随着2006年7月的RoHS最后期限逼近，关于用哪些方法取代锡铅加工最合适的问题很多。无铅HASL（热风焊锡整平）是取得一定成功的表面处理取代方法。不管贵公司实际上正在转向其它的表面处理方法，还是你只是需要更了解上述工序，这个便利的问答部分会澄清无铅HASL方法的一些疑问。

No Hassle LEAD-FREE HASL

It's not a drop-in replacement for HASL. But moving to lead-free HASL can be less painful than you think. **by JACK FELLMAN and SIMON LEE**

As the July 2006 Restrictions on Hazardous Substances (RoHS) deadline looms, PCB fabricators and even designers continue to search for information on lead-free processes. Many PCB shops are preparing to convert to alternative surface finishes (or at least add the capability). But despite all the ink that's been spilled – and hot air expounded – on the subject of alternative surface finishes, there seem to be more questions than answers. There are numerous alternative surface finishes available, and all have their supporters and detractors.

One of these, lead-free hot-air solder leveling (LFH) has shown success in lead-free manufacturing. This Q&A session should help provide some clarity on LFH – what it is, what it isn't and how it works.

Q. What are the operating costs of LFH?

A. Cost for the LFH surface finish includes several elements: the cost of metals, density of metals and coating thickness. Since the LF alloys are almost pure tin or tin with 3 to 4% silver, their metal cost is significantly higher than eutectic tin-lead (63/37) solder. LF alloys are approximately 15 to 16% lighter in density, which means that 84 kilograms of a LF alloy will equal the volume of 100 kilograms of the higher density tin-lead alloy. There are indications that the average thickness of LF solder is about 50% less than that of tin-lead solder, which means less solder is consumed. This observation has been confirmed by comparing consumption data of LF solder with that of tin-lead solder. The reduced consumption offsets the higher cost of the LF alloy.

Q. What are the laminate requirements for LFH?

A. The most commonly used laminates for circuit boards using LFH as a surface finish are standard FR-4 with a Tg from 130 to 165°C, which works well with either black or alternative oxide. Work has also been done with higher performance, multifunctional laminates. Single-sided boards made of CEM-1 material have been successfully run with no discoloration or staining of the unprotected backside of the board. Delamination of multilayer boards has not been an issue, despite the higher operating temperature of the solder pot and assembly with multiple reflow cycles at higher temperatures.

Q. What solder paste is most commonly used with LFH?

A. SAC alloys, such as 305 (Sn3.0Ag0.5Cu), are the solder pastes most commonly used at this time.

Q. Have any incidents of whisker formation been reported from deposits of LFH?

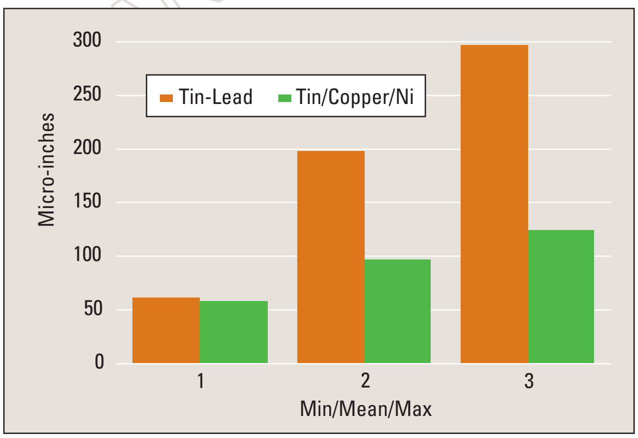

FIGURE 1. Comparison of solder thickness for an SMD feature, with leaded and lead-free solder.

