Environmentally Preferred Products:
Development of Lead (Pb)- Free and Bromine (Br)- Free Solutions

Table of Contents

1.0 Lead (PB) Free Development
2.0 Lead (PB) Free Solder
    2.1 Development Activities
    2.2 Package View
3.0 Lead (PB) Finishes
4.0 Evaluation Plan
    4.1 Moisture Sensitivity Evaluation
    4.2 Reflow Profile
    4.3 Plating Finish Evaluation Method
5.0 Evaluation Summary
    5.1 Selection Results
    5.2 Assembling with Lead (Pb) Free Components
    5.3 Reliability of Lead (Pb) Free Component Finishes and Sn Pb Board Solder Surfaces
6.0 Sample and Product Readiness
    6.1 Conversion Plans
    6.2 Roadmap for Development of Environmentally Preferred Packaging
    6.3 Manufacturing Readiness
    6.4 Lead (Pb) Free Products Identification
7.0 Environmentally Preferred Packages

If you have any environmentally preferred product needs, please contact your sales or marketing representatives directly, or through the contacts below:

Technical Support
Americas: 1 (800) 521-6274 6 a.m. - 5 p.m. Mountain Standard Time
Asia: +852-2666-8307 8 a.m. - 6 p.m. Hong Kong
Japan: 0120-191-014 8 a.m. - 5 p.m. Tokyo
Europe: +49-89-92103-559 9 a.m. - 5 p.m. Munich

For the purpose of Freescale's Environmentally Preferred Product (EPP) Program the following definition applies:

Freescale Lead (Pb) Free Compliant. Electrical and electronic assemblies and components in which the LEAD (Pb) level in any of the homogeneous materials and the end product is less than or equal to 0.1% by weight or meets all LEAD (Pb) free requirements and exemptions adopted by the Restrictions on Hazardous Substances (ROHS) Directive 2002/95/EC.

Overview

At Freescale Semiconductor, we have embarked on a challenging journey–to become a company that fully supports a sustainable use of the earth's resources. We know it will take time to get there. We know that there are large challenges for us. But we also know that we must begin this journey–for the benefit of our company, its stockholders and our neighbors throughout the world. In essence, sustainability is about conserving natural resources and reducing our burden on the land, air and water to offer future generations the opportunity to thrive on our planet. Here we focus on very specific activities in the journey–Pb (lead)-free and bromine-free product development–within Freescale Semiconductor.

1.0 Lead (Pb) Free Development:

Our Lead (PB) free development program includes:

- implementation of robust lead (Pb) free plating finishes across multiple factories and subcontractors
- qualification of lead (Pb) free solder balls for area array packages
- implementation of lead (Pb) free solder balls on 2nd level interconnect for flipchip packages
- evaluation of Br-free encapsulants and organic substrates
- incorporation of lead (Pb) free terminations and high temperature reflow capability into new product designs

2. Lead (Pb) Free Solder:

In order to use the new lead (Pb) free solders such as the tin silver copper solder (Sn 3.8Ag 0.7Cu) recommended by NEMI, reflow temperatures have to be increased. Eutectic solder melts at 183°C-210°C. SnAgCu melts at 221°C-227°C. Thus to get a good flow to the solder joint typicalsoldering temperatures will have to increase by 20 to 30 degrees.

2.1 Development Activities:

There are two activities in the development process to reduce Pb from components or systems:

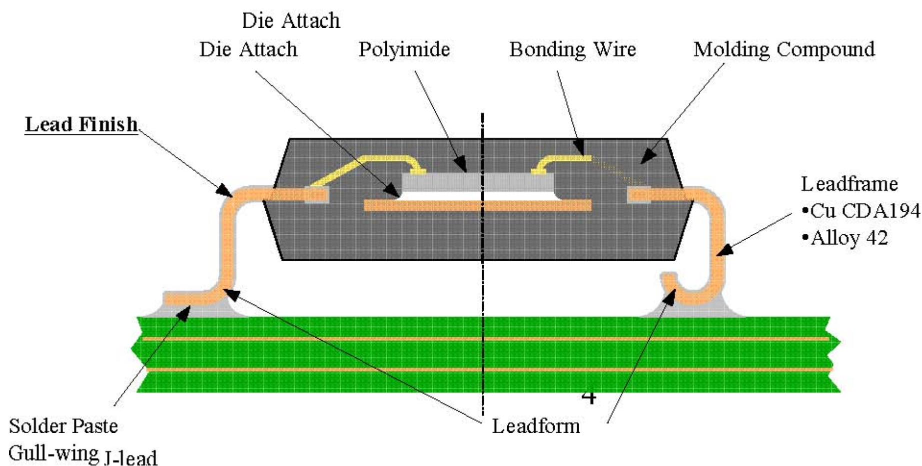
The first activity is the evaluation of Pb-free terminals and terminal plating finishes for components. Evaluations are performed on Pb-free components to validate reliability of Pb-free plating finishes for peripheral packages and Pb-free spheres for area array packages. Pb-free packages must also be compliant with the new high-temperature reflow

moisture sensitivity level (MSL) conditions.

