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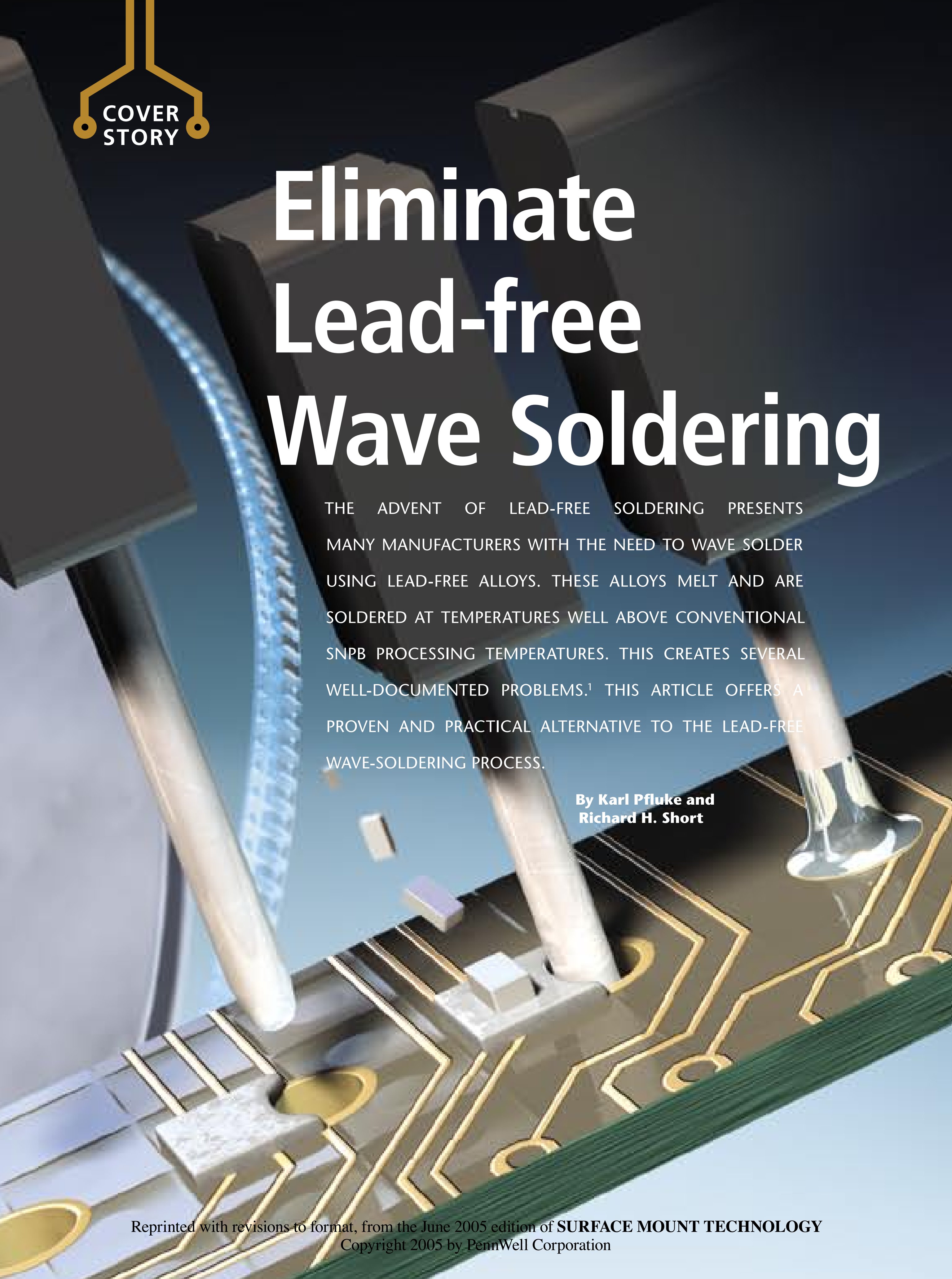
INSIDE:



