THE VERSATILE PREFORM

Ed Briggs
Indium Corporation
Clinton, NY, USA
ebriggs@indium.com

ABSTRACT

Solder preforms are composed of solder alloys and are designed and manufactured into various shapes and configurations. The solder preform concept is quite simple; however, the applications are very diverse. Solder preforms are used in numerous ways, e.g., from simple PCB rework to high-reliability applications, and from package level to board level assembly. They are used in low-volume applications, as in military electronics as well as in high throughput, high-volume applications, such as smartphones. Preforms are also used in robotics and automated processes and to optimize labor-intensive steps in manufacturing processes such as hand soldering. Solder preforms and solder-cored wire offer an opportunity to increase consistency and decrease cycle times in many manufacturing environments.

This paper will discuss attributes associated within the solder families that the preforms are composed of, offer simple rule of thumb considerations when considering solder preforms, and take a look at various applications, including the automation of hand soldering to improve consistency and reduce cycle times.

Key words: preform, low-temperature soldering, laser, robotic soldering

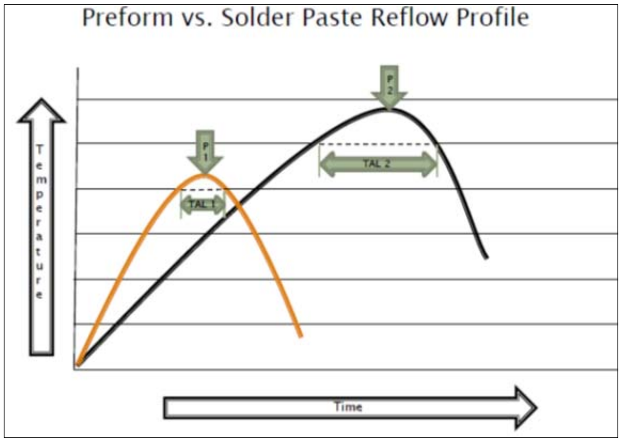
INTRODUCTION

Solder preforms are composed of more alloy options and of the highest purity alloys available than any other fabricated solder form. Some of the alloy purities are as high as 99.999%. They provide precise solder volumes, thus helping to achieve the most consistent and repeatable results possible. Solder preforms can often be used in physically difficult-to-reach locations within the electronic assembly. With certain solder alloys, solder preforms can provide a true low temperature option when a low temperature soldering process is necessary. Due to their solder volume consistency, solder preforms eliminate deviation significantly in manual soldering from operator to operator, and solder joint to solder joint, thus reducing inspection and rework. These savings will often offset the initial cost of the preform. Solder preforms can be flux-coated or flux-cored to provide a consistent and optimum amount of flux. This optimum quantity of flux reduces flux outgassing under devices such as bottom terminated components, resulting in less voiding as the preform replaces some of the solder paste. This benefit is seen when one considers that solder paste by volume is approximately 50% flux and 50% solder powder, which creates a significant amount of flux outgassing. The shapes and thicknesses of solder preforms can be adapted to a wide variety of processes, working well with component placement equipment such as vibratory feeders, vacuum pick-up manifolds, and tube-type dispensers. In addition, preforms work well with a variety of reflow processes from simple hot plates to convection ovens.

PREFORM APPLICATIONS

Low-Temperature Soldering

One advantage of solder preforms formed from a low-melting temperature alloy is the ability to allow for a true low-temperature reflow process. In applications that require reflow soldering below 170°C, solder pastes generally are not a viable option. Regardless of how low the liquidus temperature of the alloy is within the solder paste, a peak temperature of 180°C is most often required to provide adequate wetting (see Figure 1). Solder pastes contain a homogenous mixture of fine solder powder mixed in a flux medium. The fine powder dramatically increases the exposed surface area. Not only can this greater powder surface area become oxidized, but it can become affected by its direct contact with the flux chemicals. This later concern limits how active the flux chemicals can be and when or at what temperature they become active. This temperature is