The second activity is the development of solutions to Pb reduction to the flip-chip packages and to evaluate high-temperature die attach soldering solutions for power packages that require high thermal conductivity top heat sinks integral to the package.

2.2 Package View:

The following drawings illustrate the package areas affected by Pb elimination.



In order to be classified as lead (Pb) free the component will have a Pb free finish and be high temp reflow capable. The plating finish on the leads or the solder ball will be Pb free.

3. Lead (Pb) Free finishes

Freescale has various existing solutions for lead (Pb) free terminations, such as matte tin (Sn), tin bismuth (SnBi) and nickel palladium gold (NiPdAu). For lead (Pb) free conversions on leaded packages, Freescale has selected matte tin as the preferred solution for plating finishes even though SnBi or NiPdAu may be used for a small subset of packages and factories. For lead (Pb) free conversions on array packages, Freescale has selected tin silver copper (SnAgCu) solder spheres as the solution.

3.1 Exemptions

The Waste in Electrical and Electronic Equipment Directive (WEEE) will be applicable

throughout the European Union by 1st July 2006 for the ban and on the use of certain substances including lead (Pb). In February 2003 the Restriction of the use of Hazardous Substances (RoHS) in electrical and electronic equipment entered into force. RoHS allows certain exemptions to banned materials. The directive allows high lead (Pb) solders greater than 85%; this applies to lead (Pb) in glass or ceramic seals, or high lead (Pb) content solders for which there is no technological or cost effective solution. The current End of Life Vehicle (ELV) directive exempts all lead (Pb) in solders of electronic circuit boards in vehicles.

Flip chip BGA will be available with lead (Pb) free solder balls for external soldering, however it will continue to have its high content lead (Pb) internal bumps. Heat Sink Small Outline Packages (HSOP) with exposed heat sinks and solder die attach will contain a high lead (Pb)solder, and ceramic parts with vitreous glass will also contain lead (Pb).

4. Evaluation Plan

4.1 Moisture Sensitivity Evaluation

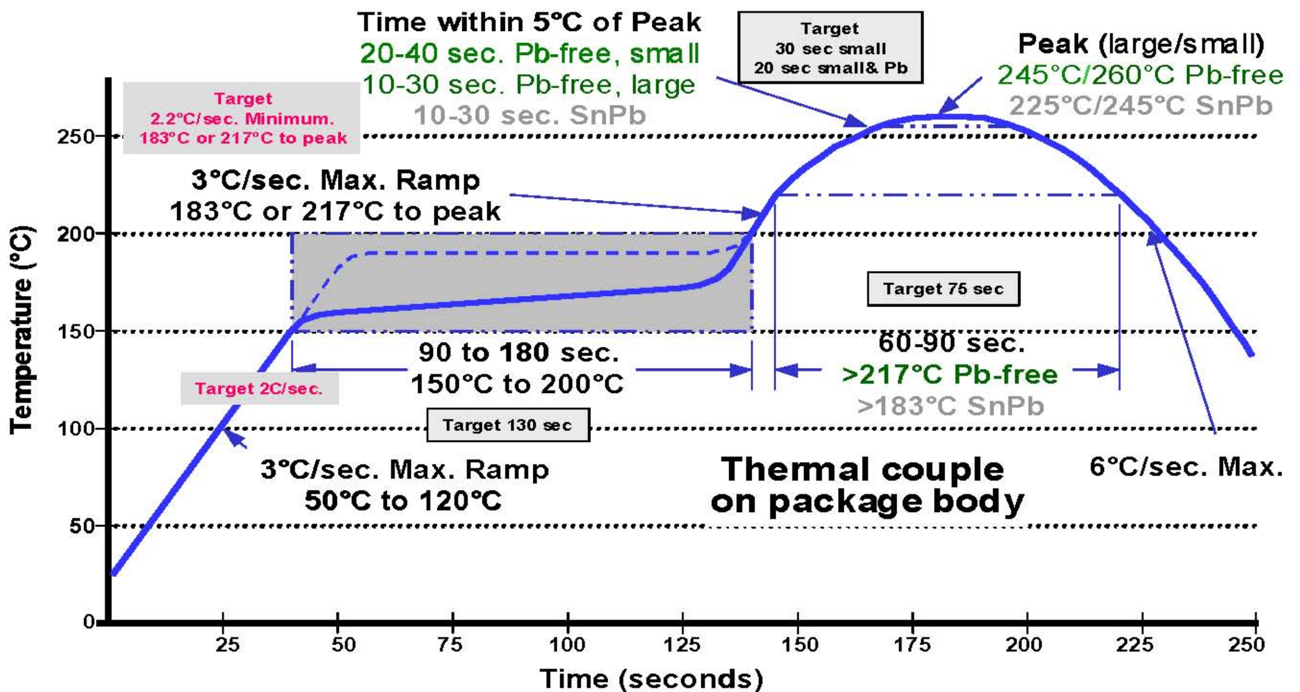
The MSL classification is a way of rating surface mount devices that are sensitive to moisture-induced stress so that they may be properly packaged, stored, and handled to avoid subsequent thermal/mechanical damage during the assembly solder reflow attachment and/or repair operations. Freescale uses the IPC/JEDEC standard as a basis of moisture sensitivity evaluation, J-STD-020B (Moisture/Reflow Sensitivity Classification for Non-hermetic Solid State Surface Mount Devices) and numerous customer specifications to define the moisture sensitivity level (MSL) test method of plastic packages.

