# The Future of Hot-Air Leveling

## Is it time to retire the old warhorse?

Jim Higson

Although hot-air leveling ( HAL) has been the preferred end-user specification for the past 15 years, most fabricators would rather not have the process in their shops. Since its inception, HAL has been associated with process problems and extensive maintenance; it's one of the harshest and least understood processes in the PCB manufacturing cycle. Many alternatives have been offered, in the form of organic and inorganic coatings and tin/lead depositions. But all have presented either smaller process windows, inconsistently thick deposits, or additional steps for the user. Customer demands for longer shelf life, solder-ability, and SMOBC maintain HAL as the commercially successful, specified process. With SMT and shrinking pitch on high-pin-count devices pushing IIAL to new limits, the process continues to be commercially successful and specified. Until a viable replacement can be found, steps can be taken to increase the yields and reduce the costs of the process.

## Yield Optimization

HAL should be viewed as a process, not just a machine. The process includes precleaning, flux application, solder coat/hot-air leveling, and postclean. Upstream problems result in poor final solder deposition and rework. Because improper cleaning is a leading cause of exposed copper and dewetting in the HAL process, all surface contaminants must be removed in a one- or two-step microetch. Daily analysis of the microetchant and associated equipment saves rework.

There are literally hundreds of fluxes for the HAL process, and their selection and application are critical. HAL fluxes pm-form the following functions:

- provide oxidation protection to the precleaned surface
- affect beat transfer during solder immersion
- provide oxidation protection during HAL
- postlevel solder on the pads.

Complete flux coating results in little or no oxidation prior to HAL. The other three functions performed by fluxes are related to flux viscosity. Higher-viscosity fluxes reduce overall heat transfer efficiency, requiring longer dwell time in the solder pot or a higher temperature. If the energy transfer is not sufficient, the copper pad will not reach the temperature needed to form the intermetallic $Cu_6Sn_5$ bond that allows eutectic solder to wet the entire surface. However, the higher-viscosity fluxes provide better oxidation protection in the hot-air stream and more uniform solder leveling on pads. The user is therefore faced with a choice between the advantages of higher viscosity with better protection and leveling vs. the superior heat transfer rates provided by lower-viscosity fluxes. The optimal combination is high-viscosity flux with minimal thickness. This gives the benefits of good oxidation protection and postleveling with respectable heat transfer rates and dwell times.

Warpage and thermal shock or barrel cracking can create a yield obstacle that appears after postcleaning. As background, water is one of the most efficient media of thermal exchange. Because the heat transfer rate is greater in water than in molten solder, more thermal damage occurs in postcleaning than in the solder pot. Several means exist to minimize this problem, all of which involve gentle cooling, with air as the medium. These methods range from placing panels on stand-offs for free air convection to using air cooling/flotation tables as part of a continuous HAL process. Whatever the method, the critical point is slow cooling at low heat transfer rates.

Although fine pitches on flat packages provide a

### Alternatives to Lead Solder

*Ken Gilleo*

There are numerous alternatives to lead solder. Some are in development, and a few are in commercial use. But none is a drop-in substitute for the 5,000-year-old eutectic tin/lead.

The high cost of eutectic tin/silver (96.5/3.5) is compounded by the need for a very high Tg substrate to go with the alloy's high melting point (221°C). Tin/indium and tin/bismuth solders have reasonable melting points but are expensive and have some unfortunate properties, such as expansion on cooling. Alloys comprising three or more metals are being researched, with no alloy of any composition expected to be a direct Sn/Pb replacement. The need for electroplateability greatly complicates the search for an alternative alloy.

Metal-filled conductive adhesives have already taken some niche markets, as in Mylar flex circuit assembly and flat-panel display interconnection. But so far they've struck out as solder substitutes on FR-4 substrates due to the gradual formation of oxides on components and circuit junctions. To counter this junction instability, Poly-Flex Circuits Inc. (Cranston, RI) has developed a product called Poly Solder (licensed to Alpha Metals) that contains sharp particles to retain conductivity by punching through the oxide barriers.

Acsist (Minneapolis, MN), IBM (Endicott, NY), IVF (Gothenburg, Sweden), and the University of Wisconsin (Madison, WI) are just some of the organizations working on various ways to form dendritic surfaces on PCBs and components that would bind them together somewhat in the fashion of Velcro. Some of the technologies are successful enough to be commercially used to make connections for electrical testing, but none are strong enough for field use.

A change in the status of lead is bound to come. The question is when, and the realistic answer is when regulatory agencies demand it. As scientists, environmentalists, and legislators grapple with the future of lead, we suggest you keep your shirt on and your solder pot hot. FAB

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particularly difficult problem, process adjustments can be made to increase thickness uniformity and reduce bridging. The most recognized technique adjusts the panels at an angle to the air knives. This provides a uniform shear area to the hot-air stream, evening the solder deposition and minimizing bridging problems on sub-20-mil-pitch features.

Persistent problems arise with the use of older HAL equipment designed to the military specification of depositing up to 3 roils of solder on pads. New machines are designed to provide a more even distribution of solder in the 300- to 1200-uin. range. Some manufacturers offer retrofit packages to upgrade the capabilities of the older equipment. This alternative should be explored prior to capital outlay for new equipment or processes.

## Cost Reduction

Equipment is now available that can significantly lower the cost of the HAL process by reducing the cost of raw materials and waste disposal. Flux applicators that are available with adjustable squeegee rolls provide flux savings of 50% or more. This translates to similar savings in spent flux disposal. With disposal costs approaching raw material costs, the overall savings can be substantial.

Solder is another large expense. Only a small percentage of solder goes out the door in the form of product, with the majority leaving the plant as dross or contaminated solder, One method of controlling this cost is regular pot skimming for copper and dross. With proper skimming and regular solder additions, the solder bath need not be changed. Equipment now exists to minimize solder usage by extending the combing procedure. This is done by providing a separate container to settle copper and other contaminants out of the solder. The key to the process is maintaining consistent temperatures and allowing sufficient time for the solder contaminants to separate from the eutectic solid,

> HAL is one of the harshest and least understood processes in the PCB manufacturing cycle.

Regular maintenance of any piece of equipment provides longer service life and higher return on capital investment. This is especially true in the harsh hot-air leveling environment, where even the most corrosion-resistant stainless steels (316 and 316L,) are attacked by the acids in Iligl]-temperature fluxes. Add to this the violent air blast, which distributes the corrosives throughout the machine, and equipment life is dramatitally shortened Cleaning and maintenance are obvious musts for producing quality panels and extending machine life.

Investment in operator training will be returned many times over. Since a bit of black magic exists with the industrial art of the HAL operation, the experienced operator provides better results in terms of fewer reruns and greater throughput. Maintenance personnel should also be familiar with the peculiarities of equipment working in the destructive HAL environment.

## Conclusion

Although tighter component geometry and requirements for uniformly controlled surface topography arc forcing the process to its limits, HAL will be a viable surface coating for years to come. No other technology brings all the advantages of HAL to the end user. The process of choice is still hot-air leveling, strongly supplemented with better process control, the addition of ancillary equipment, and a commitment to thorough operator training.

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