„Pb-free“ ante portas

No End for Conventional SnPb Board Soldering

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Introduction

July 1st 2006, the date when the RoHS directive and related environmental legislation (1 -3) become effective, knocks at the front door. Time is getting short for suppliers and customers that major parts of the electronic and electrical industry have to dramatically reduce the use of the so-called “dirty 6”: Pb, Hg, Cr-VI, Cd, PBB und PBDE. In addition to lengthy discussions about the already existing and new submitted exemptions and limits of substances or the definition of „homogeneous materials“, newly formal insufficiencies contributed to further delays in Brussels. All that was not helpful at all to grow understanding and acceptance in support of concerted conversion activities of all parties involved. Local optimizations lead to sometimes isolated solutions which do not fit into the whole picture of complex challenges. Available good solutions did not find application, yet. Existing legislative imponderabilities and residual risk from mostly solved technical challenges possibly resulted in disregard of „Pb-free“ logistics and the rising questions how to arrange for the further coexistance of conventional components and board production lines for exempt applications and markets. Poor communication about „Pb-free“ along the whole supply chain can run the industry into a dilemma along the whole value chain. Meanwhile everyone confronted with RoHS is influenced and under stress in the field of technologies, logistics, supply and demand.

Demand Triggers Supply of „Pb-free“ Components

Obviously there are market specific differences that suppliers of components are exposed to. Thus we need to offer solutions covering the portfolio for a wide range of applications. “Consumer has to, Industrial can, Automotive has time, however, is closely watching what is going on“ is a rough description of the scene for “Pb-free”. It also reflects the missing balance of 1. some sudden and immediate demand from one market segment, of 2. the desire to possibly fall under this or that exemption to take advantage to keep the running production as it is and of 3. the well prepared delay of change to “Pb-free” in Automotive. ELV (4) grants 60g of Pb are left ‚smeared’ in any vehicle on the scrap yard prior to being turned back into steel. But as soon as any car manufacturer offers a „Pb-free“ car and wins market share, when customers appreciate and select „Pb-free“, then everyone wants to be the second winner, at least.

Pb-free solders have been early on the list in support of solutions for a better environment. Freescale developed and introduced Pb-free component terminations. In response to the necessary higher temperatures for Pb-free (**Table 1**), exisiting solutions were improved and new packaging materials are being used to ensure adequate processability facing the hotter conditions in the board assembly lines (5).

Solder Paste Liquidus	Sn/Pb 183 °C- 210 °C		Sn/Ag/Cu 221 °C-227 °C	
	Maximum Package Peak Temperature	Minimum Solder Joint Temperature	Maximum Package Peak Temperature	Minimum Solder Joint Temperature
Large, thick Packages	225 °C	205-220 °C	245 °C	225-240 °C
Small, thin Packages	240 °C	205-220 °C	250-260 °C	225-240 °C

Table 1: Typical temperatures in SnPb and Pb-free board assembly processes for good solderjoints and intact package integrity.

New Standard Products are manufactured and introduced compliant with RoHS. At the beginning of a project, especially for any custom part, the developers have to document the requirements and decisions made concerning Environmentally Preferred Products selection (EPP, http://www.freescale.com/epp). It has to be clearly stated if there is justification and clear need to go for non-EPP materials and production. Only EPP components will offer by design the necessary Moisture Sensitivity Level / Package Peak Temperature robustness against the higher thermal stress of Pb-free board soldering and related processability per J-STD-020C (8, http://jedec.org). Legacy products of older generation package technologies do not always offer robust MSL/PPT. Among those there are also the long-supplied components with NiPd(Au) plated leadframes which fall well under Pb-free termination. Also RoHS can apply if all other material criteria are fullfilled, however many of those are classified for PPT of 220 °C only. Component soldering always requires to watch-out for the specified MSL/PPT. In case such „legacy“ parts are needed for Pb-free board soldering and no re-classification for the higher package temperature is available, dry-bake prior to soldering can make parts useable, however, can not be generally recommended. This needs careful evaluation taking the application and its “mission profile” fully into account. Owners of production lines are asked to study their running processes and to characterize typical applications for the differences between solderjoint and package temperatures (**Figure 1**) so that components will not be thermo-mechanically pre-damaged during board soldering (5, 6).

