

Environmentally Friendly Solutions to Meet Your Semiconductor Packaging Needs

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Introduction

The impact of preparing for compliance to global environmental legislative initiatives represents one of the largest challenges facing the Semiconductor industry today. One of the primary factors driving the legislative requirements is the safe disposal of electronic components in landfills after their useful life has expired. Of primary concern is the impact of lead (Pb) and other hazardous materials leaching into the groundwater and contaminating the water supply over time. As such, legislative and marketing forces are driving the electronics industry to remove certain hazardous materials from their products. The most notable legislative work is the European Restriction of Hazardous Substances (RoHS) which goes into effect on July 1st, 2006. This legislation sets very tight threshold limits on lead (Pb), Mercury(Hg), Hexavalent Chromium (Cr6+), Polybrominated Biphenyls (PBBs), Polybrominated Diphenyl Ethers (PBDEs) and Cadmium. Of primary concern for semiconductor manufacturers is the reduction and/or elimination of Pb which is typically used in leadframe terminal finishes, BGA solder balls, flip chip solder bumps and solder die attach materials. In addition to the various legislative initiatives, many companies are seizing this opportunity to secure competitive advantage by early compliance and conversion. As such, the entire Semiconductor industry is working feverishly to engineer and implement material solutions that will comply with the RoHS requirements and meet the needs of their customers.

General Package Construction

Texas Instruments (TI) has long been recognized as an industry leader in terms of Pb Free for leadframe based packages with the implementation of the NiPd leadframe finish introduced in 1989 and the subsequent conversion to NiPdAu in the 2001 timeframe. Texas Instruments has now produced well over 50 billion Pd finish components and the use of this finish is well understood and accepted by customers. Two key attributes of the NiPd and NiPdAu lead finishes are that they are compatible with both Sn/Pb pastes and Pb-Free pastes and do not produce tin (Sn) whiskers which is a major concern for Sn bearing alloys being considered by many in the industry as a replacement for SnPb. SnPb solder pastes melt at 183C and typically requires a peak reflow of 215C to 235C while Pb-Free (SnAgCu) pastes melt at approximately 220C and typically requires a peak reflow temperature of 235C or higher. Careful consideration must be given during package material selection process to ensure that the material system used for the package construction will withstand the stresses of Pb-Free reflow and maintain package integrity. TI Pb-Free products are classified per JEDEC J-STD-020 (transitioning from revision B to C at the time of this writing) and are designed to withstand the associated peak reflow temperatures and storage conditions (Table I) per the classifications indicated on the device label (Example 1).

TI defines "Lead (Pb)-Free" or "Pb-Free" to mean semiconductor products that comply with the current RoHS requirements for all 6 targeted hazardous substances in Table II, including the requirement that Pb not exceed 0.1% by weight in homogeneous materials. In addition to meeting the RoHS requirements addressing the 6 targeted materials identified in Table II, Texas Instruments is taking a proactive step in pre-emptively reducing the bromine and antimony levels typically used in the mold compound flame retardant systems as these materials are believed to be substances of future concern. TI defines "Green" to mean "Pb-Free" and free of Bromine (Br) and Antimony (Sb) based flame retardants where Br or Sb do not exceed 0.1% by weight in the homogeneous material. Texas Instruments is aggressively working a 3 phase strategy to provide customers with packaging solutions that meet the following criteria:

- Have a Pb-Free finish

- Have high temperature reflow capability for compatibility with Pb-Free soldering processes
- Are constructed with “Green” (Br-Free/Sb-Free) mold compounds

TI’s Goal is to offer customers a total “Green Package Solution”.

Green Package Solution = Pb-Free finish + High-temperature compatibility + Br-Free/Sb-Free

For leadframe based packages, the TI preferred Pb-Free solution is NiPdAu pre-plated leadframes and represents the majority of our product offerings. TI’s leadframe based packages using the NiPdAu finish are fully backward compatible with existing SnPb processes in use today which allows the end user to seamlessly transition to TI’s Pb-Free components. For packages where NiPdAu may not be feasible or cannot be employed for other reasons, alternative Pb-Free solutions may be offered. For BGA packages, TI offers the industry standard Tin-Silver-Copper (SnAgCu) alloy solder balls. Approximately 97% of TI’s Standard Logic and Linear portfolio is now converted to a Pb-Free solution. Likewise, the majority of TI’s Pb-Free converted parts utilize a “whisker free” solution.

