



(https://semicd.nui.media/pipeline/609091/0/cj?ajkey=V122DA22169J-

573J8100L60569116CFDB35BL712080L712079QL605709QQP0G00G0Q1FE9ED81000001010000G0PG30H36W8d1f58b5a2DW485552DW447d22DW4b2t

SEMICONDUCTOR DIGEST (http://semiconductor-digest.com/)
NEWS AND INDUSTRY TRENDS

Solid State TECHNOLOGY
Insights for Electronics Manufacturing

(https://sst.semiconductor-digest.com/)

in (https://www.linkedin.com/groups/4905453/) **f**

(https://www.facebook.com/SolidStateTechnology) **rss**

(https://sst.semiconductor-digest.com/feed/)

Lead-free solders vs. conductive adhesives

Two types of materials replace leaded solders effectively.

BY DARRYL J. SMALL AND PETER BIOCCA

Figure 1. Lead-free alloys must take a variety of forms, such as wire, bar, preforms, and as powder for solder paste (which is used in this stencil-print application).

[Click here to enlarge image](#)



Around the world, interest in lead-free solder alternatives is increasing dramatically, primarily because of initiatives in both Asia and Europe to rapidly eliminate the presence of leaded solders in electronic assemblies. Japanese electronics manufacturers have voluntarily mandated that products manufactured or sold domestically be lead-free by 2001. Europe is also requiring lead-free electronics, as mandated by the 1998 Waste Electrical and Electronic Equipment directive (WEEE). However, because of opposition within the European community, the final deadline is less certain, with the current cut-off date estimated beyond 2004. There are a number of reasons behind the effort to eliminate lead from electronic solder materials. In addition to environmental pressures resulting from the element's toxicity, motivations include hazardous waste disposal concerns, workplace safety considerations, device reliability issues, market competitiveness and environmental corporate image maintenance.

The pressures experienced currently by electronics manufacturers in North America are economic, rather than regulatory, in nature. To eliminate the risk that products will no longer be acceptable for export to Asian and European electronics markets, manufacturers are seeking viable leaded solder substitutes, including lead-free solder materials and conductive adhesives.

Lead-free Solders

Lead-free solder technology is not new. For years, many manufacturers have used lead-free alloys in niche applications to provide a higher melting point or to satisfy particular material requirements. However, the goal of today's lead-free solder research is to determine which alloys should be used to replace the estimated

50,000 metric tons of tin-lead solder currently used each year. Eliminating lead, which is abundant and inexpensive (approximately \$0.40 per pound), and replacing it with another element(s) may well increase the cost of raw materials.

The materials chosen to replace lead must meet a variety of requirements:

- They must be available worldwide in quantities sufficient to supply global needs. Certain metals – such as indium and bismuth – are not available in large quantities and would be sufficient only as incremental additions to the lead-free solder alloy.
- The replacement alloy must also be considered non-toxic. Some replacement metals under consideration, such as cadmium or tellurium, are toxic; other metals, such as antimony, may fall into the toxic category as a result of changing regulations.
- The substitute alloys must be able to take all forms used by the electronics industry, including wire for repair and rework, powder for solder paste, bar for wave soldering, and as preforms (Figure 1). Not all proposed alloys can be manufactured in all forms; for example, a high bismuth content would make the alloy too brittle to be drawn into wire.
- Substitute alloys should also be recyclable – combining three or four metals into a lead-free substitute solder formulation may complicate and add expense to the recycling process.

Not all substitute alloys can easily replace present soldering processes. The National Center for Manufacturing Sciences (NCMS) concluded in 1997 that there are no “drop-in” replacements for eutectic tin-lead solder. Research done in 1994 as part of Europe’s IDEALS program found that, of more than 200 alloys studied, less than 10 lead-free solder options were viable.

Figure 2. Elevated melting points will require high soldering temperatures that may cause damage to temperature-sensitive components or reduce board life.

[Click here to enlarge image](#)



Elements that are available in quantities sufficient to satisfy the high volume of demand for solder include tin (Sn), copper (Cu), silver (Ag) and antimony (Sb). Some commercially viable examples of lead-free alloys include 99.3 Sn/0.7 Cu, 96.5 Sn/3.5 Ag, 95.5 Sn/3.8 Ag/0.7 Cu, and 96.2 Sn/2.5 Ag/0.8 Cu/0.5 Sb. All of the elements incorporated into these substitute alloys have different melting points, mechanical properties, wetting characteristics and cosmetic appearances when compared to tin-lead solders. The current industry trend is to use the near-eutectic tin-silver-copper alloy.

Most lead-free alloys, including tin-silver-copper, have melting points in excess of 200°C – substantially higher than traditional tin-lead solders, which melt at approximately 180°C. These elevated melting points will require higher soldering temperatures. For package and flip chip assemblies, the higher melting points of lead-free solders may prove to be a concern, because package substrates may not be able to withstand elevated reflow temperatures (Figure 2). Designers are currently investigating alternate substrate materials that can withstand higher temperatures, as well as anisotropic conductive adhesives to replace solder in flip chip and package applications.