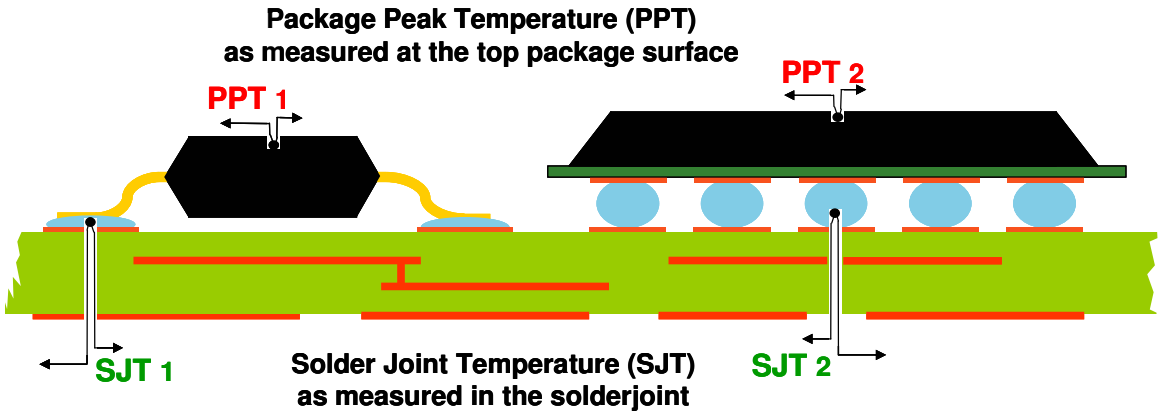

Fig. 1: During board soldering the minimum solderjoint temperature (SJT) has to be reached for good solderjoint formation AND the specified package peak temperature (PPT) must not be exceeded for any component on the board for proper package integrity.

When it comes to failure analyses, it is of highest importance to maintain the component in its initial fail mode. Electrical failure verification and characterization have to be done with the component on the board prior to any desoldering. After careful removal of the unit including a possibly necessary dry-bake per MSL handling recommendations, the part has to be verified to exhibit the (mal)function identical to that found on the board before. Only this procedure ensures and proves no change occured or no additional damage was introduced during desoldering. CSAM of the part should be considered on board-level already, and is advised for complex high pincount and large dimension components. Otherwise, wrong results might lead to false conclusions and initiate more of useless and cost-intensive failure analsis work. Subsequent corrective actions by the user or supplier do not help anyone if based on inaccurate findings.

Conversion to Pb-free Products and their Compatibility

Freescale http://www.freescale.com will not automatically change all its existing conventional products in 2005. Sequence and portfolio depend on customer demand. It shows an increasing trend from 20% in January to 38% in April this year, however, so far further forecast still runs below 50% for middle of 2006. Product mix of markets and exemptions are ruling and playing into the numbers. By the end of 2005 we will offer qualified package solutions for all products with Pb-free terminations, compliant with RoHS and also with robust Pb-free processability. Customers can prepare for their RoHS compliant system assemblies and order products accordingly (**Table 2**).

Package Description	RoHS Compliant
SOIC	**Q4 04**
CSP / MAP BGA Thin & Standard	**Q1 05**
PBGA	**Q1 05**
TSSOP	**Q1 05**
SSOP	**Q1 05**
PLCC	**Q2 05**
TBGA (for Non-Low-K dielectric chip)	**Q2 05**
TBGA (for Low-K dielectric chip)	**TBD****
QFP (PQFP, TQFP, MQFP, LQFP)	**Q2 05**
QFP-MCR	**Q3 05**
Power QFN	**Q2 05**
QFN	**Q4 05**
Dedicated Automotive Qualifications	**Q4 05**

Table 2: Demand triggers product conversion, most package solutions are ready by the end of 2005.

