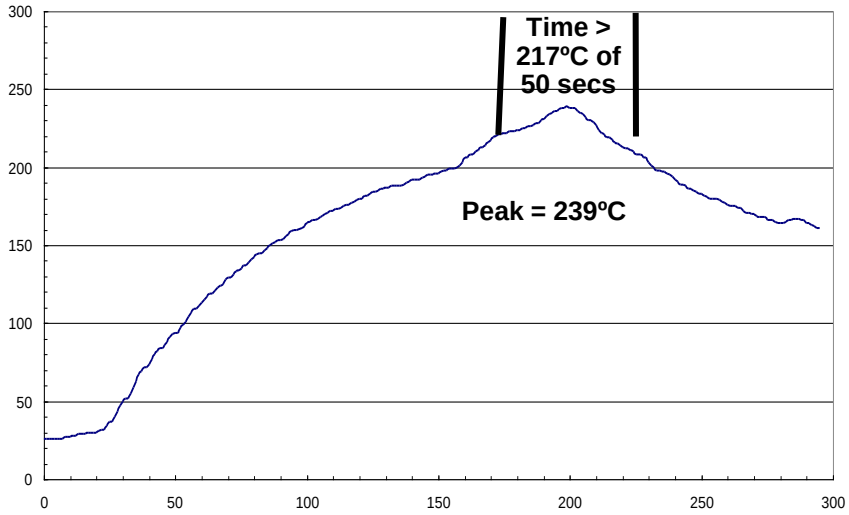
Using Surface Mount Simulation (Ceramic Plate Test)



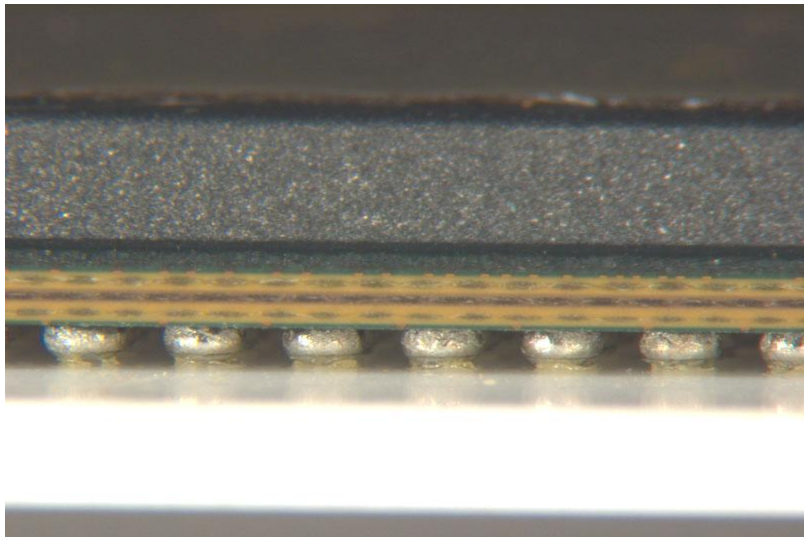
Step 1 - Print SAC387 Solder Paste



Step 2 - Place PBGA into Paste



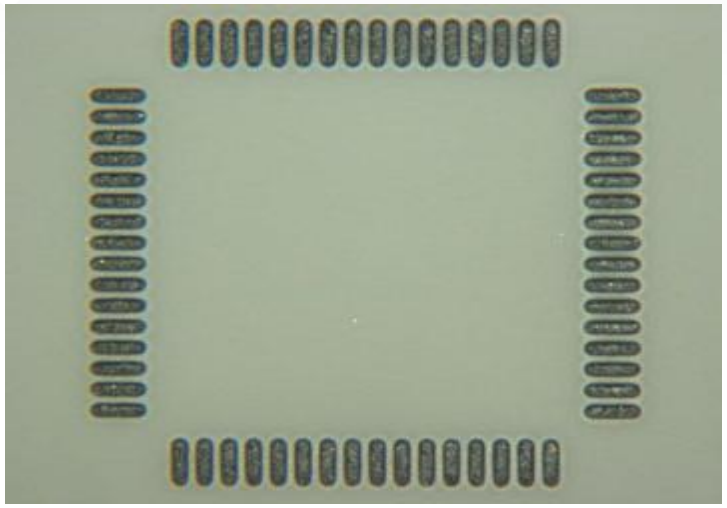
Step 3 - Reflow PBGA (Pb-Free Shown)