									Minimum Peak Temperature °C		Minimum TAL (Seconds)	
Indalloy® #	Liquidus (°C)	Solidus (°C)	Element 1	%	Element 2	%	Element 3	%	P1 (Preform)	P2 (Paste)	TAL 1 (Preform)	TAL 2 (Paste)
42	96	96	Bi	46	Sn	34	Pb	20	116	180	15	120
1E	118	118	In	52	Sn	48			138	180	15	120
281	138	138	Bi	58	Sn	42			158	180	15	120
282	140	139	Bi	57	Sn	42	Ag	1	160	180	15	120
290	143	143	In	97	Ag	3			163	180	15	120

Figure 1. Preform vs. Solder Paste Reflow Profile

called the flux activation temperature. If the activation temperature is too low, the flux chemistry aggressively reacts with the surface oxide on the solder powder. This may turn the solder paste in the storage container into a "concrete block" before it is even used. Fabricated solder preforms do not share these issues. The flux is separate from the solder and the flux has no metal oxide to remove, so a more active flux with a lower activation temperature can be utilized. In those instances where the solder preform is flux-coated or flux-cored, the surface area in contact is minimal in comparison to solder pastes, and there is no concern for the effect on viscosity due to metal salt formation as found in solder pastes. This positive situation also dramatically increases the shelf life of fabricated solders such as solder preforms. Solder paste shelf life is measured in months; the shelf life of fabricated solders is measured in years. Under the right conditions, such as using a nitrogen dry box, solder preforms theoretically may have an unlimited shelf life.

Exact and Precise Volume and High Reliability

Manufactured with very tight tolerances, solder preforms deliver highly accurate solder volumes with the most consistent results for an individual operator—and more importantly—from operator to operator. Such consistency can eliminate inspection and testing steps and avoid costly rework, easily saving the upfront cost of the preform. There is also the added benefit of reduced cycle times by adding solder preforms into an automated process, as seen in many high volume assemblies.

Alloy Availability

Another advantage of solder preforms is alloy selection diversity. They are available in more than 200 alloys, far greater than other solder delivery vehicles. Solder paste is very limited in the number of alloys available in comparison to solder preforms. A wider selection of alloys is offered even within the realm of fabricated solders. As an example, flux-cored solder wire has some alloy limitations. High-bismuth alloys are too brittle to flux core and high indium-containing alloys are too soft. However, these alloys can easily be flux-coated in the form of solder preforms.

SOLDER FAMILIES FOR PREFORMS

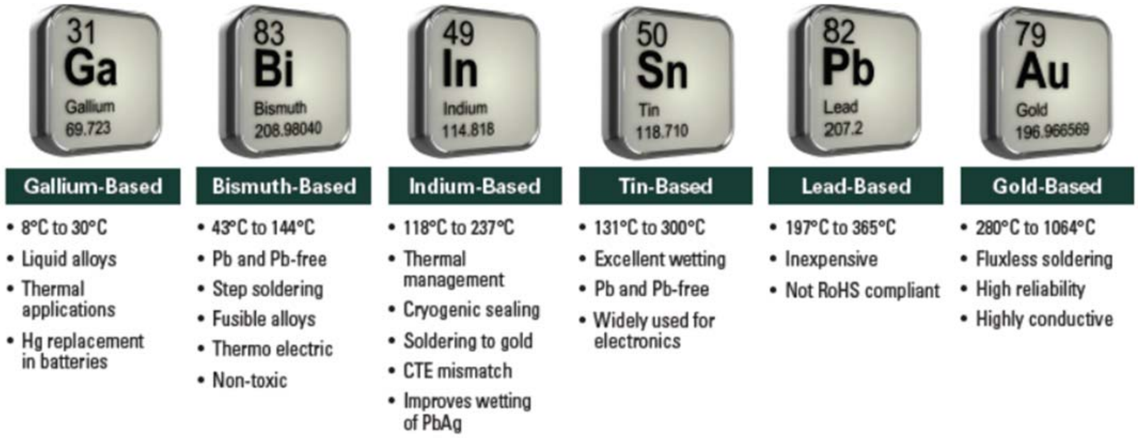


Figure 2. Solder Families for Preforms

Several elements make up most alloys found in the solder families with melting temperatures up to 450°C (Figure 2).