Matte Sn plated leadframe EPP units provide full compatibility for conventional SnPb and the hotter Pb-free board assembly operations (**Figure 2**). Matte Sn finishes give good solderjoints in both solder types as the volume of the solder paste or wave rule the system (6, 7).

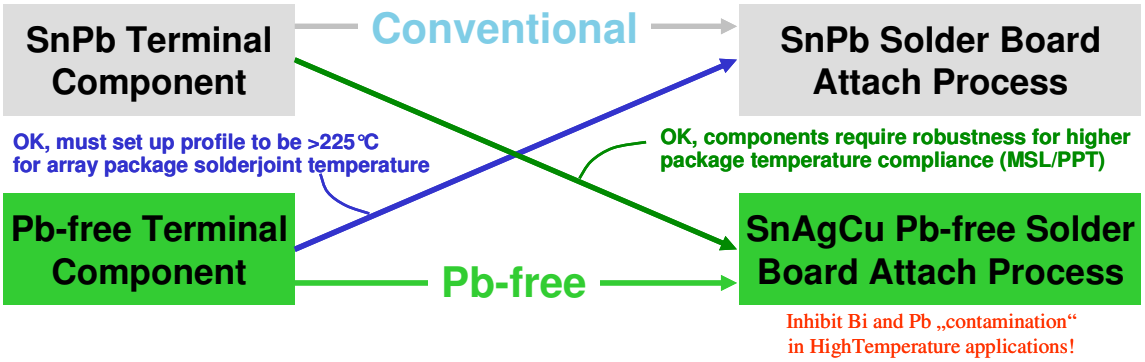

Fig. 2: Conditional Forward and Backward Compatibility for component board soldering is due to possible MSL/PPT limitations of conventional parts not meeting the higher package temperature requirement for Pb-free board processes or due to insufficient solderjoint formation of SnAgCu area array solder balls under conventional cool SnPb board processes.

Ball Grid Array (BGA) EPP units are not backward compatible unless the SnPb board soldering process is run at an upper end yielding minimum solderjoint temperatures of >225°C for the SnAgCu solderballs so that these fully melt and mix with the SnPb paste. This mix is not recommended for high-temperature applications and general care is advised to watch other components on the same board for their package peak temperature and not to exceed their MSL/PPT limitations during such a hotter than usual SnPb process. Especially older generation package technologies and small components, i.e. products with small heat capacity can be easily thermally overstressed as they get the full heat. Freescale will supply also the already higher temperature processable BGA products with conventional SnPbAg solderballs until further notice. Customers are asked for details about their conversion plans for area array application as soon as possible so that the introduction of SnAgCu solderball parts can go hand-in-hand.

Pb-free production roadmaps need to be shared for both-side alignment in order to minimize stock and to optimize consumption of conventional products before Pb-free components make the volume. Foreseeable mix of conventional and Pb-free products needs clear communication, further necessary SnPbAg solder ball BGAs need clear orders for our capacity planning.

Environmentally Preferred Product (EPP) Status

Pb-free product terminations, i.e. <0,1wt% Pb in the lead finish, on the solder pads or in the solder balls does not suffice RoHS. The other „dirty 5“ have to be below the limits as well or exemptions must apply. This leads to the strange situation that RoHS compliant products can have more Pb in the product than the conventional part before with its SnPb terminations. High-Pb solders (>85%Pb solder are RoHS exempt) for die attach or flip-chip devices are introduced replacing Pb-free or eutectic solders. The internal high-Pb solders do not soften or melt during the external Pb-free soldering. Liquidation and resolidification under uncontrolled conditions of internal solders can reduce the system reliability. Presence of high-Pb solders does not allow to use the Pb-free logo. Freescale barcode labels will show the Pb-free symbol only when all homogeneous materials are <0,1wt% of Pb. Pb-free and RoHS marking can apply to older products which do not have the resistance against soldering heat (RaSH) during Pb-free board processing. Freescale **Environmentally Preferred Products** (EPP) fullfil all material limitations of the RoHS directive AND the MSL/PPT processability requirements of Pb-free board assembly lines.