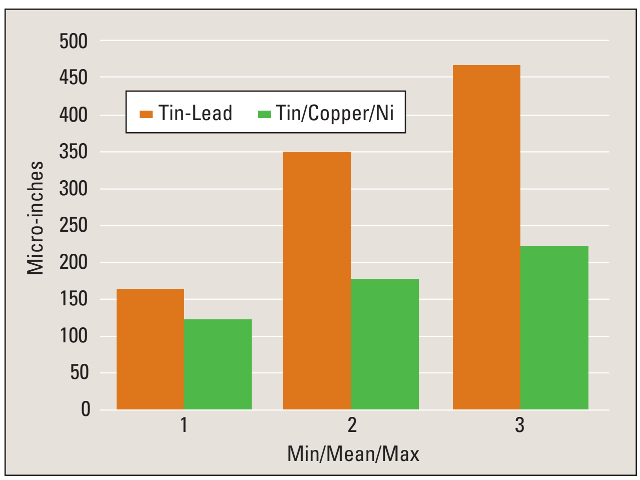

FIGURE 2. Comparison of solder thickness for a BGA feature, with leaded and lead-free solder.

TABLE 1. Comparison of process operating windows for HASL with different alloys.

ALLOY	MELTING POINT (°C)	OPERATING TEMPERATURE (°C)	PROCESS WINDOW (°C)
Tin-Lead	183	250-260	67-77
Tin-Silver-Copper	217	265-270	48-53
Tin-Copper-Nickel	227	265-270	38-43

A. The authors are not aware of any reports of the formation of tin whiskers.

Q. What applications will be suitable for LFH?

A. LFH can be used for those applications whose requirements are currently being met by tin-lead HASL. Uniformity of solder thickness is better with LFH than tin-lead, but deposits are not co-planar.

Q. How does LFH compare to tin-lead HASL (TLH) for uniformity of solder thickness or co-planarity?

A. LFH has considerably better solder thickness uniformity than TLH. This is more easily observed with the horizontal process than the vertical. Of course, it is also dependent upon the set-up conditions for the machine and the process, but under optimum conditions the results will be better. This can be demonstrated with the following graphs for QFP and BGA pads (**FIGURES 1** and **2**).

Q. Why should I spend engineering time and money now on LFH when I don't have orders for it yet?

A. Not much study is needed to be ready for the process conversion. Remove tin-lead solder from the machine and add back pure tin to remove lead impurities. Repeating a second time will usually result in the lead concentration being <0.1%. No extra equipment investment is required, unless heaters or heating control are not adequate. The time to reach acceptable quality deposits and optimize the machine on a preliminary basis is typically about four hours.

Q. What process changes are required for implementation of LFH?

A. Since the melting points of lead-free solders – whether tin-copper-nickel or tin-silver-copper – are higher than tin-lead, the solder pot temperature is higher. The operating window comparison is shown in **TABLE 1**.

With tin-lead solder, the copper concentration must be maintained below 0.3%, while for tin-copper-nickel, the process control range is from 0.7-0.9%. With the tin-copper-nickel alloy, nickel must be controlled between 0.025-0.05%. It is necessary to increase the preheat in horizontal application to aid in clearing holes. The additional heat required depends on the same variables as for tin-lead solder: board thickness, the number of inner layers and the amount of copper sandwiched within the layers. With tin-lead solder, it is possible to achieve acceptable results without the use of an etching cleaner. With LFH, a micro-etch is required for cleaning. When compared to tin-lead solder, lower pressures on the air knives can be used with LFH to clear the holes, resulting in a more uniform solder thickness.

Q. What is the shelf life of boards using lead-free solder vs. that of the HASL process?

A. Data show the shelf life of lead-free solder to be more than 1 year under proper storage conditions, which is the same as for tin-lead solder.

Q. How many PCB shops are running LFH in their machines at this time?

A. As of June 2005, approximately 63 shops were running LFH globally (FIGURE 3).

Q. Can tin-copper be used to replace tin-copper-nickel in order to reduce the cost?

A. Deposits of tin-copper suffer from a grainy surface and show increased growth of intermetallic compound (IMC), compared to tin-copper-nickel. It has been found that the presence of nickel in the lead-free alloy leads to a finer grain structure and has a definite role in controlling the growth of IMC.

