Lead Free Solder and Rework Operations

Patrick McCall, Senior Product Manager
&
Chris Barrett, Training Administrator

Why Lead Free Solder?

Solder comprised of Tin (Sn) and Lead (Pb) is the most commonly used solder in the electronics industry. However, as we all know, lead is toxic to humans. Lead is known to cause neurological and reproductive disorders and is well documented as causing physiological development disorders in children. Over the last 30 years, in the US, and elsewhere, legislation has been passed to eliminate lead from paint, gasoline, plumbing, etc. The desire to eliminate lead from materials such as paint that can easily be contacted and/or eaten or ingested by humans (and more importantly children because they do not know any better) is an admirable goal that we can all agree upon. However, as part of numerous international initiatives to eliminate the use of lead, the electronics industry is now facing a huge challenge in attempting to eliminate lead from the most commonly used material in electronics production, Sn/Pb eutectic solder.

If we take a quick look at which industries use lead, Electronics accounts for the smallest percentage of use at less than 0.5%. In sharp contrast, the Battery industry uses 81%, the Oxides industry (paint, ceramics, pigments, etc) uses almost 5% and the ammunition industry utilizes about 5% as well. One of the strongest drivers in wanting to eliminate lead from products is that as products are disposed in landfills the lead can leach out of the waste material and can end up in our ground water supplies that are used to provide potable water. While this makes good sense for raw lead containing materials, there is little evidence that lead can leach itself out of solder alloy.

Legislation

In the early 1990s the Reid Bill – Lead Reduction Act was passed in the US, however the electronics industry fought for and won an exemption. Currently, in the US there are no federal requirements to eliminate lead from electronics. However, some states have initiated programs to control the amount of lead reaching our landfills through pilot recycling programs that will most likely, become permanent. Initiatives in Europe and in certain parts of Asia (if enacted) will eventually force US manufacturers to comply with lead free requirements if those manufacturers want to sell products into those geographic regions. Legislatively the Japanese government has elected to deal with the lead in electronics issue through mandatory recycling/reclamation programs. However, