Are you ready for lead-free?

J. Pierre Menard, Conceptronic / Research International
Divisions of CVD Equipment Corporation

Lead-free is coming.

Although electronics components and assembly make up for less than two percent of lead consumption and that there seems to be scientific proof lead does not leach from circuit boards to contaminate ground water, the political battle is already lost – boards must be made "lead-free." "Lead-free" does not necessarily mean "better for the environment." Proposed lead-free alloys containing heavy metals (like Silver) cause a new set of environmental problems.

In reality, the marketing of "green" products is a bigger push than legislation. Panasonic has introduced their green mini-disc player late in '98. Samsung has introduced "green" memory modules without lead or halides early in 2001 as part of a concerted effort to develop environmentally friendly products initiated in 1994.

Look for lead-free solders to be first introduced into consumer products as part of marketing differentiation and in high volume, low-cost products where future recovery and recycling liabilities might be extremely expensive.

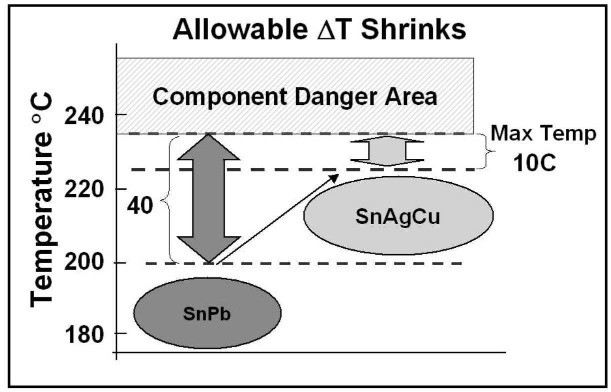
But what alloy?

Given that "lead-free" solder assembly is coming, the alloys being considered typically fall in the 180-230°C melting temperature regime. In general, temperatures below this range raise questions of reliability during thermal cycling; temperatures above this range require component packaging out of materials that have yet to be invented. Several alloys are being considered as a replacement to SnPb solder and are gaining some acceptance:[i]

SnCu with a melting temperature of 227°C has the advantage of being a eutectic solder. A eutectic solder transitions from solid to liquidus without moving through a pasty region, with the result that components are less likely to move during processing. It is quite inexpensive, but the high melting temperature makes its widespread adoption unlikely.

SnAg does significantly reduce the melting temperature; Sn-3.5Ag melts at 221°C. The silver content adds cost and raises the new environmental concerns of contamination.

If the environmental impact of silver alloys is considered better than SnPb solders, the use of Sn-3.8Ag-.7Cu seems to gaining the most acceptance with a melting temperature of 217°C. It has very good strength and reliability, in fact, better than SnPb. With the majority of assembly component standards based on a melting temperature of 183°C, the upper process limit for most components is around 240°C. This results in



shrinkage of the reflow process window from 40°C to around 10°C.[ii]

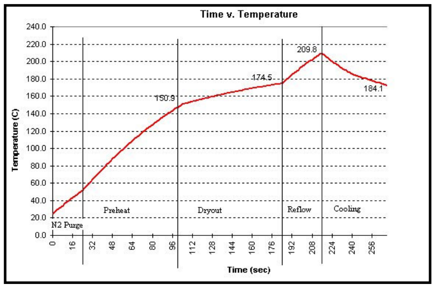
Lower melting temperatures can be had with the addition of Bismuth. Sn-3.5Ag-3Bi melts in the range of 206-213. This is not a eutectic solder, but instead has a pasty region of 7°C. This alloy consistently is rated the best solderability of the proposed lead-free alloys. Bismuth alloys have good reliability as well, but some bismuth alloys have shown a tendency for lifting fillets, so caution is appropriate during implementation. One study makes a case that alloys containing less than 6% bismuth exhibit equivalent strength to SnPb alloys.[iii]

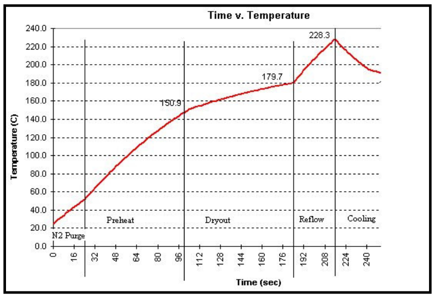
Alloys with Zn, Sb, Ge, and In, are also being considered in limited applications. Associated with some of these alloys are high rates of corrosion, limited shelf life, large pasty regions, low melting temperatures, and high costs.

