AN2034
APPLICATION NOTE

Soldering Compatibility (Backward and Forward)

COMPATIBILITY OF LEAD-FREE COMPONENTS

The semiconductor industry is moving towards the elimination of lead from packages, in accordance with new international regulations.

This concerns both solder paste, for the board mounting process, as well as semi-conductor packages themselves.

A major impact is on the solder reflow process step, as most of the lead-free alloys under investigation for solder paste melt at temperatures that are 30 to 40°C higher than eutectic SnPb (Tin, Lead) solder.

For a transitional period, leaded and lead-free technologies already coexist, either by having leaded packages mounted with lead-free paste or by having eutectic Sn/Pb paste used with lead-free components.

The tight collaboration between STMicroelectronics, Infineon Technologies, Philips Semiconductors and Freescale (E4 group) lead to the proposal of consistent and compatible solutions to customers and made it possible to promote the necessary standardization.

ST Lead-free Finishing Solutions

For lead-frame based packages

- Post-plated of matte Tin for insertion components (DIP), Power packages and some Surface Mount Technology Components (PLCC).

  Note: Post-plated SnBi finishing in some products is used only as an exception, based on customer request.
- Hot dipped tin coating
- Pre-plated of 3 layers of NiPdAu coating for Surface Mount Technology signal components (SO and QFP families mainly)

For Ball Grid Array packages:

- SnAgCu (SAC) solder balls.

PACKAGE FINISHING AND SOLDERING PROCESSES COMPATIBILITY

For component coating materials and board solder materials to be compatible, the three criteria below have to be met:

- processability
- solderability
- solder joint reliability

For Lead-frame packages, the contribution of connection coating in solder joint material is typically of 10% to 20%. The solder paste is the major contributor.

For BGA packages, the contribution of solder balls in the solder joint material is typically of 70% to 80%, which explains why from the thermal point of view and for the solder joint's metallurgical uniformity, the SnPb soldering profile may not be suitable for Lead-free BGA assembly

For compatibility assessment purposes, Lead-frame and BGA packages therefore have to be considered separately.

LEAD-FRAME PACKAGE COMPATIBILITY

The present situation, with the on-going conversion of leaded electronic components and board mounting processes to Lead-free finishing and mounting processes leads us to consider three new cases (as summarized in Table 1.):

- Customers who use leaded solder on lead-free components (backward compatibility)
- Customers who use lead-free solder (and a 30 to 40°C higher soldering temperature) on leaded components (forward compatibility)
- Customers who use lead-free solder on lead-free components

Table 1. Forward and Backward Compatibility: Lead-frame Based Components

Lead-frame Based Packages		Customer	
		Leaded Solder	**Lead-free Solder**
Supplier	**Leaded component Tin-Lead finish**	Today and past majority of cases	Processability: OK Solderability: OK Reliability: OK
	Lead-free components Tin finish	Processability: OK Solderability: OK Reliability: OK	Processability: OK Solderability: OK Reliability: OK
	Lead-free components NiPdAu finish	Processability: OK Solderability: OK Reliability: OK	Processability: OK Solderability: OK Reliability: OK
	Lead-free components Tin Bismuth finish	Processability: OK Solderability: OK Reliability: not recommended	Processability: OK Solderability: OK Reliability: OK

Processability

Components are warranted to withstand the soldering temperatures required for soldering them with standard alloys (SnPb) and with Lead-free alloys (SnAgCu). Jedec/IPC standard J-STD020 is the reference standard used to ensure the soldering resistance of components.

- For reflow soldering: paste application and component placement do not require specific actions
- For wave soldering: glue application, component placement and glue cure do not require specific actions
- The main differences in the soldering process are time and temperature (both of which are higher when using lead-free solder pastes)

International standards for the soldering resistance of components, such as IPC/ JEDEC J-STD020, should not be confused with the required profiles for the soldering of components on board.

The aim of the soldering resistance profile is to describe the maximum heat that components have to withstand during soldering. The soldering process is possible at lower temperatures: see Table 2.