Q. Can LFH using Sn-Cu-Ni be reworked?

A. In some instances, improved solder uniformity can be achieved by running panels a second time through the machine. There is evidence that a second immersion in a vertical solder pot will remove approximately 0.7 µ of copper and a second dip will show a total copper removal of 1.0 µ, which is well within acceptable limits for tin-lead solder.

Q. How much difference is there in the thermal profiles for reflowing lead-free solder paste on a board with the LFH surface finish?

A. A thermal profile for lead-free solder paste was recommended by Ravi Sharma of Microchip Technology in Application Note 233. The lower control limits for tin-lead solder and lead-free solder were similar, but the upper control limits were slightly higher for lead-free solder (FIGURE 4). The comparison was made with the assumption that matte tin and tin-lead was the finish on the components. Factors that influence thermal profiles are circuit board thickness, interconnect density, surface finish and compatibility of the assembly process.

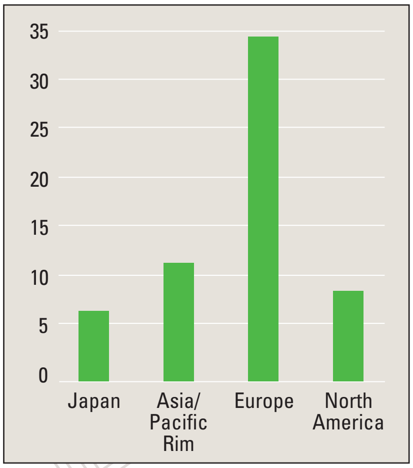

FIGURE 3. Number of shops running LFH globally; most are located in Europe.

Q. Is cracking on the surface of lead-free solder joints a new problem, one not experienced with tin-lead solder?

A. Surface cracks on lead-free solder joints are the result of the rate of cooling of the solder from the wave solder process and are influenced by the difference of the alloy from its