How does this change the reflow process?

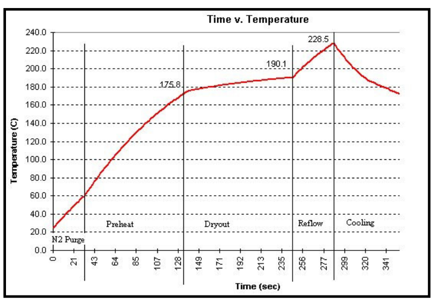
Whatever the alloy, the melting temperature for the solder will generally be 20-35°C warmer than current SnPb solder. To accomplish these corresponding higher PCB temperatures required during the reflow, either higher rates of heat transfer are required (increased oven temperatures or greater convection flow) or slower processing speeds. Thermal modeling of a typical board through a Research MicriFlo reflow oven with low convection flowrates gives some indication of the magnitude of changes required for a lead-free alloy.

A SnPb profile was successfully created with a PCB peak temperature of 210°C in a 3.5 minute profile with a oven reflow setpoint of 285°C.





With the same PCB and airflow, a Pb-Free profile was successfully created with a peak temperature of 228°C in the same 3.5 minute profile with a oven reflow setpoint of 325°C. This is a temperature increase of about 14%.



Leaving the setpoint temperatures the same, a Pb-Free profile was successfully created with a peak temperature of 228°C with a 4.8 minute profile utilizing the earlier oven reflow setpoint of 285°C. This is a loading factor increase of about 37%.

A third profile could be created by a combination of slower process speeds and higher oven temperatures. Given the requirement of a tighter process window, the implementing a slower belt speed with the corresponding lower oven temperature is the most logical solution.

Because of the higher flowrates in a Conceptronic oven, the setpoints required for similar results would be approximately 50°C less.

With a difficult assembly where there are large delta T's on the PCB assembly, ramping into reflow and holding at a stable temperature is necessary to reflow all the components without thermally damaging the lower mass areas. In this case, excellent zone definition flow and control of cross-flow is sufficient to create the necessary profile shape. Similarly, the short reflow zones of Conceptronic and Research's ovens (MicriFlo: 8.5", 216mm) (ThermaFlo 10", 254mm) (Conceptronic: 12", 305mm) already have an advantage in creating ramp hold profiles.

When reflowing lead-free alloys, it may be time to reconsider nitrogen atmospheres. The rate of oxidation that will occur on a PCB inside the oven will increase, inhibiting wetting. Until flux chemistries are further refined, an O_2 free atmosphere will open the process window. Other benefits of reflowing in nitrogen that were investigated in the past may well return with the higher temperatures. It has been demonstrated that with purity levels around 8-10,000 PPM, FR4 is less likely to discolor. At purity levels of 1000 PPM, most solder fluxes are easier to clean.[iv] Again, for Conceptronic and Research customers, over 75% of the ovens sold in the past 5 years were nitrogen ready.

Conceptronic / Research ovens are lead-free ready – are you?

For most PCB assemblies, the mass reflow oven is already lead-free capable, but there are many other considerations and caveats. HASL PCB finishes are not lead free, and some OSP's will not necessarily protect double-sided assemblies during first pass reflow. Most components still ship with SnPb finishes with the exception being PdNi finishes which depending on the process have been prone to more solder defects. All existing component preparation and moisture sensitivity standards have been defined around a eutectic temperature of 183°C. Thermal fractures may appear at the elevated temperatures in some components; other components, especially the higher profile thin walled connectors may begin to deform during reflow. Given the certainty of a tighter process window, an increase in re-work is to be expected which will raise many issues as well.

In fact, the transition to lead-free, when only some components, only some PCB finishes, and only some PCB assemblies are lead-free might be more difficult than the future when lead-free has become the norm, not the exception.

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[i] A summary of materials on lead-free alloys. www.lead-free.org
ii Graphic adapted from *The Panasonic Mini Disk Player Turning a New Leaf in a Lead-Free Market,* Tom Baggio, The IPC Works, 1999 Minneapolis, MN
iii Ibid.
iv *Inert IR Reflow: The Significance of Oxygen Concentration in the Atmosphere*, Colin Lea, National Physics Laboratory, Teddington, U.K., Surface Mount International, 1991.