Table I

Pb-Free Package Classification Reflow Temperatures

Package Thickness	Volume mm ³ < 350	Volume mm ³ 350-200	Volume mm ³ >2000
<1.6mm	260 C	260 C	260 C
1.6mm – 2.5mm	260 C	250 C	245 C
2.5mm	250 C	245 C	245 C

Moisture Classification Level and Floor Life

JEDEC MSL Rating (J-STD-020C)	Floor Life Time (before re-bake required)	Floor Life Condition
1	Unlimited	<30°C / 85% RH
2	1 year	<30°C / 60% RH
2A	4 weeks	<30°C / 60% RH
3	168 hours	<30°C / 60% RH
4	72 hours	<30°C / 60% RH
5	48 hours	<30°C / 60% RH
5a	24 hours	<30°C / 60% RH
6	Time on Label (TOL)	<30°C / 60% RH




Table II

RoHS Substance	Threshold (homogeneous material)	TI Use
Lead (Pb)	<1000 ppm	Lead frame Finish, BGA Solder Balls, Also in lead frames (<300ppm), flip-chip solder bumps (exempt), and solder die attach (exempt)
Mercury (Hg)	<1000 ppm	None
Hex. Chromium (Cr6+)	<1000 ppm	None
PBBs (RoHS defined Polybrominated Biphenyls)	<1000 ppm	None
PBDEs (RoHS defined Polybrominated Diphenyl Ethers)	<1000 ppm	None
Cadmium (Cd)	< 100 ppm	BGA Solder Balls (trace impurity)

Identification of Pb-Free and Green packages

In 2003 TI implemented a “Pb-Free logo” on the device packing labels. On parts that both utilized a Pb-Free finish and were rated for high-temperature reflow (250C/260C) received the Pb-Free logo (see example 1). Many TI parts have been shipped since mid-2003 with the Pb-Free logo printed on the device packing label. In 2004, JEDEC released JESD97 “Marking, Symbols, and Labels for Identification of Lead (Pb) Free Assemblies, Components, and Devices” and TI’s **Pb-Free logo** is in compliance with this document.

Example 1

				(1P) SN74ALS245ADW (Q) 1000 (D) 0310 (31T) LOT: 3203146MLA (4W) TKY (1T) 6149902SI2 (P) (2P) REV: G (V) 0033317 (20L) CSO: SHE (21L) CCO: USA (22L) ASO: MLA (23L) ACO: MYS	
MADE IN: Malaysia 2DC: 2Q:					
MSL 2 /260C/1 YEAR	SEAL DT				
MSL 1 /235C/UNLIM	03/10/03				
OPT: ITEM: 33					
LBL: 1A (L)T0:1310					

JEDEC JESD97 also provides a classification methodology to specify the Pb-Free finish categories and a means to identify the component finish both on the packing label and in the package symbol. The Pb-Free categories are meant to describe the Pb-Free terminal finish/material of components (2nd level interconnect) and/or the solder paste/solder used in the board assembly. The Pb-Free categories defined in JESD97 are as follows:

- e1 - SnAgCu (shall not be included in category e2)
- e2 - Sn alloys with no Bi or Zn excluding SnAgCu
- e3 - Sn
- e4 - Preplated (e.g., Ag, Au, NiPd, NiPdAu)
- e5 - SnZn, SnZnx (no Bi)
- e6 - contains Bi
- e7 - low temperature solder (≤ 150 °C) containing Indium (no Bi)
- e0, e8, e9 symbols are unassigned at this time.

The majority of TI's leadframe based packages fall into the "e4" category (NiPdAu). In June of 2004, TI updated all packing labels to include the JESD97 Pb-Free categories placed directly below the Pb-Free logo as shown in Example 2. In an effort to provide our customer base with as much meaningful information as possible, TI has elected to 'extend' this coding methodology as a means to identify components manufactured with 'Green' molding compounds, i.e, Bromine and Antimony free per the TI defined limits (Br or Sb do not exceed 0.1% by weight in the homogeneous material). When a 'Green' mold compound is used in the construction of the package, the 'e' will be replaced with a 'G' in the first character of the Pb-Free category as shown in Example 2. The 'e4' printed below the Pb-Free logo denotes a package that is Pb-Free and utilizes a pre-plated NiPdAu finish. The second label in Example 2 displays a 'G4' printed below the Pb-Free logo indicating that the package is Pb-Free, is built with a "Green" mold compound (Br and Sb Free) and employs a NiPdAu pre-plated lead finish.

Example 2

				(1P) SN74LS07NSR (Q) 2000 (D) 0336 (31T) LOT: 3959047MLA (4W) TKY (1T) 7523483SI2 (P) (2P) REV: (V) 0033317 (20L) CSO: SHE (21L) CCO: USA (22L) ASO: MLA (23L) ACO: MYS	
MADE IN: Malaysia 2DC: 2Q:					
MSL 2 /260C/1 YEAR	SEAL DT				
MSL 1 /235C/UNLIM	03/29/04				
OPT: ITEM: 39					
LBL: 5A (L)T0:1750					

The new E-Cat Logo will only print when Pb-Free Logo prints



When a “Green” mold compound is used, the “e” will be replaced with “G”

Pb-Free / Green Symbolization

TI utilizes the same methodology and coding scheme employed on the packing label to symbolize or mark the actual package. To differentiate the Pb-Free Category (eCat) code from other alphanumeric characters used in the package symbol, an underscore is utilized along with a slightly reduced font size for easy recognition of the ‘eCat’ code as shown in Example 3.