# Eliminate Lead-free Wave Soldering



COVER STORY

# Eliminate Lead-free Wave Soldering

THE ADVENT OF LEAD-FREE SOLDERING PRESENTS MANY MANUFACTURERS WITH THE NEED TO WAVE SOLDER USING LEAD-FREE ALLOYS. THESE ALLOYS MELT AND ARE SOLDERED AT TEMPERATURES WELL ABOVE CONVENTIONAL SNPB PROCESSING TEMPERATURES. THIS CREATES SEVERAL WELL-DOCUMENTED PROBLEMS.[1] THIS ARTICLE OFFERS A PROVEN AND PRACTICAL ALTERNATIVE TO THE LEAD-FREE WAVE-SOLDERING PROCESS.

**By Karl Pfluke and Richard H. Short**

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A recent regulatory assessment impact report from the UK estimates, "it will cost between $95 and $464 million to retool (wave solder and reflow) machines in that country, with a corresponding annualized cost of $9 million to $47 million."[2] Lead-free alloys best suited for use in the wave soldering process are higher in temperature and Sn content than their lead-bearing predecessors. Their use requires costly equipment retrofitting, new equipment purchases, specific lead-free fluxes and significant process adjustments (possibly including the expense of nitrogen utilization).

Surface mount assembly has dominated its thru-hole predecessor since the early 1990s. The higher density and lower cost of SMT continues to increase its prevalence as a common assembly technology. Still, thru-hole connectors can be found in almost every electronics assembly, including SMT assemblies.

Wave soldering has proven to be the process of choice for assemblies containing multiple thru-hole connectors, primarily due to superior mechanical strength and low process cost the design provides. When confronted with the requirement to implement a lead-free alloy, the game changes. The benefits associated with wave soldering to attach thru-hole connectors pale when compared to the consequences of switching to a higher-melting-point lead-free solder alloy. Problems associated with the alloy include:

- Equipment destruction,[3]
- Increased operating temperatures,
- Higher materials costs,
- Reduced wetting speed.

By combining two well-known and proven technologies/techniques, the requirement for lead-free wave soldering for many applications is eliminated.

To obtain the advantages of thru-hole technology and SMT assembly, the pin-in-paste (PIP) process was developed.[4,5,6] Although PIP is an effective technology, it cannot always deliver the solder volume required to create an acceptable joint (Figure 1). As SMT becomes increasingly common, wave soldering is sometimes used only to attach connectors. The added expense of an additional process step for a handful of components usually is unacceptable. The combination of solder preforms and solder paste can offer a process alternative for thru-hole connector-joint requirements, improve solder joint quality and increase the overall process profitability (Figure 2).

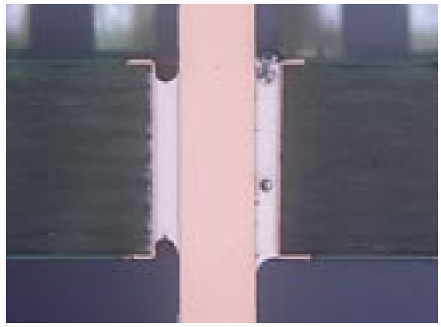

**Figure 1.** PIP joint without additional solder preform.

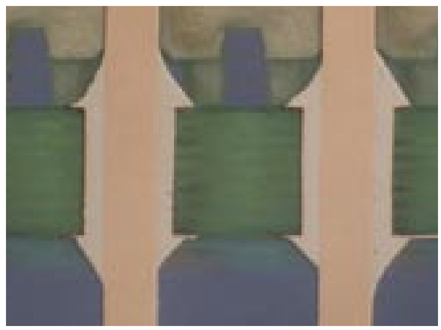

**Figure 2.** PIP joint with additional solder preform.

### In the Beginning

PIP processing has evolved from the days when it was necessary to print relatively large volumes of solder paste onto the PCB.[7] The printed paste filled the barrel of the plated thru-hole (PTH) entirely. Because of this, a large amount of the paste in the barrel was pushed out during connector insertion; resulting in a process so messy some engineers disallowed it. After reflow, there often was not enough solder volume to satisfy IPC-B-610 Class 3 solder-joint criteria (Figure 3).