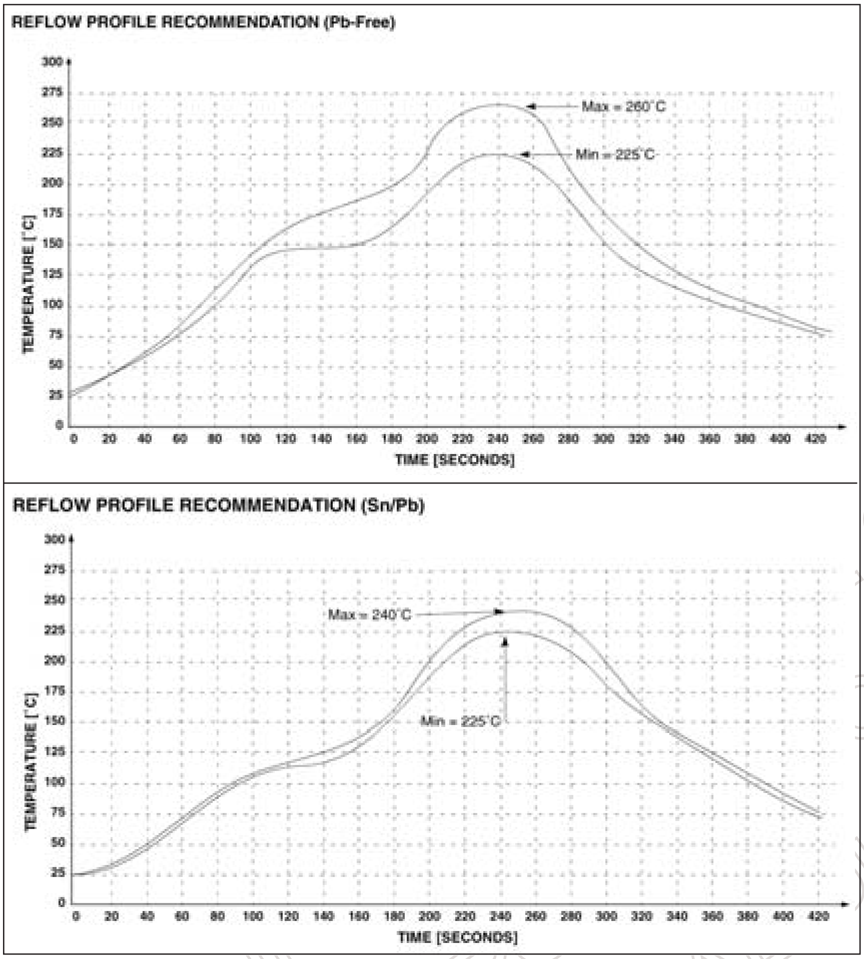

FIGURE 4. Comparison of reflow thermal profiles for tin-lead solder and lead-free solder. *Courtesy of Microchip Technology*

eutectic composition. The cracks are believed to be superficial, with no long-term deleterious effects.

Q. What is the maximum permissible lead concentration permitted in LFH?

A. To meet lead-free requirements, the lead concentration in the electronic component must be <0.1%. A thorough job of removing tin-lead solder from the solder pot will include two cycles of purging with pure tin, prior to adding the lead-free solder, and result in a lead concentration of <0.04%. The bigger risk of lead contamination will come from reworking tin-lead panels through lead-free solder.

Q. What is the difference between a flux for TLH and one for LFH?

A. Flux for LFH is more thermally stable, with lower activity, and it is less corrosive to the solder pump and solder tank. One study has shown that an ideal LFH flux can promote good solder coverage and still be rated non-corrosive and non-flammable and be shipped and stored as a non-hazardous material.

Q. How are the copper and nickel concentrations maintained in balance, when using tin-copper-nickel alloy in the LFH process?

A. Samples of solder must be taken from the solder pot daily or weekly, depending on the surface area of copper run through the machine, and then analyzed for copper and nickel. Both elements are already being analyzed in the tin-lead solder analytical scheme, but adjustments must be made to analyze them at higher concentrations. Bath dilutions are made with tin, to reduce the copper concentration, and then nickel is added to increase its concentration.

Q. There are reports that nickel in the IMC can cause weak, brittle IMC and cracks in the solder joints. Does the same thing happen with LFH, when tin-copper-nickel is being used?

A. There are reports in literature that document the effect of high concentrations of nickel on the reliability of solder joints. In all cases where this behavior was reported, the source of nickel was an electroless nickel barrier layer to protect copper from migrating and penetrating the thin gold top layer. This is not the case in LFH where the source of nickel is the solder itself. There have been no reports of weak, brittle solder joints from wave soldering with tin-copper-nickel.

FIGURE 5. Tin-copper needles being removed from solder by a skimming tool.

Q. Does a special soldermask have to be used for LFH, or will standard products work?

A. Standard soldermasks will work for most applications. In areas where soldermask is used for hole plugging, testing should be done to be sure the adhesion of soldermask in plugged holes will remain and not peel off at the higher LFH temperature.

Q. Is it possible to skim lead-free solder by reducing the temperature as with tin-lead solder?

A. Work has been done to optimize the skimming process and tin-copper needles can be removed from lead-free solder by holding the temperature in the 235-240°C range, just slightly above the melting point. When the lead-free solder is Sn-Cu-Ni, nickel is also removed with the skimmed solder, so its concentration must be replenished. The skimming process can reduce the cost of lead-free solder by 50 to 80%. See **FIGURE 5**. PCD&M

JACK FELLMAN is a senior engineer with Rohm and Haas Electronic Materials; jfellman@rohmhaas.com. **SIMON LEE** is imaging business manager with Rohm and Haas Electronic Materials; tslee@rohmhaas.com.