Bismuth and Indium Alloys for Preforms

Both bismuth and indium, when alloyed with a base metal such as tin, significantly lower the melting temperature of the alloy.

Bismuth alloyed with tin produces solders with melting temperatures in the 96–144°C range. Two popular low-temperature lead-free alloys are Bi58/Sn42, which melts at 138°C, and Bi57/Sn42/Ag1, which melts at 140°C. The 1% silver adds malleability to the solder joint, making the joint less likely to experience a brittle failure.

Indium solder alloys have a 60–184°C melting temperature range. These solders also have one of the widest ranges of applications of any of the solder alloys. They can seal at cryogenic temperatures; bond to non-metals such as glass; avoid gold embrittlement issues associated with tin-based alloys as they can bond to thick- film gold without dissolving the gold; and are used for thermal interface materials (TIMs). The softness and ductility of indium solder alloys make them the first choice for TIM materials as they can conform to even the tiniest surface irregularity, thus enabling a superior heat transmitting interface.

Tin Alloys

Tin is the base metal for a wide variety of solders and its alloys are the most popular choices for solder preforms. Tin alloys are typically divided into leaded and lead-free versions, with melting temperatures in the 118–232°C range.

Tin-lead solder alloys were the cornerstone of the electronics industry, and were only recently supplanted by lead-free versions; however, tin-lead solders still make up about one-third of all solder used in electronics. These solders have a long history, perhaps over 100 years, and hence a wealth of reliability data relating to their use exists, making it easy to get technical support for new applications. The most common tin-lead solder alloy is its eutectic composition (63Sn/37Pb).

Most lead-free solder preforms use the widely accepted SAC305 alloy (96.5Sn/3.0Ag/0.5Cu). As with SAC305 solder paste, the melting temperatures are about 219°C, quite a bit higher than eutectic tin-lead solder's 183°C.

High-Temperature Solders

Solders melting at >230°C: Many common high-temperature solder alloys contain lead (Pb), but there are many Pb-free options also available. Antimony (Sb)-based solders are commonly used in applications that need melting points just above the standard solder reflow process range. Examples include MEMS microphones and gyroscopes. Two common tin-antimony lead-free alloys that meet these temperature requirements are Indalloy®259 (90Sn/10Sb) and Indalloy®133 (95Sn/5Sb).

Solders melting at >260°C: Die-attach and similar packaging applications that must conform to JEDEC/IPC J-STD-020 require a solder alloy that melts at greater than 260–265°C. In these devices, Indalloy®151 (92.5Pb/5Sn2.5Ag) and Indalloy®163 (95.5Pb/2Sn/2.5Ag) are the most common lead-based solder alloys. Gold-based alloys such as Indalloy®182 (80Au/20Sn) and Indalloy®183 (88Au/12Ge) are commonly used in applications such as step-soldering in RF packages, hermetic sealing, aerospace, and medical. These gold-based alloys have a high tensile strength, superior thermal fatigue resistance, and exceptional thermal conductivity, as well as resistance to corrosion and oxidation.[1]

The resistance to oxidation and corrosion provide the ability to be processed in a fluxless environment when soldering to thick film (~50 micro inches or greater) gold surfaces.

ADDITIONAL COMMENTS ON PREFORM SOLDER ALLOYS

In considering low-melting alloys (low in comparison to 63Sn/37Pb at 183°C) which include the elements Ga, Cd, In, and Bi, it should be noted that Cd is very toxic, especially in powder form. Many suppliers will not work with Cd in solder paste form, but will work with small amounts in preforms. Many Bi alloys fall into the fusible alloy category and are used because of their useful melting point. For example, Bi alloys are used as safety features such as intentionally melting and releasing water in sprinkler heads when fires start, preventing electric motor overload, closing solvent hoods in case of fire, and opening pressure relief valves as temperature increases with pressure. When alloyed with Sn, Bi also provides the most common low-temperature lead-free alloy: BiSnAg at 137–139°C. BiSn is very brittle and expands upon cooling. Small amounts of precious elements such as Ag or Au increase the ductility of BiSn. There are also concerns if BiSn is used in a Pb (lead) process where it can form a low-melting eutectic at 96°C. A number of papers have been published by Hewlett Packard as they have done a tremendous amount of work with BiSnAg.[2]