Example 3



Example of a conventional marking format (no Pb Free designation) on a 56-pin TVSOP package.



Example of Pb-free category symbolized on TI 56-pin TVSOP package. ‘G4’ indicates NiPdAu finish on the component with use of “green” mold compound.



Example of Pb-free category symbol on 8-pin SOIC package. 'E4' indicates NiPdAu finish on the component.



Example of Pb-free category marking on a 20-pin TSSOP package. 'G4' indicates NiPdAu finish on the component and use of "green" mold compound.

Parts are now transitioning to be marked with the following 2-character Pb Free and green codes (Table III) where space permits.

Table III

JEDEC/IPC Finish Categories (JESD97, IPC-1066)	JEDEC/IPC Pb-Free* Marking Standard	TI-Green* Marking Standard
SnAgCu (BGA solder balls)	E1	G1
Precious Metals (No Tin) - Ag, Au, NiPd, NiPdAu	E4	G4

*JESD97 only requires Pb < 1000 ppm. TI will only use these markings when parts meet our Pb-Free and Green definitions.

(TI "Pb-Free" = RoHS & High-Temperature compatible, TI "Green" = TI "Pb-Free" and no Sb/Br)

Some TI parts (<3%) will use E3 (Matte Tin) or E6 (Tin-Bismuth).

Order Entry

As the industry transitions to Pb-Free processes, it is critical for customers to be able to insure that they can differentiate between standard leaded parts and Pb-Free parts to assure process compatibility and prevent package damage. To meet this need, the TI Standard Logic and Linear (SLL) business unit is applying the same coding structure as used for the packing labels and device symbol using the JEDEC Pb-Free codes to create unique Pb-Free part numbers. To differentiate Pb-Free and 'Green' packages in the orderable part number, the two character Pb Free code is added as a *suffix* to the standard part number as shown in Example

4. Both the Standard part number and the Pb-Free part number will be valid orderable part numbers.

Example 4

SN74LS00D	Standard part number
SN74LS00DE4	Pb-Free + NiPdAu part number
SN74LS00DG4	Pb-Free + NiPdAu + 'green' mold compound part number

Since ball array products are not backward compatible, a new Pb-Free version will be offered with a unique part number by using a 'Z' in the package designator as illustrated in the examples below (Example 5).

Example 5

	<u>Pb designator</u>	<u>Pb-Free Designator</u>
Array Packages		
Ball Grid Packages	Gxx	Zxx
NanoStar	YEx	YZx
BGA Pb version	SN74CBTLV3245AGQNR	
BGA Pb-Free version	SN74CBTLV3245AZQNR	
NanoStar version	SN74LVC1G86YEAR	
NanoStar Pb-Free version	SN74LVC1G86YZAR	

During the transition to Pb-Free, customers can insure that they are receiving Pb-Free parts capable of withstanding the more stringent Pb-Free conditions by specifying unique Pb-Free part numbers.

Since compliance to the RoHS directive impacts the entire supply chain, Texas Instruments has also developed an external search tool for customers to use which will display the package product content, including the 6 banned RoHS substances listed in Table I. The ECO-INFO Product Content Database search tool provides detailed product content information on the complete list of materials used in the construction of the package. This search tool can be accessed at the following URL:

www.ti.com/productcontent

Conclusion

As the semiconductor industry transitions to Pb-Free products and processes, Texas Instruments is fully prepared to meet your packaging needs by offering one of the most comprehensive portfolios of Pb-Free and green products available within the industry today. In addition, TI is taking proactive steps in making this transition as seamless as possible for our customer base by providing a consistent methodology of identifying Pb-Free and green products from order entry, package labeling and on down to the corresponding physical symbol on the package itself. To minimize customer qualifications, TI is working hard to stay ahead of the curve on hazardous materials by taking voluntary actions to remove materials that are likely to become a concern in the near future. Our external ECO-INFO Product Content Database provides customers with an effective tool to validate the construction materials used in our products to insure compliance throughout the supply chain. Lastly, Texas Instruments has a proven track record with our NiPdAu lead finish. With the present concerns regarding Sn Whiskers on other Sn bearing Pb-Free plating options, TI represents a safe haven as the NiPdAu

finish is a preferred mitigation technique and is not susceptible to Sn whisker growth. As the industry moves full speed ahead into the Pb-Free transition, Texas Instruments is well prepared to provide environmentally friendly solutions to meet your semiconductor packaging needs.