The Freescale web site http://www.freescale.com offers an on-line customer self-service capability for standard products. This portal allows users to gather product information and provides EPP details by typing the Freescale part number or portions thereof at the top-right of the screen then listing all standard parts after ENTER. Pb-free and/or RoHS symbols categorize the components. Clicking on more gives access to MSL/PPT processability per J-STD-020C (8) and the 2nd level interconnect material, i.e. the solder leadframe finish or solder ball composition is given as e1 ..... e7 per JESD97 (9). This level of technical detail is a solid baseline for developers and assemblers giving clear direction about what the parts are and can do and how to process them.

Sales contacts can provide the necessary information for customer specific parts which are not accessible to everyone on the web. These parts require detailed exchange and planning between customer purchasing and our sales to prevent excess stock or shortages along the value chain.

Freescale standard declarations of compliance for RoHS and ELV are available on the external web (10, 11). Material Content Data Sheets (MCDS) for individual products can be received as EXCEL sheets detailing typical compositions of the products' packages. Our above mentioned web portal gives access to individual Product Content Reports and Material Composition Declaration for download.

Summary

Freescale will offer RoHS compliant product packaging across its portfolio by the end of 2005. Many Pb-free, RoHS compliant product are available and shipping today to enable customers to align with the European Union RoHS directive which takes effect July 2006. Freescale may not create RoHS compliant versions of products that transition to en-of-life status.

Freescale will temporarily have both Pb and Pb-free capabilities. If customers are expected to comply with the RoHS directive, Freescale will help rapid conversion to lessen inventory and cost risks for both parties. Backlog transition schedules are based on customer demand, package qualification, manufacturing cycle time and inventory positions. Freesclae will use standard product conversion practices so that stock of Pb- products are sold prior to production ramp of Pb-free products. Environmentally Preferred Products have robust processability for Pb-free board processes per J-STD-020C. EPP unique part numbers are generated and the box labeling will be marked within JEDEC compliance per JESD97. RoHS and/or Pb-free symbols on the barcode labels help categorize the products for environmental aspects.

The Freescale Matte Sn plating for leadframe-based components provides high product quality. A 1-hour, 150°C bake after plating provides reasonable mitigation of tin whisker growth to meet our quality specification for standard products (12MSH005556). This spec allows 50µm maximum whisker length. Freescale continues to collect reliability data on Matte Sn plating and to work with research and industry consortia and JEDEC to further define, document and test the reliability of the Pb-free plating process.

SnAgCu replaces SnPbAg solderballs on EPP area array packages. BGA conversions require intensive exchange between customer purchasing and our sales or customer supply analysts for inventory and production management.

All EPP will have enough resistance against soldering heat for Pb-free board solder processing; goal for moisture sensitivity level is MSL3 or better per J-STD-020C.

Any move to Pb-free terminations respectively any introduction of new materials to make Freescale existing products RoHS compliant or any obsolescence of components are subject to the usual PCN (Product Change Notification) or PTN (Product Termination Notification) or EOL (End-of-Life) procedures.

References

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Dr. Friedrich-Wilhelm Wulfert studied physics at the Technical University Clausthal. He finalized the diploma in 1976 and then change to the Unversity Hannover where he got his PhD in 1982 for further detailed work on atomic defects and development of a high-resolution LEED system for detection and quantitative measurements of crystalline imperfections at the Si-SiO2 interface. His industrial career started at National Semiconductor with strong focus on technology, quality, reliability, production processes and yield analysis in wafer fabs and assemblies, also in close cooperation with customers for audits and failure analysis on finished products. In 1995 he moved to Motorola SPS -Freescale Semiconductor since April 2004- and is supporting internal and external design teams as EMEA Quaqlity Manager following the objective to engineer requirements all along the value chain with risk and opportunity assessment in mind for bothside success. National and international standardization bodies or industry consortia enjoy his technology oriented contributions.