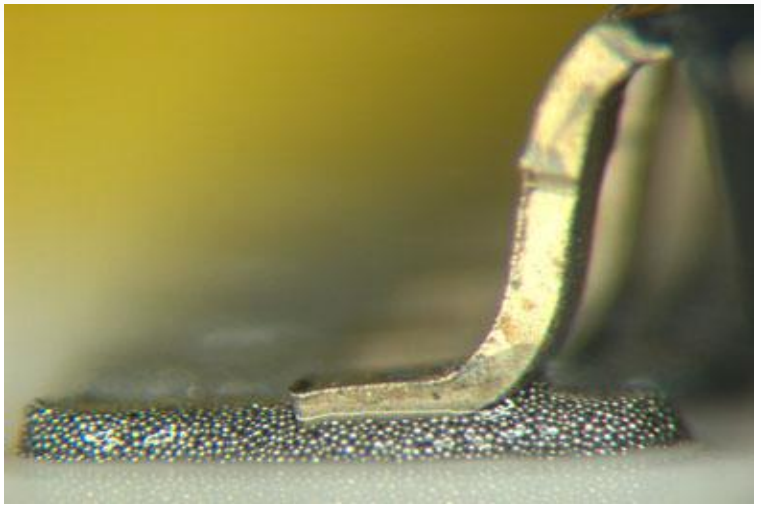
Step 4 - After reflow

Solderability Test for QFPs

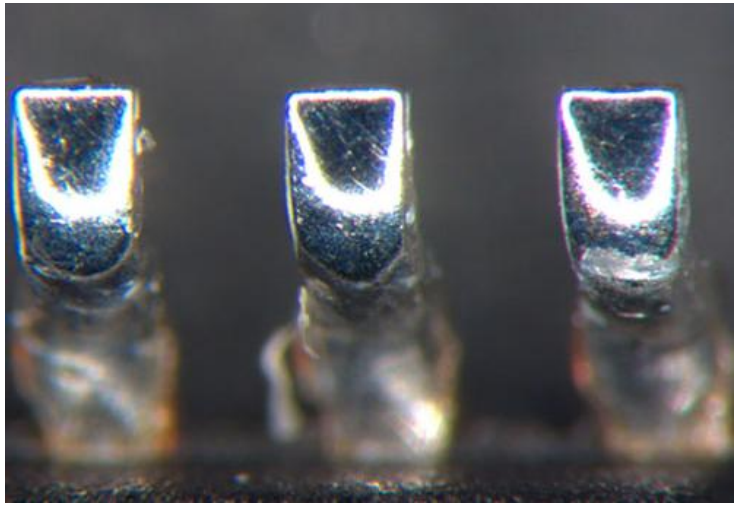
Using Surface Mount Simulation (Ceramic Plate Test)