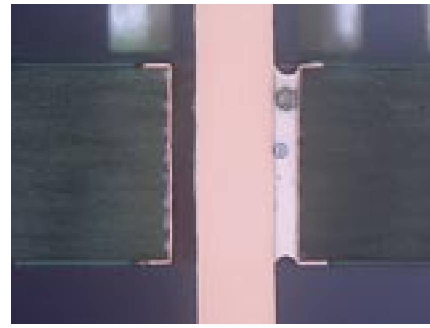

**Figure 3.** Starved solder joint.

PIP processing has evolved into a more-acceptable and efficient process that relies on specific stencil design and solder-paste-printing techniques.[8] One example of this includes the use of step-stencils to overprint solder paste around the barrel mouth, leaving the PTH barrel free of any paste. This has become the process of choice for many manufacturers who are soldering a small number of connectors and cannot justify the cost of maintaining wave-soldering equipment and processing. Figure 4 shows examples of the printed-paste appearance using modern stencil designs.

Even with these improvements, there are cases where the techniques do not deliver adequate solder volume. Although PIP has improved from the early days, there still are challenges to attain full-barrel fill and proper fillets. Figure 5 shows two examples of how PIP solder joints can look.

### Taking PIP to the Next Level

We seem to have reached our limitations on how much solder can be delivered without clogging step-stencil apertures and/or running out of PCB real estate available for overprinting. When printing solder paste through a stencil, we must be mindful of the "aspect ratio." Aspect ratio is calculated as follows: print footprint/print height. Due to viscosity properties, solder paste has limitations as to how thickly it can be printed vs. a given pad (footprint) dimension. However, the requirement for better-formed, fuller solder joints is stronger than ever. To deliver that necessary, additional amount of solder, some engineers are using PIP and solder preforms in a process called PIP$^{+}$.

Solder preforms are precisely engineered shapes that are punched out of

**Figure 4.** Various printed paste patterns.

**Figure 5.** PIP solder-joint appearance.

solder ribbon. Solder preforms provide a method of adding pure solder without the addition of more flux. Placing a preform onto printed solder paste delivers a significant increase in solder-joint volume. Because a solder preform is made to precise tolerances, volume can be controlled tightly and accurately. Other benefits include the elimination of the wave-solder process and the elimination of the need for step stencils. Fluxing also is not an issue because the solder paste contains adequate volumes.

Solder preforms solve the solder-volume problem while creating a more reliable and robust solder joint. They also can eliminate the wave-soldering process. But there is at least one more benefit to be derived. Because solder preforms are manufactured in specific sizes and shapes, a "0603" preform that delivers the proper solder volume to affect the desired board/connector solder-joint geometry can be produced. This size and shape lends itself to be packaged in tape-and-reel format for automated high-volume manufacturing. This concept uses existing pick-and-place equipment; taking advantage of its speed and accuracy, while delivering a higher return on capital equipment.

**Conclusion**

Two techniques that threaten to make process engineers' lives difficult: wave soldering and lead-free soldering. Adding the lead-free requirement to a situation that already is based on numerous compromises simply adds complexity, while reducing quality and profitability.

However, both PIP processing and the use of solder preforms are well-proven methods. The combination of pin-in-paste plus solder preforms delivers numerous benefits compared to a combined SMT and wave-solder process, especially when factoring in the lead-free requirement (Figure 6). Benefits include:

- Elimination of wave-soldering equipment, materials, staffing, processes, environmental concerns and safety concerns.
- Elimination of the incremental problems associated with lead-free wave soldering.
- Elimination of step-stenciling design, purchases, inventories and processes.
- Reduction of solder-paste consumption.
- Reduction of solder-joint defects and rejects.
- Improvement in process speed, efficiency and quality.
- Improvement in first-pass yield of finished goods.
- Improvement in quality of finished goods.
- Improvement in capital equipment utilization and return on equipment.
- Improvement in process profitability. SMT

**Figure 6.** PIP+ process steps.


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*For a complete list of references, please contact the authors.*


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