The higher melting temperatures of lead-free alloys may offer benefits, such as improved tensile strength and better thermal fatigue resistance, making them suitable for high-temperature applications like automotive electronic components.

Board and component finishes also must be compatible with lead-free solders. For example, solder joints on boards with copper finishes may be affected both mechanically and cosmetically by the higher surface mount technology (SMT) reflow temperatures of lead-free solders, which can cause the formation of harmful intermetallics between tin and copper. The cosmetic appearance of lead-free solders is also different (for example, certain formulations appear bright but slightly less reflective than traditional tin-lead solders), and may require changes in standard quality control procedures. Finally, because no substitutes for high-lead-bearing solders exist at present, a completely lead-free assembly is not yet possible.

While current flux systems work well with tin-lead solders, lead-free substitute alloys will not behave similarly on all board component finishes and do not wet as easily to form the same types of intermetallic bonds. Therefore, modified fluxes may be required that promote better wetting and reduce voiding in BGA soldering.

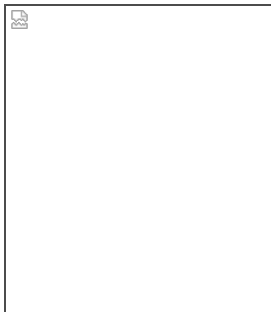


Figure 3. Adhesives are ideal for bonding temperature-sensitive components.

[Click here to enlarge image](#)

The ideal lead-free solder alloy combination will offer manufacturers good electrical and mechanical properties, good wetting abilities, no electrolytic corrosion potential or dendritic growth concerns, acceptable cost, and current and future availability in different forms. The solder will use conventional flux systems and will not require the use of nitrogen to enable effective wetting.

Lead-free alternatives that satisfy wave soldering, SMT and hand assembly requirements are available on the market today, although more research is required in the areas of component lead-free alloys, board finish compatibility, flux system development and processing issues.

Conductive Adhesives

Conductive adhesives traditionally have been used as die-attach materials that bond integrated circuits to lead frames. They are also used to make laminates for printed circuits, to attach copper foil to boards or flexible substrates, and to bond circuits to heat sinks. As a result of lead-free initiatives, conductive adhesives have become an attractive alternative to solder for attaching surface mount components.

Curing at room temperature or processing quickly with minimal exposure to temperatures between 100 and 150°C, these adhesives are excellent for bonding temperature-sensitive components and for providing electrical connections on non-solderable substrates like plastic and glass (Figure 3). Available in highly flexible formulations, conductive adhesives are also a solution for applications such as assembly and repair of flexible circuits or bonding flexible substrates and connectors (Figure 4).

Conductive adhesives provide both a mechanical bond and an electrical interconnection between a device and a circuit board. There are three types of electrically conductive adhesives formulated to provide specific benefits where an electrical interconnect is desired. Similar to solder, isotropic materials conduct electricity equally in all directions and can be used on devices that require a ground path. Conductive silicones help protect devices from environmental hazards, such as moisture, and shield electromagnetic and radio frequency interference (EMI/RFI) emissions. Anisotropic conductive polymers or z-axis adhesive films allow electrical current to flow in only a single direction, and provide electrical connectivity and strain relief for flip-chip devices.

Conductive adhesives are a composite of thermosetting epoxy adhesive resin and conductive metal (or metal-coated) particles, such as silver, nickel, gold, copper and indium or tin oxides. Relatively soft metals promote good particle contact by deforming when the adhesive shrinks during cure. The most popular filler material is currently silver because of its moderate cost, wide availability and superior conductivity. Electrical and thermal conduction occurs when filler particles carry current through the cured adhesive resin. Associated thermal conductivity eliminates the need for mechanical fastening and provides efficient transfer of heat between transistors or microprocessors and their heat sinks.

Conductive adhesives are lead- and CFC-free, do not damage the ozone layer and do not contain VOCs. These materials offer excellent design flexibility because they fill odd-shaped areas and gaps of varying sizes. The lower processing temperatures of adhesives reduce energy costs, allow less-expensive substrates to be used in the assembly, and reduce thermal-mechanical stress and component damage on the PCB.

Comparison of Solders and Adhesives

Both lead-free solders and conductive adhesives are strong candidates for providing electrical interconnection and thermal transfer in electronic devices; however, each technology has its own strengths and weaknesses. Depending upon the application, one bonding technology may deliver better performance characteristics, or offer processing or cost advantages.

By nature, solders form metallurgical junctions between metal substrates, whereas conductive adhesives form mechanical and chemical bonds at the substrate surface. Metallurgical bonds are more conductive and

generally stronger than bonds formed with conductive adhesives, because adhesives require effective dispersion of the metal filler content to provide good electrical properties. But while filler particles are prone to oxidation, which may degrade adhesive conductivity over time, solder is prone to leaching metals (e.g., gold or copper), which may embrittle and weaken soldered joints. Adhesives form a strong bond to tarnished and oxidized metal surfaces that are typically non-solderable.

