Lead-free soldering and RoHS implementation - Questions from the Frontline, Part 2

By Peter Biocca

There are less than eight months remaining before the "Restriction on Hazardous Substances" (RoHS) takes effect.

With the start date for compliance in Europe being July 1, 2006, assemblers don't have much time to make their products destined for European markets not only lead-free but also free of cadmium, mercury, chromium VI, polybrominated bipenyls (PBB) and polybrominated diphenyl ethers (PBDE).

This article is a compilation of some of these questions that are coming from Kester's customers in the U.S., Asia and Europe. Surely more questions will be asked as this year comes to an end and 2006 begins. We will bring more of these questions and answers to you in subsequent issues.

Stay tuned for more answers coming from customers on the frontline of the transition. Here are some often asked questions for the autumn of 2005.

What are the reliability risks associated with the higher thermal profile demanded when reflow soldering with SAC305 solder pastes?

SAC305 solder melts in the range of 217-221°C and the thermal profile is therefore running hotter with peak temperatures of approximately 235-255°C depending on the assembly. Times above the liquidus temperature will range from 40-90 seconds for most assemblies.

The peak temperatures for SAC305 thermal profiles are about 25 to 35 degrees hotter than the traditional leaded paste processes. Components, boards and flux systems can be stressed by this increased temperature and create reliability risks. Some of these risks are detailed below.

-- Component molding compound damage
-- Component internal damage
-- Board delamination
-- Component and board discoloration
-- Dissolution of primary component metallization
-- Increased thickness of intermetallic bond line
-- Leaching and reduction of metallization
-- Increased oxidation impacting subsequent soldering operations

To reduce the reliability risks, engineers must insure both components and boards are lead-free process capable. It is important to see if the components are rated lead-free peak reflow temperatures up to 250 or 260°C. Additionally, moisture sensitivity ratings may be lower with lead-free processing; for further information on this please refer to the IPC-J-STD-020C. This document should be quite useful to procurement, where lead-free components can be referenced to the requirements set in this standard.

Using the lowest peak temperatures and dwells above liquidus temperature will reduce intermetallic formation and leaching of metallization. Sufficient heat will be required to solder all parts adequately and a careful balancing of the thermal profile will therefore be necessary.

Are there reliability risks associated with SAC305 or Tin-Copper wave soldering?

When SAC305 solder is used in wave soldering the temperature is normally set at 255-260°C and for Tin-Copper based solders the temperature normally is higher 260-270°C.

When soldering with Sn63Pb37 solder, the pot temperature is typically close to 260°C (500°F). If the contact times with molten solder in a SAC305 process is kept the same there is no detrimental effect.

However, many assemblers are finding that they need reduce conveyor speeds and increase contact times to achieve adequate hole-fill with lead-free solders. This can be further aggravated with thicker boards above 0.093" where contact times may need to be even longer to avoid poor hole-fill. This is a direct result of the differences in the alloys' physical properties; SAC305 and other lead-free alloys simply do not flow as quickly as Sn63Pb37. This means that adequate hole-fill may only be achieved by decreasing the conveyor speed and thereby increasing the contact time at the wave. Extra contact time does not come without risks; damage to the solder mask, laminate and bottom-side SMD's may occur if the process is not carefully controlled.

With Tin-Copper based solders, contact times can be even longer due to reduced wetting speeds of these alloys; the risks of thermal damage may be higher.

How can tip life be increased in lead-free hand-soldering processes?

High tin content solders such as SAC and Tin-Copper based alloys will leach metals more aggressively than traditional leaded alloys. This is the reason stainless steel wave soldering pots have a reduced life when used with lead-free alloys. The same process of iron being leached by tin to form Fe3Sn will occur with soldering tips.

To prolong tip life, it is recommended to use the lowest soldering or contact temperature possible; usually 700°F works quite well with SAC solders. The other way to extend tip life is turning off the heat when the iron is not in use. Proper soldering techniques such as using the correct tip size and insuring the tip is well tinned at all times will reduce tip damage by operators not fully accustomed to the reduced wetting of lead-free solders.

Using more aggressive cored wire and liquid fluxes can also reduce tip life. Assemblers using water washable solder wires will experience a shorter tip life than those using no-clean fluxes.

Some soldering iron manufacturers are now coming out with thicker iron tips for lead-free soldering; this should increase tip life. However, remember not all tips are created the same and some will last longer and cost less while others will last less time and cost more to replace. There is still some work to be done at this level as to improve the life and performance of tips with lead-free.

In wave soldering of thicker boards with large thermal masses and having seen a previous heating cycling, how can I solder them with no-clean fluxes and lead-free solder?

Wave soldering of thicker boards (especially if they are copper OSP) with thicknesses in excess of 0.093" can be difficult especially in reference to hole-fill. Assemblers using water washable fluxes, which contain more chemically active materials, tend to fare better than those assemblers using no-clean fluxes with low solids content.

If no-clean fluxes are used and hole-fill is deficient, the following can be tried to increase solder penetration.

-- Reduce conveyor speed
-- Increase the contact time at the solder wave
-- Increase solder temperature 5 to 10°C
-- Turn off chip wave
-- Apply more flux to the board
-- Turn off the air knife or reduce air pressure
-- Use a no-clean flux with higher solids
-- Use a flux with higher activity rating such as ROL1
-- If using Tin-Copper alloys, switch to SAC305
-- Use board finishes that are more easily solderable

In reference to board finish, fewer difficulties are experienced with hole-fill if the finishes are silver immersion, pure tin or lead-free HASL. Higher solids fluxes with higher potential for board residue after soldering preserve activator life during the preheating and soldering cycle; they tend to do better with hole-fill than lower solids fluxes.