> Moisture Sensitivity Classification Whisker growth is evaluated based on experimentation in concert with NEMI and JEIDA. The Freescale procedure is to store one set of units at 60°C/95%RH and perform a SEM analysis after 500hrs; temp cycle second set of units at -55°CC/85°CC followed by SEM after 500 cycles; a third set of units are stored at room atmosphere conditions for 500 hours and examined by SEM analysis. The maximum length of a whisker allowed is 75 microns.

Reliability Level Classification	Moisture Soak	Dry Pack Required?	Customer Handling After Barrier Bag is Opened
L1	85C/85%RH 168hrs	No	No Restrictions
L2	85C/60%RH 168hrs	Yes	Up to 1 year @ 30C, <60%RH
L3	30C/60%RH 192hrs	Yes	Up to 1 week @ 30C, <60%RH
L4	30C/60%RH 96hrs	Yes	Up to 72 hours @ 30C, <60%RH
L5	30C/60%RH 72hrs	Yes	Up to 24 hours @ 30C, <60%RH

4.2 Reflow Profile:

One standard temperature reflow profile is used for Moisture Sensitivity Characterization. The profile was developed using IPC/JEDEC J-STD-020 as the base line document and numerous customer specifications.



4.3 Plating Finish Evaluation Method:

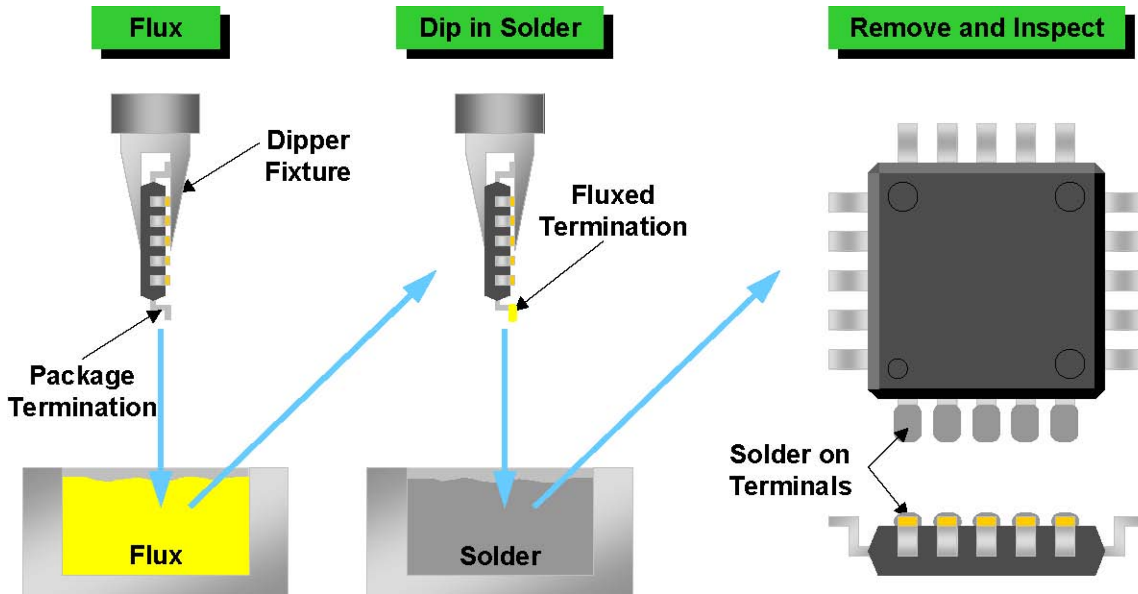
Evaluation of Pb-free terminal finish includes 1) manufacturability, 2) whisker growth, 3) solderability and 4) solder joint reliability for standard packages. These items may vary from package family and die. This is in addition to the standard qualification procedures.

Manufacturability:

The plating process is evaluated looking at several key factors: bath performance, plated deposit, and compatibility with subsequent processes.