TYPICAL PREFORM SHAPES

Solder preforms are available in many forms from the typical washer, rectangle, square, disc, and frame, to the special shapes which can be very intricate with many cutouts and/or large dimensions (See Figure 3). Preforms are also available as single preforms to clusters of washers.

Figure 3. Solder preforms come in a wide variety of shapes and sizes

EXAMPLES OF PREFORM USES

The Pin-in-Paste Process

The pin-in-paste process was developed to eliminate wave soldering when assembling through-hole components. In this process, solder paste is printed on the pad of the through-hole pin. During the reflow process, the solder paste reflows and fills the through-hole and forms a solder joint on the pin. Unfortunately, considering that solder paste is 50% by volume flux, the resulting joint can be solder starved and also have too much residual flux as seen in Figure 4.

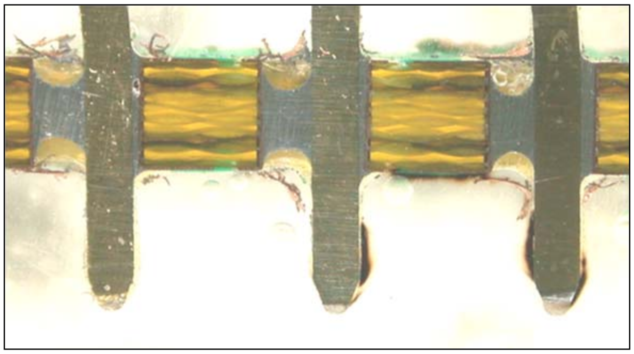


Figure 4. This cross-section of a pin-in-paste assembled PCB shows solder starvation in the solder joint and an excess of flux.

By printing less solder paste and adding a solder preform, as shown in Figure 5, solder starvation and excess flux problems can be solved.

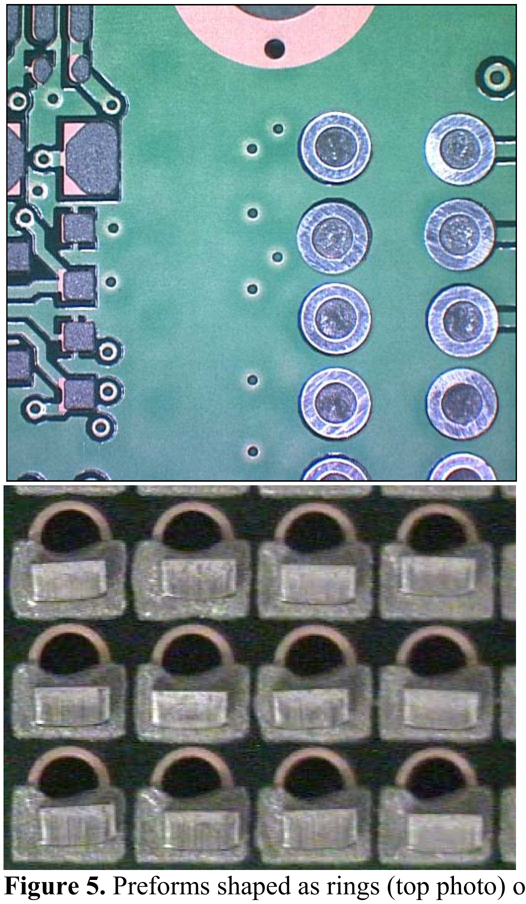


Figure 5. Preforms shaped as rings (top photo) or rectangles (bottom photo) can be used to solve the solder starvation and excess flux problems in the PIP process.

By using solder preforms in the PIP process, the resulting solder joint will have an excellent result as shown in Figure 6.