In the reflow SMT process do I have to modify printing parameters or stencil design for lead-free?

If a lead-free solder paste is properly designed it will contain possibly a lower metal percentage by weight but printing parameters will not necessarily change. The printing speeds of most lead-free pastes can be as high as 100 mm/second with good print definition. The solder paste's idle time and stencil life with lead-free are comparable to traditional Sn63Pb37 solder pastes.

Due to the lower spread of lead-free solders, exposed base metals may be seen around the perimeter of the solder joint. Although this is not a defect as per IPC-610, some customers may prefer complete pad coverage. If this is the case, it is recommended to open the apertures on the stencil to resolve this problem. However, care must be taken to avoid bridging, solderballs and solderbeads with higher pad coverage.

In the selection of a lead-free paste with excellent printing characteristics check the following:

-- Printing pressure requirements
-- Printing speeds and print definition
-- Idle time
-- Stencil life
-- Ability to spread on various finishes
-- Tack life
-- Powder diameter, Type III versus Type IV

For finer pitch applications there is a trend to use Type IV powder but this can lead to slightly higher paste costs and a reduced shelf life for the paste. Type IV powder also oxidizes more rapidly and can have a reduced stencil life.

What methods are available to test for banned substances in electronic and electrical products as required by the RoHS Directive?

The RoHS Directive requires that homogeneous parts included in electronic and electrical products sold in the European Community after July 1, 2006 contain less than 0.1% lead, 0.01% cadmium, 0.1% PBB and PBDE, 0.1% chromium VI and 0.1% mercury.

The testing of PBB and PBDE is not easy and can be very expensive; Chromium VI can also be expensive although analytical tests can be of a destructive nature requiring digestion in acids prior to analysis.

The proposed screening methods as per IEC 62321 dated September 2005, Procedures for the Determination of Regulated Substances in Electro-Technical Products is X-Ray Fluorescence (XRF) Spectrometry.

XRF is a non-destructive testing of banned substances and is an effective way to identify the presence of lead, mercury, and cadmium. It will also detect elemental bromine and chromium but will not be able to identify if it is in its molecular form as PBB or PBDE or the valent state of chromium. XRF will detect their presence but to further determine the chemical identify other analytical methods are described in the above document.

XRF Spectrometer units with the accuracy needed cost in the range of $50,000 to $80,000 and therefore assemblers wishing to avoid liability are doing some spot testing of components, boards, wires, plastics and metal parts by sending them out to outside laboratories.

Kester has recently acquired a Fischer Technology XRF unit to assist customers in the screening of these parts.

Can lead-free BGAs be soldered reliably with leaded solder paste?

Lead-free BGAs contain SAC spheres for interconnection and many users of leaded pastes have this concern.

Some assemblers are soldering these with SAC solder paste and here material compatibility is a non-issue. However, in some cases, lead-free BGAs are required to be soldered with leaded solder pastes such as Sn63Pb37 and joint reliability can be questionable.

When soldering with Sn63Pb37 solder paste there is a risk of increased voiding if the thermal profile used is a lead-free one to insure proper ball collapse. This generally means that the leaded soldering process needs to be taken up to temperatures typical of lead-free assembly in order to produce good solder joints.

Soldering lead-free BGAs can be reliable when soldered with leaded or lead-free pastes provided that good wetting can be achieved without excess voids.

Is nitrogen inerting required in lead-free wave soldering?

Nitrogen inerting may not be required in reflow soldering however in wave soldering it can help reduce dross to a minimum. Reports indicate an average reduction of 95% in oxide formation. Since the cost of lead-free bar solder is much more than Sn63Pb37 about 2.5 times more, the use of nitrogen in an operation where the solder wave is used 8 hours per day can be beneficial to the bottom line.

Nitrogen is only required at the solder pot to reduce oxide formation.

Nitrogen inerting can also reduce defects such as non-wetting, insufficients but may increase bridging and icicling, particularly if the flux system is weak (no-clean L0 type) and overheated during preheat.

If nitrogen is not used a flux designed for lead-free soldering can still insure excellent results if the other process parameters are optimized.

What are flux systems designed for lead-free soldering processes?

Flux systems designed for lead-free soldering differ from traditional fluxes for Sn63Pb37 in several ways.

For solder pastes, the flux must have a greater ability to reduce the surface tension of lead-free alloys, which tend to have slightly higher values. This reduction in surface tension will promote adequate wetting and spread. Also the flux system must remain active at higher temperatures and not char or discolor at these temperatures. The flux system must also possess excellent hot slump behavior as to not case bridging during the preheat time.

In wave soldering, the flux must be thermally stable at higher temperatures and longer contact times, plus have the ability to adequately reduce of surface tension to promote good hole-fill. The flux must remain easily removable if it is a water wash type.

In hand-soldering the flux must be able to reduce wetting rapidly and give good wetting as to not extend the contact times with the parts to be soldered. The flux must remain unaffected by the higher soldering temperatures of up to 800°C. No charring or discoloration in no-clean type fluxes and easily removable flux residues for water wash types is expected.

About the author
Peter Biocca is a Senior Market Development Engineer with Kester in Des Plaines, Illinois. He is a chemist with 24 years experience in soldering technologies and flux development. He has presented around the world in matters relating to process optimization and assembly.

He has been working with lead-free for over 8 years and has assisted hundreds of assemblers with their lead-free implementation.

He has been involved in numerous consortia within this time including iNEMI in the United States. He is an active member of IPC, SMTA, ASM and iNEMI. He is the author of numerous technical papers and articles many of which have been delivered globally. He is also a Certified SMT Process Engineer.

email: pbiocca@kester.com