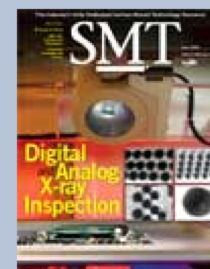

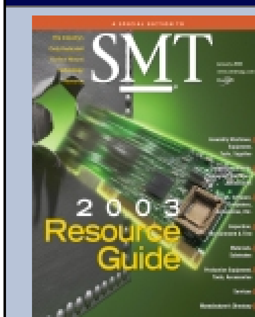

Lead-free Wave Soldering: A Cost-effective Alternative

As the growth of lead-free production continues, manufacturers are finding they can save money by upgrading their existing wavesoldering machines for lead-free assembly.

By Tony Gyemant

Much emphasis has been placed on converting the reflow soldering process to lead-free, due to the dominance of SM components. Wave soldering must also be changed to lead-free to avoid mixing of lead-bearing and non-lead-bearing alloys on the same assembly.

A common notion is that one can simply switch from tin-lead (SnPb) to lead-free by dropping lead-free solder into an existing wave machine. Another general misunderstanding is that a new wave machine for lead-free processing is necessary.

For lead-free wave soldering to be successful, changes to the entire process must be considered. The majority of lead-free solder alloys possess good solderability, but exhibit decreased wetting characteristics compared to tin-lead solders. Since wetting is a critical factor affected by several variables, changes are required that will affect the majority of machine parameters.

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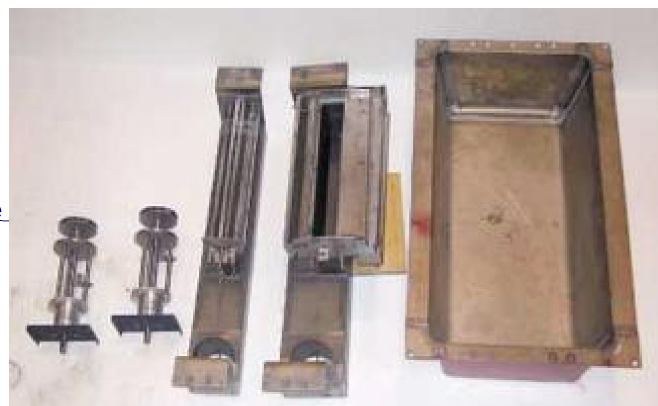

Figure 1. A lead-free retrofit kit with titanium impellers, baffles and solder nozzles.

Lead-free alloys have a significantly higher tin content than tin-lead solder and require higher processing temperatures. Many products will be converted to lead-free over a gradual phase-in; however numerous manufacturers are now making their wavesoldering machines lead-free compatible.

Because the wetting characteristics of lead-free alloys tend to be less than tin-lead solder, it is critical to use good flux chemistry. Additionally, the higher temperatures needed for lead-free soldering require a flux chemistry that can withstand preheat temperatures up to 130°C and liquidus solder temperatures as high as 280°C for up to 3 seconds. A volatile organic compound- (VOC) free, water-based flux generally is recommended.

An existing wavesolder machine may need upgrading with a newer spray fluxer to be suitable for processing VOC, water-based fluxes. An ultrasonic or nozzle-type spray fluxer works best, since the flux droplet size can be controlled and a continuous, uniform spray pattern can be applied across the entire printed circuit board (PCB). Achieving the smallest possible droplet size with VOC-free fluxes helps obtain good through-hole penetration.

A longer preheating section often is needed to reach these higher temperatures and avoid thermal shocking of the PCB when entering the chip or laminar wave. Achieving proper preheat temperatures on the top of the PCB has the greatest single effect in reducing solder defects. Optimum preheating of a PCB can best be achieved with a combination of infrared heating from the bottom and convection heating from the top.

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TABLE

Characteristics of lead-free alloys

Alloy Composition	Melting Point (°C)	Solder Pot Temperature (°C)	Density
SnCu	227	270-280	7.29
SnAg	221	265-275	7.44
SnAgCu	217	260-270	7.38
SnAgCuSb	217	260	7.24
SnPb	183	250	8.80

Preheating for lead-free wave soldering can require a heating length of up to 1.8 meters for conveyor speeds as high as 120 mm/minute and as long as 2.4 meters for conveyor speeds greater than 180 mm/minute. An effective upgrade strategy is to replace an existing spray fluxer with an external spray fluxer. This not only improves the quality of flux application but frees up space inside the wavesolder machine.

For tin-silver-copper alloys (SnAgCu) with a melting point of 217°C, the solder pot temperature may be between 260° and 270°C. For high melting point alloys such as tin-copper (SnCu), the solder temperature may be as high as 270° to 280°C.