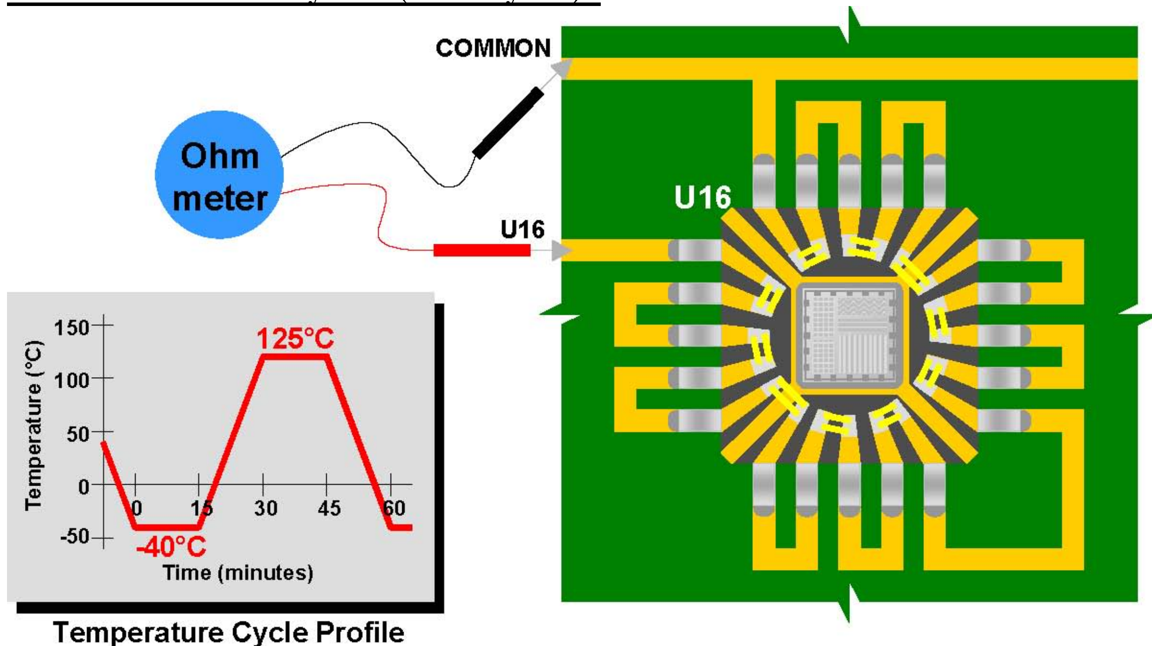
Whisker Growth:

Solderability test (>95% wetting):



Solderability is performed in accordance with IPC J STD 002 or IEC 68-2-20. Precondition units (~97°C, 100RH, 8hrs) and perform dip and look test with both Sn/37Pb and Sn/3.8Ag/0.7Cu solder. The criterion is 95% coverage.

Solder Joint Reliability Test (>2000cycles):



Board level solder joint reliability is performed by reflow soldering surface mount units onto printed wired boards (PWB) with Sn37Pb and Sn3.8Ag0.7Cu solders. Temperature cycling the PWB assembly is performed from 0°C/100°C or -40°C/125°C and monitored in-situ or manually each week. Temperature cycle ranges are determined based on the application.

5. Evaluation Summary

5.1 Selection Results: Peripheral Packages:

Based on the results of the manufacturability and reliability evaluations, pure Sn, NiPdAu, and SnBi are selected as preferred Pb-free finishes. Lead finish is dependent on package type and assembly location.

Area Array Package:

Sn-4.0Ag-0.5Cu is selected as the Pb-free solder sphere for area array packages.

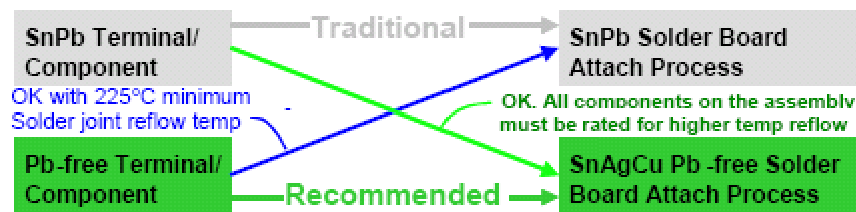
5.2 Assembling with Pb Free Components.

Soldering of the SnAgCu spheres supplied on Pb free BGA's will typically require extensive changes to the board assembly reflow profile. SnAgCu based solders have a melt temperature that is approximately 40°C higher than eutectic SnPb based solders. It is preferable that Pb free BGAs be soldered with Sn-based Pb free solder pastes employing fluxes formulated for the associated higher process temperatures. The Sn4.0Ag0.5Cu sphere that Freescale has standardized on for Pb free solutions melts at 222°C. Reflow profiles from approximately 230°C up to the component's rated moisture sensitivity level (MSL) package peak temperature that optimize the solderability of the Pb-free paste and sphere combination should be used. MSL package peak temperatures for Pbfree components typically range from 245°C to 260°C and should always be verified with Freescale.