150um Thick Solder Paste Applied to the Ceramic Coupon



QFP Lead in Paste, Prior to Reflow

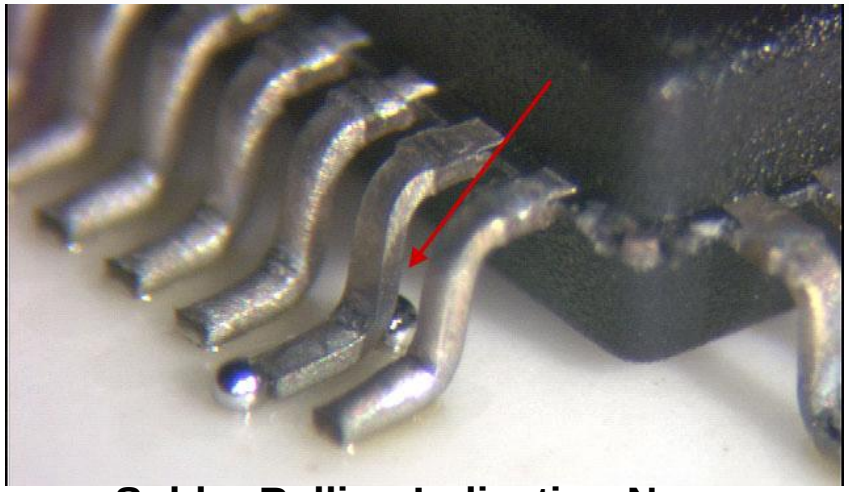


Bottom of QFP Leads Showing Full Wetting

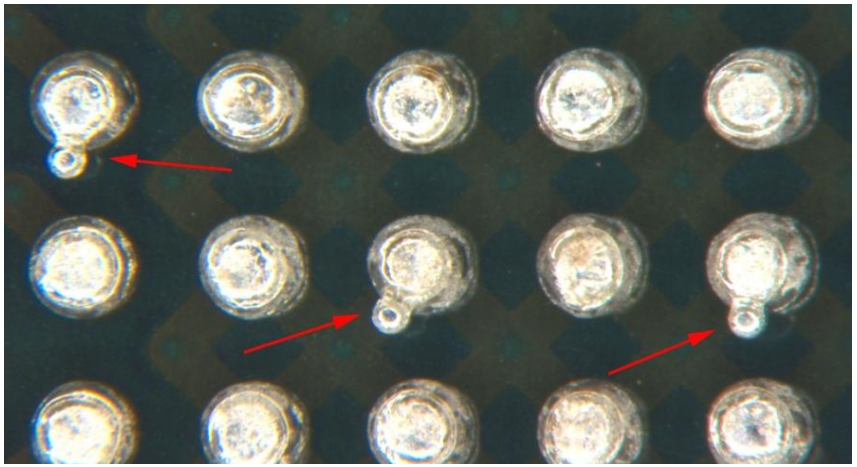
QFP Lead That Fully Wet

Solderability Test - Examples

Fail

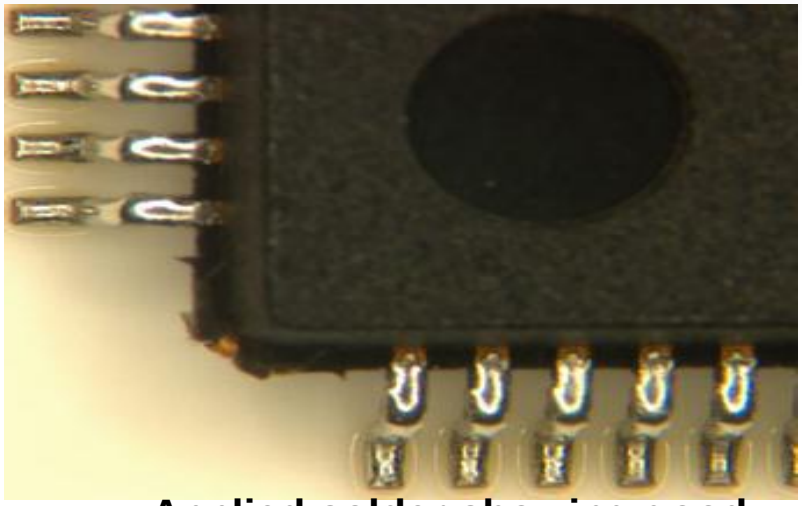


Solder Balling Indicating Non-Wetting at the Foot on a QFP

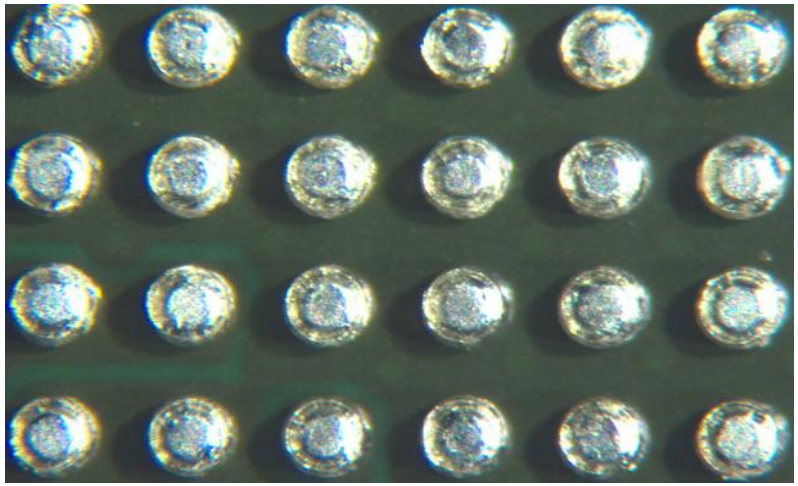


Flipped PBGA Where Applied Solder Did Not Completely Wet the Spheres

Pass



Applied solder showing good Wetting up Lead



Flipped PBGA Where Applied Solder Completely Wet the Spheres

Results: Ceramic Plate Solderability

FSL Product Type	Package Type	Year Assembled	Sphere/ Plating Comp	Aging	Oxide (Å) by AES	Solderability Results
Memory	119 PBGA	1996	SnPbAg	MSL Bake	~ 20	Pass 0/20
				Steam Age	~ 70	Pass 0/20
Automotive Microcontroller	272 PBGA	2003	SnPbAg	MSL Bake	~ 20	Pass 0/20
				Steam Age	~ 30	Pass 0/20
Network Processor	516 PBGA	2003	SAC387	MSL Bake	~ 20	Pass 0/20
				150ºC Bake	~ 50	Pass 0/20
				Steam Age	~ 200	Fail 9/20
Multimedia Apps Processor	280 MAP	2005	SAC105	MSL Bake	~ 40	Pass 0/20
				Steam Age	~ 70	Pass 0/20
Network Processor	357 PBGA	2002	SAC405	MSL Bake	~ 20	Pass 0/20
				150ºC Bake	~ 40	Pass 0/20
				Steam Age	~ 80	Fail 4/20
DSP	144 LQFP	2003	Matte Sn	MSL Bake	~ 40	Pass 0/20
				Steam Age	~ 60	Pass 0/20
DSP	80 LQFP	2004	Matte Sn	MSL Bake	~ 30	Pass 0/20
				Steam Age	~ 60	Pass 0/20
Automotive Microcontroller	64 LQFP	2004	Matte Sn	MSL Bake	~ 30	Pass 0/20