Table 2. Minimum and Recommended Profiles For Convection Reflow Soldering

Convection Reflow Profile	Minimum Peak Temperature	Minimum Time Above Liquidus Of Solder Paste Materials	Recommended Peak Temperature And Time Above Liquidus
Lead solders (SnPb)	210°C	20 seconds	220°C – 30 seconds
Lead-free solders (SnAgCu)	235°C	20 seconds	245°C – 30 seconds

Lead-frame Package Soldering Processes

The soldering process for Copper lead-frames with NiPdAu coatings includes the wetting of surface by molten solder, the dissolution of Pd and Au thin layers in the solder and the creation of an SnNi intermetallic layer by diffusion.

The soldering process for Copper and Alloy42 lead-frames with Tin-Lead coating includes the melting of the solder paste and of the thin solder coating on connections, wetting and soldering by diffusion, with the subsequent creation of an intermetallic layer (NiSn or CuSn).

The soldering process for Copper and Alloy42 lead-frames with Tin coating includes the melting of the solder, wetting on the Tin coated connection and, as a result of the quick diffusion process, the melting of the coating layer, and then soldering by diffusion leading to the creation of an intermetallic layer (NiSn or CuSn).

The preheating and the length of the typical convection reflow profile result in no major difference when soldering Tin plated or Tin-Lead plated components.

Lead-frame Package Solderability

Sn- and NiPdAu- coated surfaces are solderable with SnPb and Lead-free solder pastes. Refer to the Application Note AN2036 on solderability.

Lead-frame Package Solder Joint Reliability

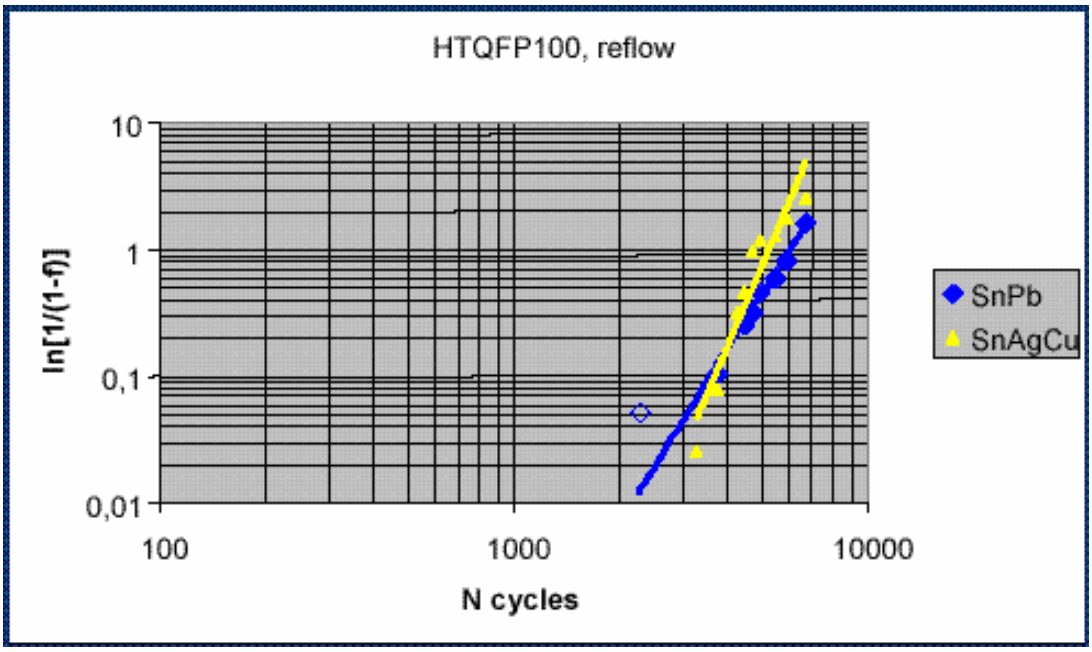
Tin-Bismuth coated units soldered with Tin-Lead may show unstable solder joint reliability due to the very low melting eutectic of Tin-Bismuth-Lead (92°C).

The use of TinBismuth coating with standard Leaded solder alloys is not recommended. It may however be validated by the customers for specific applications.

The solder joint reliability of components with Tin and NiPdAu coatings has been shown to be similar or better than that of components with Tin-lead coating.

Thermal Cycling has been used as a reliability test for solder joint because it causes thermo-mechanical solder fatigue and it is a good simulation tool for the long term reliability of electronic systems.