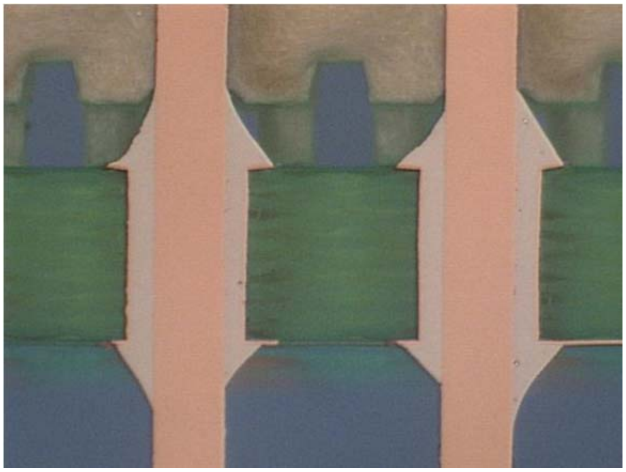


Figure 6. This cross-section of through-hole solder joints formed by using solder preforms shows how effectively the preforms work. Detailed discussions of the PIP process can be found in work by Berntson et al.[3]

Voiding in Bottom Terminated Components (BTCs)

Bottom terminated components (BTCs) typically contain a thermal pad that must be connected to a pad on the PCB to form a thermal connection. The purpose is to transfer heat away from the IC in the BTC. A BTC, in this case a quad-flat pack no-leads (QFN) is shown in Figure 7. Solder paste is typically printed on the receiving pad of the PCB to form this thermal connection. However, the high percentage of flux in the solder paste can result in the final solder joint having a high percentage of voids (see Figure 8). These voids inhibit the transfer of heat away from the IC in the BTC, possibly resulting in reliability issues.

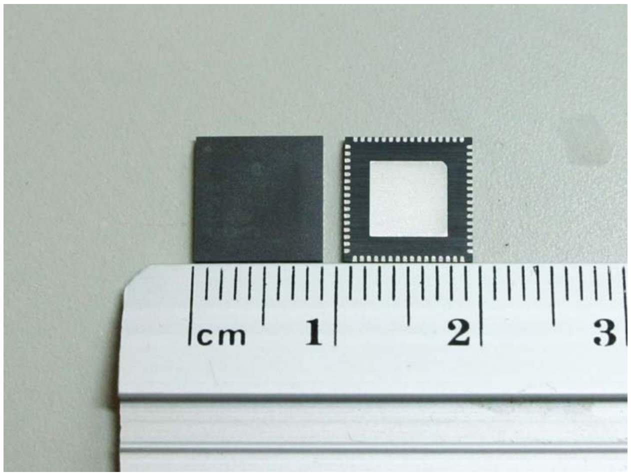


Figure 7. A BTC; in this case, a QFN showing its solder and thermal pads

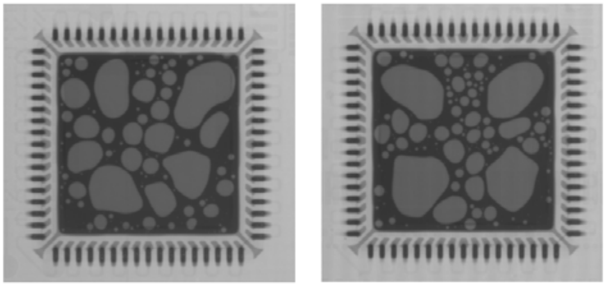


Figure 8. X-ray images of voiding. These "lake voids" and greater than 40% area of voiding would likely cause reliability and performance problems for most BTCs.

By placing a flux-coated preform in the solder paste that is printed on the PCB pad, voids can be virtually eliminated (see Figure 9). More detailed information on this process can be found in work by Gowans et al.[4]

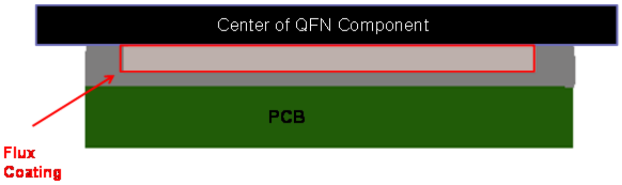


Figure 9. The use of a flux-coated preform almost eliminates voiding in BTCs

Solder Fortification®

Many of the new, highly-dense, mobile phone designs often make it difficult to print enough solder paste to form an effective solder joint to connect the shield electrically to the PWB pad. In such cases, the shield will not perform its EM and ESD protection tasks.