		Composition (Weight %)		
		95.5Sn4.0Ag0.5Cu (Pb-free Sphere)	62Sn36Pb2Ag (Std Pb Bearing Sphere)	63Sn37Pb (Typical Pb Bearing Pastes)
Temp (°C)	Solidus	216	179	183
	Liquidus (Approx. Melt)	222	189	

Source: http://www.nist.gov/

Pb free BGAs can also be soldered with traditional SnPb solder paste, but at higher than the typical 205°C-220°C reflow temperatures commonly used with SnPb. A minimum peak temperature of 225°C is recommended in this case. Temperatures below that can result in decreased assembly yield and/or interconnect reliability. However, SnPb solder pastes may not be optimized for these increased reflow temperatures resulting in diminished flux effectiveness. At peak temperatures at or above 225°C, reliable interconnections have been demonstrated with Pb-free spheres and SnPb solder paste. Temperatures closer to or below the 222°C melting temperature of the SnAgCu sphere will result in incomplete collapse of the SnAgCu sphere and prevent homogenization of the sphere with the SnPb paste. Care must be taken that any Pb-bearing components on the assembly may only be rated to a peak reflow of 225°C. The other potential mixed alloy soldering scenario of the standard SnPb based sphere assembled with Pb free solder paste has also been shown to yield a reliable interconnect. When soldering SnPb based BGAs at Pb free reflow temperatures it is especially important to verify the MSL rating since they may not be rated for high temperature reflow.



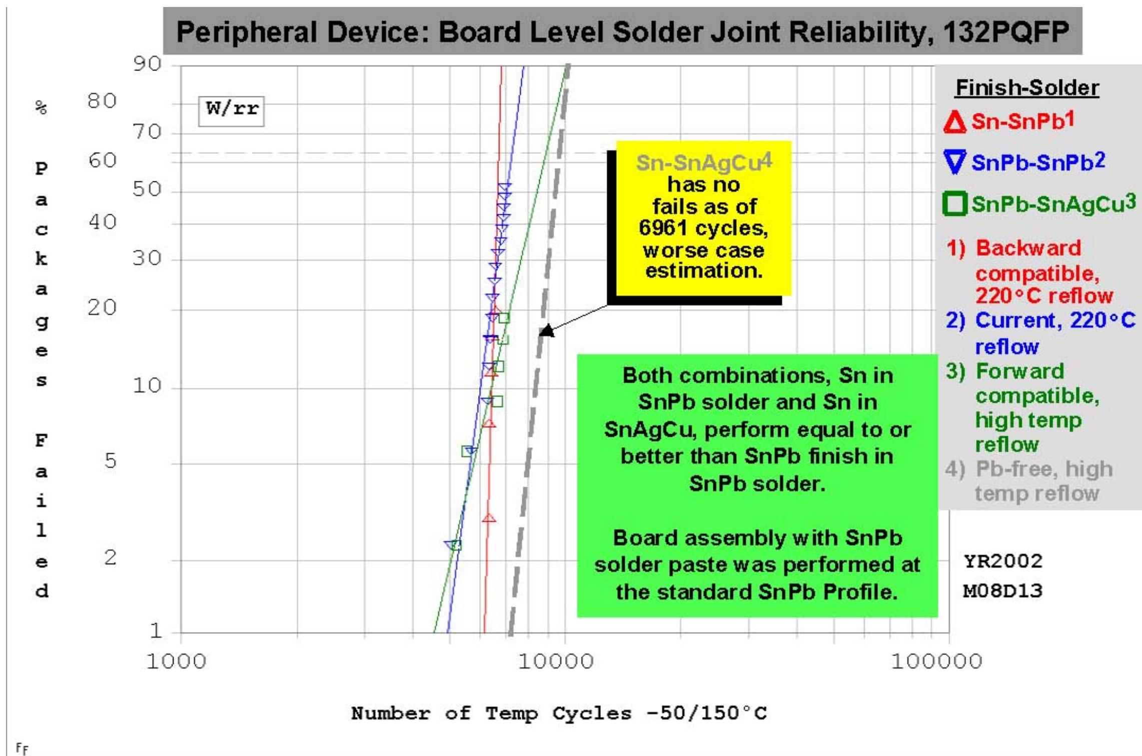
The graphic above summarizes the combinations of Pb- free versus SnPb components and board attach processes. With all options, careful reflow profiling should be performed with calibrated thermocouples embedded in the spheres of the BGA.