Figure 1. Example of Weibull Failure Analysis after Thermal Cycling of Lead-free and Leaded Soldered Boards with Sn plated TQFP100 Components (–40/+125°C) (Cu-based lead- frame)



Note: 1. The source is Philips Semiconductors.

BGA PACKAGE COMPATIBILITY

Again, three new cases need to be considered (as summarized in Table 3.), on top of the present situation, with the supplier supplying leaded components, and the customer using leaded solder:

- Customers who use leaded solder on lead-free components (backward compatibility)
- Customers who use lead-free solder (and a 30 to 40°C higher soldering temperature) on leaded components (forward compatibility)
- Customers who use lead-free solder on lead-free components

The main problem is with the second new case: the customer who uses leaded solder on lead-free components. Reliability is all right, and even an improvement on using SnPb solder; but processability is a critical issue, due to the low temperature used (215°C, instead of the 235°C that the package was designed to work with).

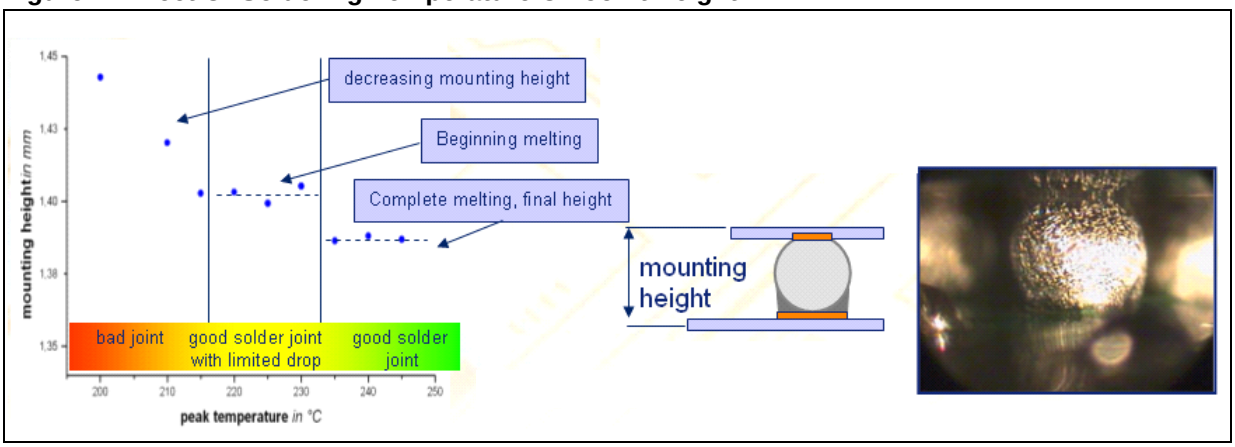
Table 3. Forward and Backward Compatibility: BGA Components

BGA packages using laminated substrates		Customer	
		Leaded Solder	Lead-free Solder
Supplier	Leaded component Tin-Lead Balls	Today and past majority of cases	Processability: OK Solderability: OK Reliability: OK
	Lead-free components Tin Silver Copper balls	Processability: critical Solderability: OK Reliability: critical If solder joints temperature is below 230°C	Processability: OK Solderability: OK Reliability: OK

BGA Package Processability

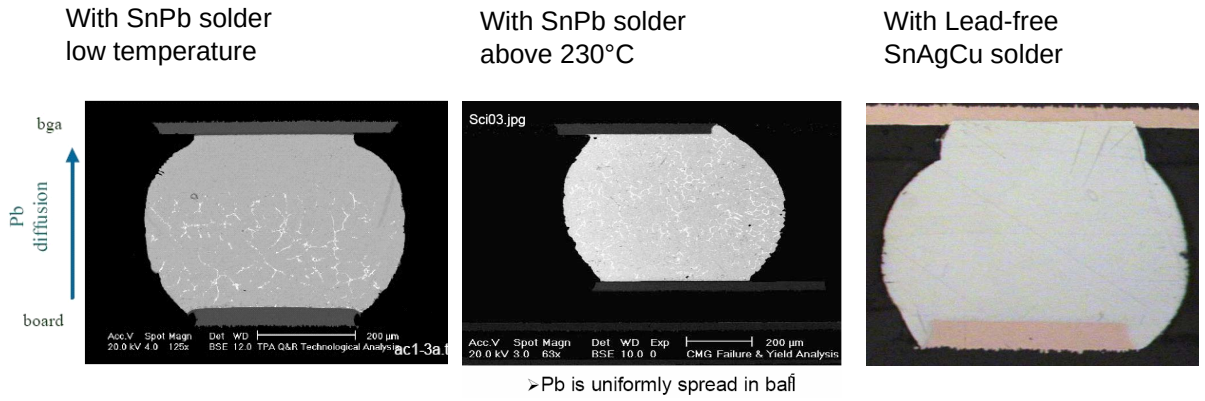
In the case of lead-free BGA-packages the soldering temperature must be above 230°C for processability and joint reliability. This is because a different temperature at the balls leads to different mounting heights (see Figure 2.). Low BGA soldering temperature may also result in poor joint uniformity (see Figure 3.).