				Steam Age	~ 60	Pass 0/20

Results : Oxide Thickness Vs. Solderability

Oxide Thickness (Å) Data	Solderability Results
~ 20	Pass 0/20
~ 70	Pass 0/20
~ 20	Pass 0/20
~ 30	Pass 0/20
~ 20	Pass 0/20
~ 50	Pass 0/20
~ 200	Fail 9/20
~ 40	Pass 0/20
~ 70	Pass 0/20
~ 20	Pass 0/20
~ 40	Pass 0/20
~ 80	Fail 4/20
~ 40	Pass 0/20
~ 60	Pass 0/20
~ 30	Pass 0/20
~ 60	Pass 0/20
~ 30	Pass 0/20
~ 60	Pass 0/20

- A correlation found between oxide thickness & solderability
- Oxide thickness below ~ 80Å all resulted in good solderability

Conclusions and Recommendations

- Oxide thickness following MSL bake only ranged from 20 to 40Å
- BGAs as old as 1996 (non-dry packed) and 2002 (dry packed) for SnPb and Pb-free, respectively, showed good solderability following the MSL bake
- QFPs as old as 2003 showed good solderability results following MSL bake and steam aging
- The only solderability failures observed were on two of the three Pb-free BGAs that were subjected to steam aging
- These were the only parts with oxide thickness measured at 80Å and above
- Steam aging may be an invalid solderability acceleration of proper dry package storage for Pb-free BGAs
- Overall, good solderability following extended storage (10+ years) is achievable
- This can give customers confidence when carrying out an EOL purchase
- Proper storage with good dry package integrity is always recommended
- This study is not intended to extend or modify the terms of FSL's warranty

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