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The Truth Shall Make You Lead Free

Uncovering the myths about drop-in technologies.

As July 2006 comes rushing at us, the electronics industry is coming to grips with the inevitable lead-free demands of the Restriction of Hazardous Substances (RoHS) in Electrical and Electronic Equipment and Waste Electrical and Electronic Equipment (WEEE) initiatives. Everyday, practitioners in our field are taking their heads out of the sand and accepting the fact that, if their products are marketed in the European Union, all products sold after July 1, 2006, must comply with the mandates.

While it is not an easy transition, things are mostly falling into place. The SAC alloy, Sn3.9Ag0.6Cu (±0.2%), in spite of having a higher melting point and reflow temperature than tin-lead alloys, shows excellent reliability characteristics. We are still waiting on workmanship standards to guide us through lead-free acceptability criteria, but industry association committees are convening and the wheels are slowly turning. The new process appears to have little effect on our current process equipment other than a required retrofit to wave soldering pots and pumps and some concern for five-zone reflow ovens meeting the new thermal requirements. Many newer generation reflow ovens have the thermal and cooling capacity to handle the rigors of lead-free reflow.

Though process studies are nearly complete and the effect on our processing equipment has been identified, we are not out of the woods. Besides the need for standards and additional reliability testing, concern about moisture sensitive devices and other component and printed circuit board (PCB) materials is increasing. As daunting as lead-free adoption is, it is no wonder that we are looking for practical shortcuts and remedies.

Some individuals and firms purport to provide "drop-in" solder replacement materials. The solutions range from medicine show hype to valid alternative lead-free alloys. *Caveat emptor* applies across the board because things are not always what they appear to be and a great deal of confusion is ensuing in the meantime. The bottom line: Plenty of misinformation and disinformation is being disseminated in the industry in the name of lead free.

No standard solder alloy exists; nor will it. Most of the industry currently uses Sn63Pb37 or Sn62Pb36 Ag2, though many applications use other alloys. Accordingly, the SAC alloy will fit a wide range of applications—that was NEMI's intention when it originally sought to find a best-fit lead-free alloy for the industry that is widely available and not covered by patents in any country. Some applications might benefit from the properties of an alternative lead-free alloy. However, since the SAC alloy is the most economical among the reliable lead-free alloys examined by NEMI, practitioners must carefully examine whether the benefits of alternative alloys are worth the cost incurred.

One alternative lead-free alloy that is getting a good deal of airtime lately is tin-silver-copper-indium (Sn3.0-4.1Ag0.4-1.5Cu4.0-8.0In). Its proponents claim that it is an ideal drop-in replacement for tin-lead and a better choice than SAC because its melting temperature is approximately 205°C and it attains full liquidus at 220-235°C. The SAC alloy melts at 215°C and reflows at 235°C. Although some thermal savings are gained, the last time we looked at Sn63Pb37, it melted at 183°C and attained full liquidus at 205-210°C, so how do indium alloys qualify as a drop-in?

When the industry first began examining lead-free alloys around 10 years ago, the properties of tin-indium were appealing as a true lead-free drop-in replacement except for one major factor—cost.

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In a series of articles appearing in a trade journal, workshops and papers presented at national conferences, one proponent ascertains that tin-lead users reach a reflow temperature of 238°C: "[B]ased on numerous on-site examinations over the years, the actual temperature used for the process across industry and geographic regions has largely fallen between 225° to 238°C for various reasons."[1]

Hmmm, do you reflow at 238°C with your current tin-lead alloy? That is not a common reflow temperature in processes we have observed or set up in any factory. With a minimum reflow temperature of, at most, 210°C for Sn63Pb37, most users try to get all joints to this temperature and minimize the gradient across the board. In some complex, high thermal mass assemblies with a high gradient at peak, we have seen maximum temperatures attain 238°C and higher, but most users try to get close to the minimum requirement and no higher.

Why would assemblers want to reflow at 238°C if it can be avoided? Why expose the board, materials and components to extreme thermal excursion when the solder specification does not require it? Why risk thermal damage and excessive intermetallic growth? How about MSD danger? JEDEC 020 does not recommend exposing components to such high temperatures; it qualifies all large or thick IC packages for tin-lead eutectic assembly at a peak temperature of 225°C. Certainly, a few users routinely reflow at 238°C. For them, this is a viable drop-in alternative, but not so for the rest of us.

If the indium-bearing alloy becomes the hot choice, the 10° thermal discount is overwhelmingly appealing. But is that enough to consider this a drop-in? We think not. When the industry first began examining lead-free alloys around 10 years ago, the properties of tin-indium were appealing as a true lead-free drop-in replacement except for one major factor—cost.

Indium is rare—a current world supply of 300 metric tons is mined annually—and thus, expensive.[2] If the industry made a wholesale conversion to using high indium content alloys, the price would skyrocket. Even with a 4% indium alloy, the cost factor gets scary.

Assuming current consumption of solder paste is about 10,000 metric tons per year (MT/Y), with industry growth approximately 10% per year, about 20,000 MT/Y of solder paste will be used in 10 years. If 50% of the market is lead free in 10 years and 30% of that market adopts the 4% indium alloy, 120 MT of indium would be required. Additional investments in the indium-mining infrastructure would have to be made, and the change could take decades.

To get a feel for how little indium is produced each year, consider that the annual production of 300 MT would just about fit in Dilbert's boss' office. Fifty times more silver and eight times more gold are produced each year. Currently, 60% of indium production is used to make indium tin oxide (ITO) for flat panel and plasma displays, an application which is rapidly growing. The increased use has driven the price from less than $200/kg to nearly $600/kg in less than two years.

Some suggest that if indium were used in lead-free solder, the demand would create more supply. Indium is predominantly extracted from zinc ore, though it is found in small amounts in copper, lead and tin ores. The fraction of indium in zinc ore is only 1 to 100 ppm, hence production of indium is not trivial and not inexpensive. One indium expert we interviewed suggested that an additional demand of 120 MT/Y would require a dramatic change in mining that would take decades to develop. At that rate, the demand for the additional amounts of indium would never be realized.

With additional investment to mine and 10 or more years to meet an increased demand, how is the investment to be recovered? Oh, yeah—pass the cost on to the user.

Since the price of a scarce commodity soars with an increase in demand, imagine what it will be like with 120 MT of excess demand. And add to that an increase in demand for indium in the manufacture of flat panel displays.

With an approximate 10°C thermal discount, the alloy does not appear to be any more of a drop-in replacement than the SAC alloy, but it costs considerably more. So, unless you are planning to invest in indium futures or have some other stake in its usage, the benefits of this particular alloy may not surmount the increase in cost.

The more you know about the properties and requirements of the materials and components in your process, the better off you will be. If you hear someone promoting a drop-in replacement, be leery and check it out. Remember, we are all in this together. ■

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References

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2. B. McCutcheon, Canadian Mineral Yearbook, 2001.