Thermal conductivity is higher in solders (60-65 W/mK) than adhesives (3-25 W/mK). Volume resistivity for solder (0.000015 ohm.cm) is much less than for adhesives (0.0006 ohm.cm), indicating that solders are typically more electrically conductive than adhesives.

Figure 4. Electrically conductive epoxies develop strong, durable bonds on many different substrates (e.g., flex, glass and FR4). Adhesives are used as a solder replacement on non-solderable substrates (e.g., plastic and glass).

[Click here to enlarge image](#)



While lead-free solders generally resist mechanical shock on rigid substrates better than conductive adhesives, solders are often prone to stress cracking on flexible substrates. In addition to being available in highly flexible formulations, conductive adhesives also resist cracking from vibration and shock better than solder. Because adhesives do not offer the self-alignment effect of solder's surface tension, component placement with adhesives is critical, especially with ultra fine-pitch components. Poor alignment results in inferior electrical contact and meager resistance to mechanical forces.

Solders are well-suited for J-leaded components as well as plated and dipped parts. Adhesives bond well to plated component leads and boards that have porous surfaces. Adhesives are also the only alternative for non-solderable and highly flexible substrates. Because adhesives are available with room-temperature or low-temperature curing mechanisms, they are well-suited to bonding thermally sensitive assemblies and components.

Solder is frequently more advantageous for boards that require rework, because adhesives require a more time-consuming rework process that can damage board components. Some general-purpose epoxies have been formulated specifically for rework and repair applications on large-pitch interconnects. For example, if the trace on a circuit board's surface gets gouged, selected versions of these epoxies may be used to repair the circuit in place of the original solder.

A Matter of Cost

Both lead-free solders and conductive adhesives are more expensive than traditional tin-lead solders for a variety of reasons. Whereas lead is among the least expensive metals available (\$0.40 per pound), alternative alloys can be substantially costlier. For example, the approximate cost per pound for silver is \$90, for tin \$3.70, for bismuth \$3.50, for copper \$0.85, and for zinc \$0.60. Solder pastes normally sell for anywhere from \$0.15 to \$0.30 per gram, depending on volumes and alloy types.

Pricing for conductive adhesives varies greatly, depending upon the type of filler used and its market price. Different formulations of conductive adhesives can vary by a factor of 10 or more. The material costs of conductive adhesives that use precious metals as fillers are relatively more than the material costs of lead-free solders or conventional adhesives.

In terms of material costs alone, adhesives are typically several times more expensive than solder. However, adhesive assembly and processing requires approximately half as much material as does solder for the same application. Also, the processing costs of adhesives can be substantially lower than those of solder because there are fewer steps involved in adhesive bonding. While processing times are very similar for both solder and adhesive bonding, adhesives do not require the time and expense of flux application and cleaning, as occurs in a wave soldering application using water washable flux.

Solder flux was once removed quickly and inexpensively using CFCs. In the aftermath of the Montreal Protocol, which required manufacturers to reduce the use of CFCs, CFC use has been curtailed and board manufacturers are often forced to use less efficient and less cost-effective methods to remove flux, although many have switched to no-clean or water washable chemistries. Adhesives, however, are process friendly

and reduce hazardous waste chemicals or associated disposal costs.

The Future

Lead-free solders can be purchased today in all forms – from bar to paste to preforms. Work continues in the development of new flux chemistries that will enable lead-free solders to deliver the same performance as leaded solder materials. Conductive adhesives also are being improved to provide excellent mechanical properties in lower cost formulations that incorporate alternative metal fillers or conductive polymers.

In the future, electronic device manufacturers will continue to use both conductive adhesives and solders. Once lead-free regulations go into effect, both adhesives and solders will deliver environmentally safer assembly options, individually and, at times, symbiotically. AP

***DARRYL J. SMALL** is senior applications engineer at Loctite Corp., and **PETER BIOCCA** is market development manager at Multicore Solders. For more information, contact Darryl Small, Loctite Corp., 1001 Trout Brook Crossing, Rocky Hill, CT 06067; 860-571-5100; Fax: 860-571-5358; E-mail: darryl.small@loctite.com (<mailto:darryl.small@loctite.com>).*

POST A COMMENT

Easily post a comment below using your LinkedIn, Twitter, Google or Facebook account. Comments won't automatically be posted to your social media accounts unless you select to share.

2 thoughts on "Lead-free solders vs. conductive adhesives"



kwamy

July 20, 2015 at 5:20 am

(<https://sst.semiconductor-digest.com/2000/10/lead-free-solders-vs-conductive-adhesives/#comment-173218>)

Hi,

We are planned to switch over some product from lead free solder to Electrically conductive silver epoxy , before switch over we need to know what are the problems occurs in terms of assembly /electricaly



Faiz (<http://Hkn.com>)

March 31, 2016 at 11:51 am

(<https://sst.semiconductor-digest.com/2000/10/lead-free-solders-vs-conductive-adhesives/#comment-181932>)

Need more details on silver epoxy to replace the soldering to service pcb. Need engineering manual please send soft copy.

Regards

Faiz

Comments are closed.