5.3 Reliability of Pb Free Component Finishes and SnPb Board Solder Surfaces

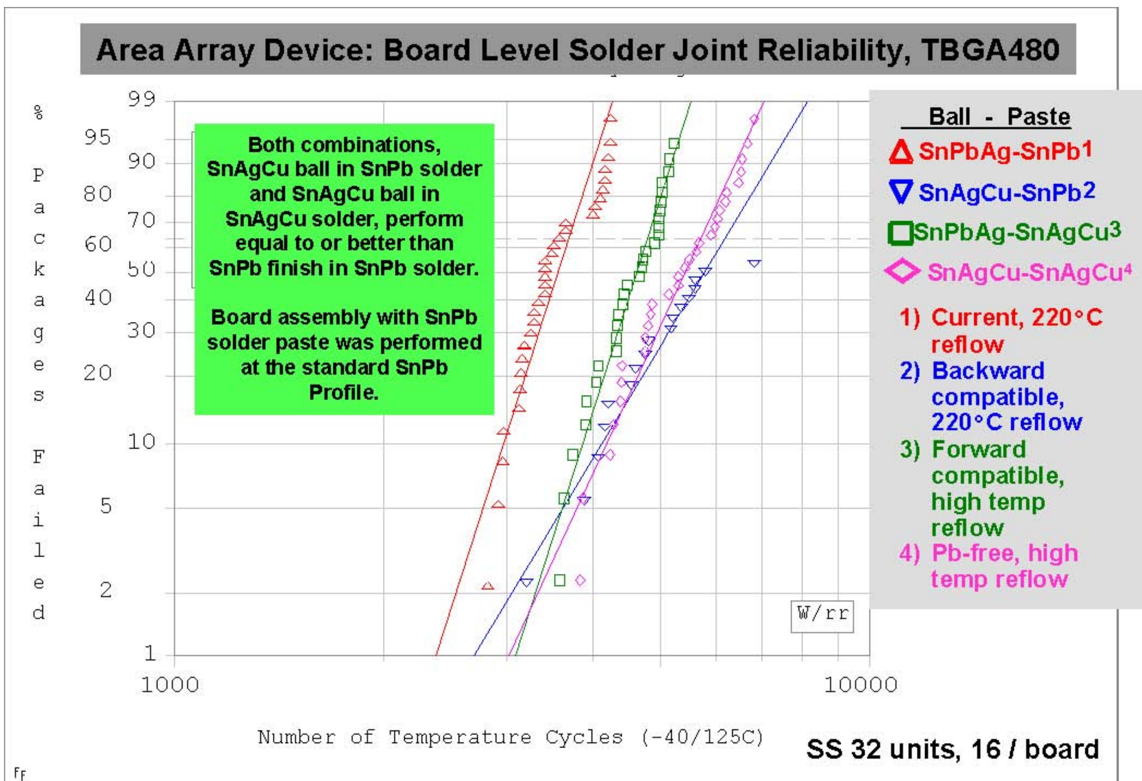
For peripheral packages backward compatibility evaluations were performed on a 64 lead QFP. 0.5mm pitch with a copper base material. The Sn finish was matte Sn. The substrate was a standard 4-layer board with copper pads and organic solderability protectant (OSP) coating. It should be noted that the reflow temperatures used to attach the packages to the printed circuit boards were appropriate for the type of solder used. The SnPb solder had a peak reflow temperature of 215°C and the SnAgCu solder had a peak temperature of 241°C.

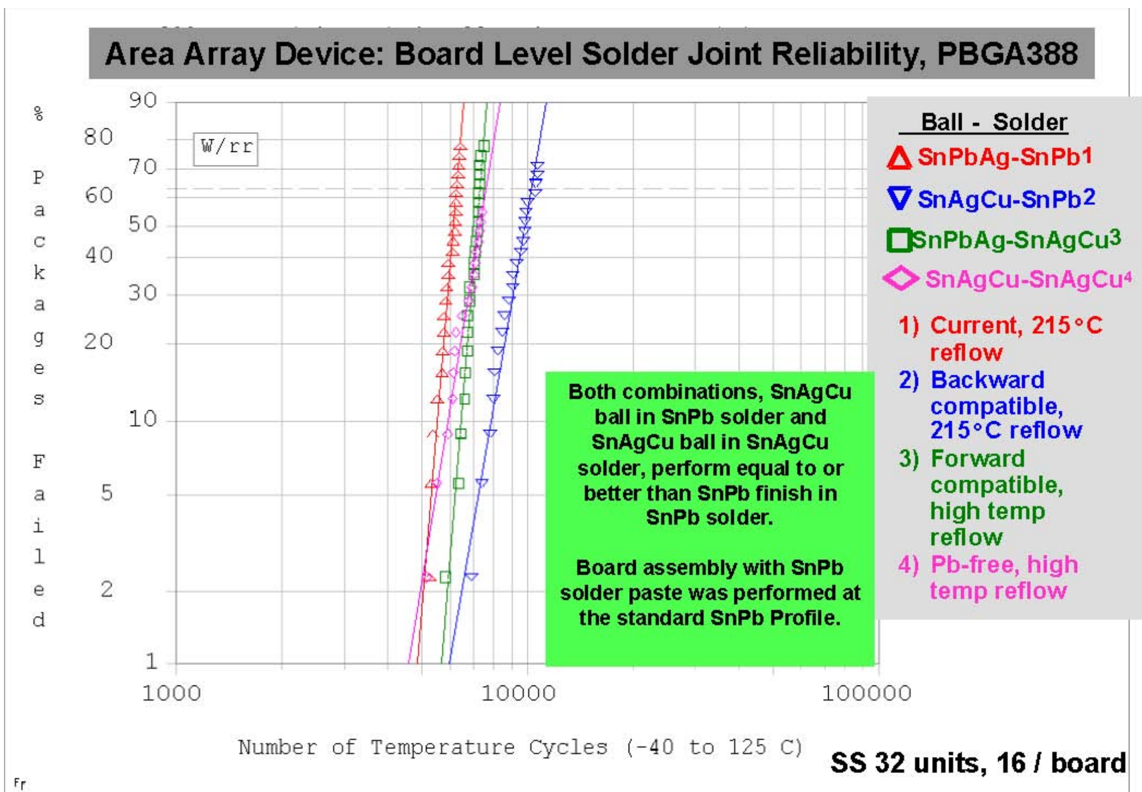
Two Weibull plots are presented. It is clear the solder joint life of a Sn Plated part is