It is common to change the characteristics of the laminar solder nozzle since a longer contact time may be required due to the lower wetting properties of lead-free alloys. Often the distance between the chip and laminar waves may be reduced to minimize any temperature drop between contact points. Increasing the length of the laminar wave improves wetting while increasing the preheat output produces a similar effect. Reducing the fall height of the wave to decrease the distance of overflowing solder reduces the amount of dross.

Compared to tin-lead solder, most lead-free alloys oxidize more rapidly when the solder is liquidus due to their increased tin content. Tin oxide, consisting of tin-oxygen (SnO and SnO_2) forms at a higher rate because of the higher processing temperature, resulting in more oxidation and dross. Nitrogen inertion of the solder pot minimizes exposure of the liquidus solder to oxygen and decreases the amount of dross. Reducing the rate of oxidation and the resulting dross buildup significantly improves performance.

OSP coating over bare copper is quickly becoming a replacement for traditional hot air solder leveled (HASL) board finishes, resulting in a trade-off between a potential source of lead contamination and a potential source of copper contamination. As lead-free wave soldering becomes more widespread, questions have been raised over increased solder pot maintenance brought about by the high copper dissolution rates of lead-free alloys.

During long periods of operation, some lead-free alloys start to become sluggish in the solder pot. This is caused by a buildup of a copper-tin intermetallic (CuSn) at the bottom of the solder pot. The problem did not exist with standard tin-lead wave soldering because the copper-tin intermetallic floats.

In a standard tin-lead wave pot, impurities such as copper form intermetallics with tin as they build up. Reducing the temperature of the solder pot, allowing the pot to sit idle for a few hours, and skimming the top surface can easily remove the intermetallics. The method works well since the density of the copper-tin intermetallic (CuSn) is 8.28, and tin-lead (SnPb) is 8.80, allowing the copper-tin intermetallic to float. Periodic maintenance of a tin-lead solder pot can maintain copper levels between an acceptable range of 0.15 to 3 percent. The density of tin-copper or tin-silver-copper lead-free solder alloys is less than that of tin-lead (Table).

Instead of floating on the surface, the copper-tin intermetallics sink in lead-free alloys and are dispersed throughout the solder pot. In addition, some lead-free alloys dissolve copper at a faster rate than tin-lead. The effect can be a higher rate of copper build-up and contamination of the solder pot, which can translate into the need to dump the solder pot more often or a complete changeover.

Studies suggest that solder pots containing lead-free alloys may have to be dumped when the copper contamination levels reach 1.55 percent. Above this point, most lead-free alloys become sluggish, and at above 1.9 to 2.0 percent, damage can result to the impeller, baffles and solder pot.

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Figure 2. Titanium solder pot liner prevents iron dissolution and increases the life of the solder pot.

Many lead-free alloys cause corrosion to the base metals used for solder pots, impellers and baffles because of the aggressiveness of tin at high temperatures. The surface of many base metals such as stainless steel or cast iron generally show signs of pitting and start to dissolve after prolonged contact with lead-free alloys. This leaching process releases iron (Fe) particles, resulting in contamination of the solder alloy.

Solder pot materials such as stainless steel can become damaged after only a few months of operation when using lead-free alloys. The use of high-grade stainless steel can reduce this effect somewhat, as does applying a proprietary, corrosive-resistant surface coating. However, surface coatings are susceptible to scratching because of the higher maintenance levels needed to remove the copper intermetallics that sink to the bottom of the solder pot. Over time, repeated scratching breaks down the surface coating and results in corrosion of the base metal and contamination of the solder pot. Without protection, parts made from these base metals degrade to the point where they may require replacement after only one to two years of operation.

Base metals resistant to tin scavenging exist, but the cost of these materials was considered excessive. However, titanium is impervious to tin scavenging.

The frequency with which solder pumps and baffles made of traditional base metals wear out in lead-free wavesoldering applications has caused a rethinking of the use of titanium. Retrofit kits replace the impeller, baffles and solder nozzles with parts made of titanium that withstand prolonged service in lead-free applications (Figure 1).

A titanium solder pot liner can be placed inside an existing cast iron solder pot to convert an existing wavesoldering machine for lead-free use (Figure 2). This titanium liner can be retrofitted to most models of wavesoldering machines. It eliminates iron dissolution, minimizes solder contamination, and avoids periodic dumping of the solder pot.

Conclusion

Upgrading an existing wavesoldering machine with an external spray fluxer, new preheat modules, a solder pot retrofit kit and a titanium solder pot liner reduces the cost of converting to lead-free wave soldering. This is especially true when applying an upgrade strategy to a used wave machine. It provides effective lead-free performance at a fraction of the cost of a new piece of equipment.

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Surface Mount Technology (SMT) December, 2003
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