Solder preforms are often used in solder starved conditions. The preforms are placed by a component placement machine, as shown in Figure 10. More information on Solder Fortification® can be found in a paper by Gowans et al.[5]

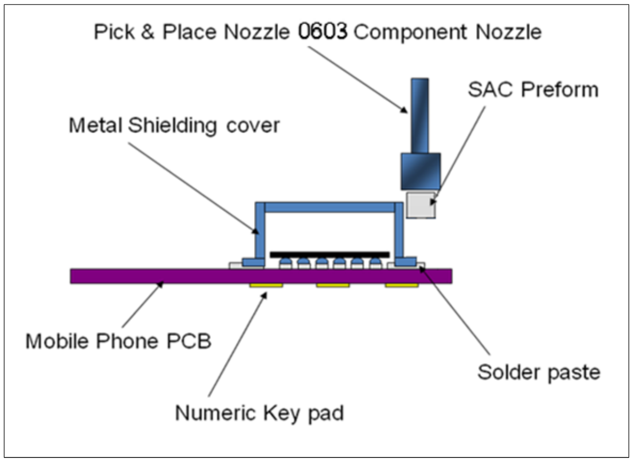


Figure 10. A SAC preform is placed by a component placement machine

Rework

Preforms can be very useful in rework applications that require high-quality results. Used in high-reliability applications, preforms may be selected to provide extremely consistent solder volumes or to substantially reduce solder voids on bottom terminated components where voiding is a high concern.

Eliminating Hand Soldering

There are a number of methods used to eliminate hand soldering, including open flame, laser, induction, ultrasonic, and robotic soldering. Several methods are described here.

Laser Soldering

Figure 11. Laser soldering

Laser soldering is a technique using an optical fiber and lens to focus a laser beam to the solder alloy melting the solder. Diode lasers are generally used as they provide the greatest alloy heat absorption versus organic heat absorption (e.g., flux residue, FR4 laminate material). Laser soldering is precise with spot diameters of 0.25mm–0.60mm and provides localized heating, limiting heat damage to surrounding components and the substrate (Figure 11). These attributes make it useful in soldering even to substrates such as molded plastics. The lasers can be focused on a single point or several contact points on the same component. There are limitations in soldering to large areas and to assemblies that have large heat sinks.

Solder pads and wires are preheated as they are fed to the solder connection, whereas solder pastes require unique chemistries to reduce solder spattering.

Induction Soldering

Induction soldering quickly provides localized heat to electrically conductive materials such as metals and solder. The part is placed within an inductor coil (normally copper), and an AC current is passed through the coil creating a magnetic field that generates eddy currents within the part (Figure 12). The eddy currents quickly and precisely heat the part without physical contact. Induction heating is very energy efficient, and can heat up to 1000°C in less than 1 second. In addition, ramp up rates, hold, and ramp down rates can be controlled.

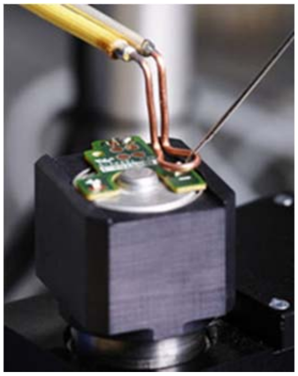


Figure 12. Induction soldering

Robotic Soldering

Automotive applications require high throughput, high yield, high reliability, and low-cost alternative solutions. Robotic soldering achieves these results providing very precise, consistent results with shorter cycle times. In the past, workers placed components into an assembly, placed the assembly into a jig, rotated the assembly into position, and then soldered the assembly. A robot accomplishes the process in as little as one-third of the time (Figure 13). Robotic soldering can also utilize different methods of heating the solder alloy, including laser and induction.