equal to or better than a SnPb plated part either in SnPb solder or SnAgCu solder.



Similar analysis was performed on a 32x32mm 480 TBGA and 27x27mm 388 BGA. The components had SnAgCu solder spheres and were attached to a standard 4 layer PCB with standard design rule capture pads. The solder mask was designed with non-solder mask defined openings and the boards coated with OSP.


Area Array Device: Board Level Solder Joint Reliability, TBGA480
Both combinations, SnAgCu ball in SnPb solder and SnAgCu ball in SnAgCu solder, perform equal to or better than SnPb finish in SnPb solder.
Board assembly with SnPb solder paste was performed at the standard SnPb Profile.
Ball - Paste
SnPbAg-SnPb1
SnAgCu-SnPb2
SnPbAg-SnAgCu3
SnAgCu-SnAgCu4
1) Current, 220°C reflow
2) Backward compatible, 220°C reflow
3) Forward compatible, high temp reflow
4) Pb-free, high temp reflow
% Packages Failed
Number of Temperature Cycles (-40/125C)
W/rr
SS 32 units, 16 / board


Area Array Device: Board Level Solder Joint Reliability, PBGA388
Ball - Solder
SnPbAg-SnPb1
SnAgCu-SnPb2
SnPbAg-SnAgCu3
SnAgCu-SnAgCu4
1) Current, 215°C reflow
2) Backward compatible, 215°C reflow
3) Forward compatible, high temp reflow
4) Pb-free, high temp reflow
Both combinations, SnAgCu ball in SnPb solder and SnAgCu ball in SnAgCu solder, perform equal to or better than SnPb finish in SnPb solder.
Board assembly with SnPb solder paste was performed at the standard SnPb Profile.
% Packages Failed
Number of Temperature Cycles (-40 to 125 C)
W/rr
SS 32 units, 16 / board

Both combinations, SnAgCu ball in SnPb solder and SnAgCu ball in SnAgCu solder, perform equal to or better than SnPb finish in SnPb solder.