Figure 2. Effect Of Soldering Temperature On Joint Height



Note: 1. The source is Infineon Technologies.

Figure 3. Mounted Lead-free Solder Balls



BGA Package Solderability

The solderability of BGA components with Leaded or Lead-free balls is equivalent.

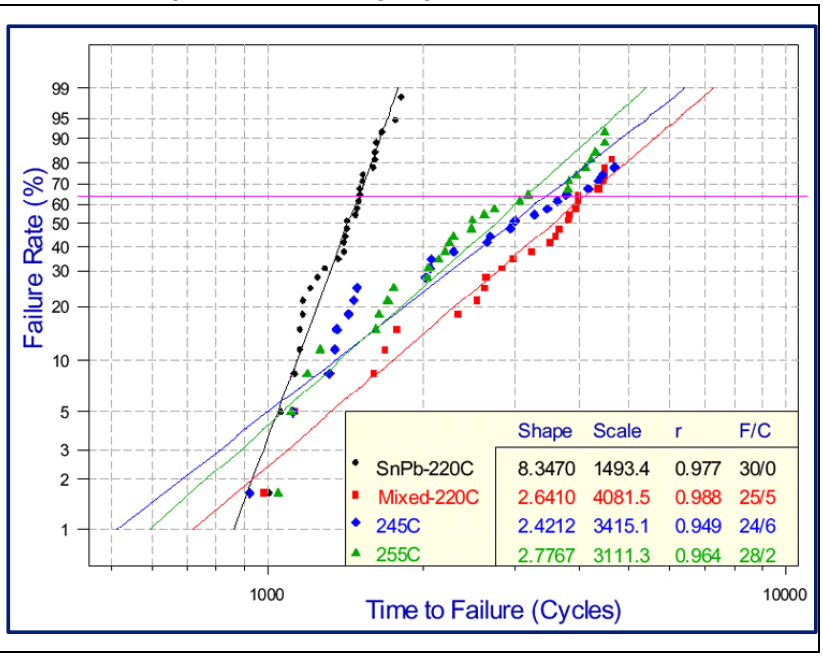
BGA Package Solder Joint Reliability

Lead-free solder joint reliability, versus thermal cycling, is improved compared to SnPb balls.

Figure 4. Weibull Failure Analysis after Thermal Cycling of lead-free and lead-containing reflow solder TFBGA6x6-46 with 0.4mm solder balls (both SnPb-SnAgCu)

4 tested processes using -40°C/ +125°C thermal cycling and continuous electrical resistance monitoring of daisy chain units

SnPb balls + SnPb paste (220°C)
SnAgCu balls + SnPb paste (220°C)
SnAgCu balls+SnAgCu paste (245°C)
SnAgCu balls+SnAgCu paste (250°C)



CONCLUSION FOR COMPATIBILITY

STMicroelectronics components, lead-free or leaded, are fully compatible, from the soldering process, and quality and reliability stand-points, with both lead-free or leaded solder pastes.

The only exception is for lead-free BGA using leaded solder process (since the reflow temperature could be too low for melting the lead-free solder balls).

Otherwise, all lead-free package dimensions, and their mechanical and electrical behaviors, are similar for the lead-free and leaded components.

REVISION HISTORY

Table 4. Document Revision History

Date	Version	Revision Details
08-Nov-2004	1.0	First Issue