In each of the instances that replace hand soldering, the techniques used apply very rapid heating methodologies. In those applications using solder pastes, the formulations require special attributes to reduce solder spattering as the heating is very abrupt. Even with special formulations, solder pastes are more prone to solder spatter because they are 50% flux by composition. Solder wire is often used with 0.5 to 1.2mm diameters and are generally flux-cored. Flux spattering is minimized by preheating the wire and the area to be soldered. Though very common, flux-coated preforms are gaining more attention in these applications. Flux-cored wire contains flux inside the wire; on a flux-coated washer preform, the flux is on the exterior of the preform where oxidation occurs. The flux is readily available to the mating surface and is able to accomplish the task of removing surface oxide from the preform and joining surface much more readily, thus providing better wetting even to more difficult-to-solder surfaces.

Figure 13. Example of robot soldering machine

CONSIDERATIONS WHEN ORDERING A SOLDER PREFORM

If the process cannot tolerate fluxes, gold-tin (AuSn) preforms or high percentage indium-containing alloys should be considered. If these alloys are not suitable to the application, forming gas may be required to minimize oxidation and assure adequate wetting and flow of the solder to form a good solder joint.

It is important to select a solder alloy that melts at a temperature that the other components in the assembly can tolerate. It should be assumed that the reflow temperature will be between 20 to as much as 40°C above the melting temperature of the preform solder alloy.

If the assembly being manufactured requires step soldering, it is advisable that the temperature delta between the liquidus of the low temperature solder be 50°C lower than the solidus of the high temperature solder. For example, consider a two-solder alloy system for step soldering. Alloy 1 has a solidus of 183°C. The assembly is soldered with this alloy first. The second soldering step will be with alloy 2, which should have a liquidus temperature of less than 133°C.

If preforms with flux coatings are desired, a decision of whether to use no-clean or RMA flux must be made. In addition, it must be determined whether the preform should have the flux on the surface or in the core of the preform.

An important decision that the process engineer must make is to assure that the preform alloy is compatible with the metal systems used on the assembly. As an example, assume that the assembly has a thick gold metallization on the leads. A tin-lead solder may be inappropriate as the tin-lead solder may dissolve the gold and the resulting solder joint may suffer from gold embrittlement.

Considerations for handling of the preforms, cleanliness, oxide removal, and other process issues should be addressed. The preform suppliers are usually very knowledgeable in helping to address any concerns in these areas.

Preforms are available in many packaging formats such as bulk, tape & reel, layer packs, and waffle trays. It is typically easy to find a format that will fit most assembly processes.

CONCLUSION

Preforms can be utilized in a wide variety of applications from low-volume high-reliability to high-volume low-reliability and from package level to board level. They can be processed in many environments from rapid heating, such as laser or induction, to conventional convection ovens. The number of alloys available in the form of a preform are the most extensive available, including true low temperature (<170°C) reflow. The ability to flux-coat alloys that cannot be flux-cored in wire form also makes them the most versatile of the forms of solder available. In addition, preforms offer the most accurate volume to the precise area needed and with the greatest consistency achievable in a soldering process, which can eliminate testing or inspection steps. Add in automation and reduced cycle times and preforms become a very attractive alternative to hand soldering applications.

REFERENCES

[1] Indium Corporation blog

[2] "57Bi-42Sn-1Ag: A Lead Free, Low Temperature Solder for the Electronic Industry", Ernesto Ferrer, Helen Holder Hewlett-Packard Company

[3] Berntson, R. B.; Lasky, R. C., Pfluke, K. P., Through-Hole Assembly Options for Mixed Technology Boards, SMT Magazine, Aug 2004

[4] Homer, S., Lasky, R. C., "Mimimizing Voiding in QFN Packages Using Solder Preforms, SMTAI October 2011

[5] Gowans, C., Socha, P., Lasky, R. C., "Applications of Solder Fortification With Preforms", SMTAI 2010