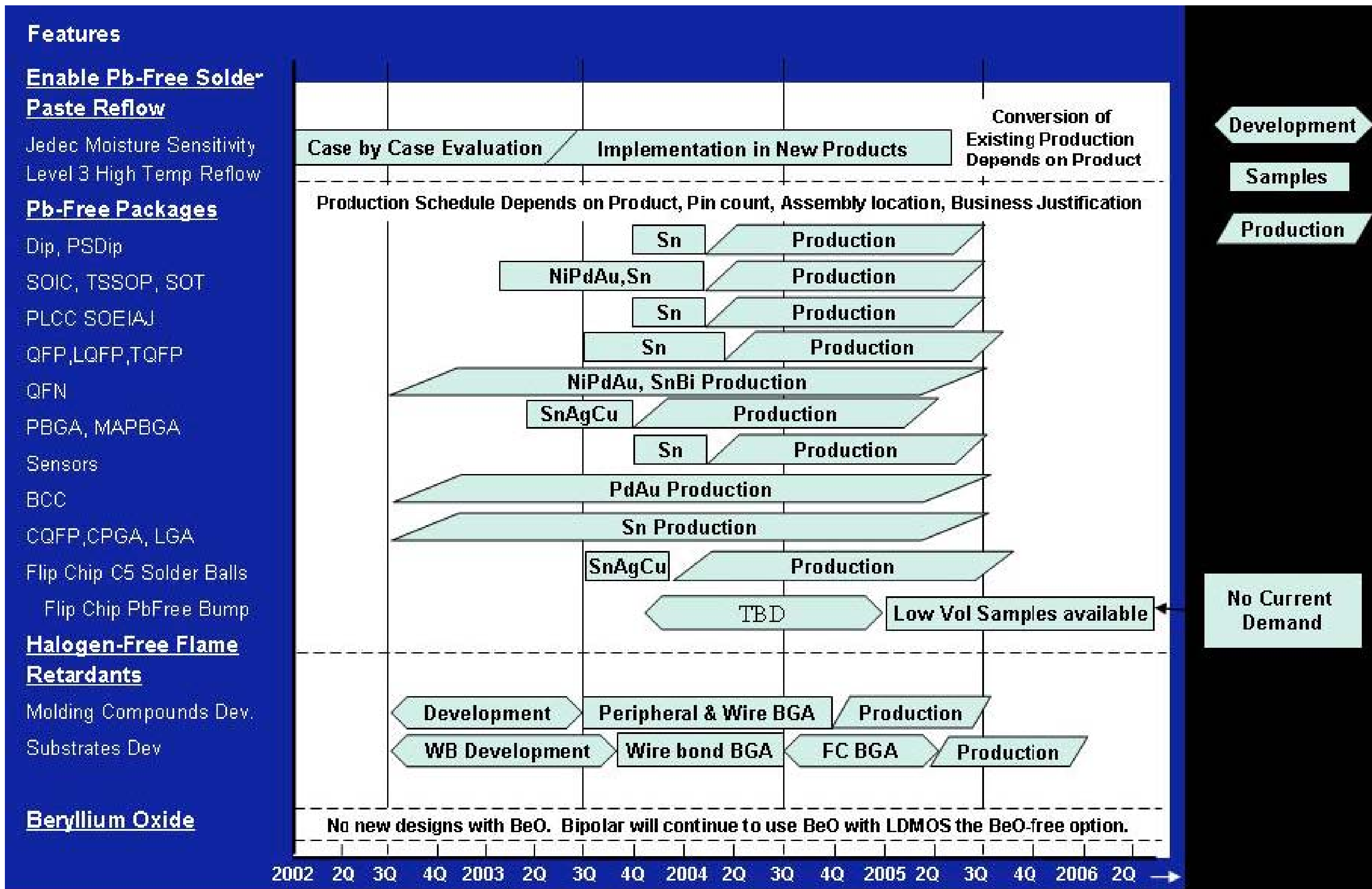
6. Sample and Product Readiness

We have been shipping Pb-free products since 2001, based on specific customer requests. In a proactive manner, Freescale will consider any new product a Pb-free candidate. Freescale's policy is to evaluate each Pb-free opportunity by component type. For manufacturing readiness by packaging type, see section 6.3. For sample or product availability please contact a Freescale sales office or the Freescale Technical Information Center.

6.1 Conversion Plan

At this time, conversions are taking place only as a per customer request basis with agreement by the business units. Conversion of existing SnPb finish products to Pb- free products will be handled by Freescale's standard Product Change Notification system.

6.2 Roadmap for Development of Environmentally Preferred Packaging



6.3 Manufacturing Readiness

PACKAGE TYPE	EXPECTED Pb-FREE SAMPLE AVAILABILITY DATE	EXPECTED Pb-FREE MANUFACTURING READINESS DATE
PDIP (copper)	October-03	January-04
PSDIP	October-03	January-04
SIP	July-03	January-04
SOT	July-03	January-04
SOIC	October-03	January-04
SOIC (Accelerometers)	June-04	June-05
SSOP	July-03	October-03
TSSOP	July-03	October-03
PLCC	October-03	January-04
SOEIAJ	October-03	January-04
BCC	March-03	April-03
PQFN/ PQFN-S	March-03	October-03
QFN- MAP	January-03	January-03
QFN- Punch	January-03	March-03
PGA (cer)	January-03	March-03
CQUAD	January-03	March-03
LGA	March-03	July-03
MAPBGA	July-03	January-04
TMAP	July-03	January-04
PBGA	July-03	January-04
FCBGA	October-03	January-04
QFP	October-03	October-03*
LQFP	April-03	July-03
FQFP	July-03	January-04
PQFP	July-03	January-04
TQFP	July-03	January-04
TO-272	July-03	January-04
PRESSURE SENSORS	July-03	January-04
MODULES	October-03	January-04
HQFP (MO-188)	July-03	January-04
MECH	July-03	January-04

*Exact date dependent upon site, lead count, body size, assy location, and business plan. Readiness applies to Pb-free terminations.

Samples are production intent material, and may or may not be qualified. Sample and manufacturing readiness dates are tentative. Please contact your sales rep for specific timing and availability.

6.4 Pb-free product identification

Freescale is currently evaluating a solution to identify Pb-free products. Freescale will communicate this information as soon as it is finalized.

7. Environmentally Preferred Packaging:

Freescale is working diligently developing environmentally preferred packaging. Pb-free development is in progress. Further developments in environmentally preferred products include the elimination of halogen, antimony, and glycol ether from IC packaging materials. Our goal is to create products that conserve resources, contain only benign materials, use low amounts of energy and are easy to recycle.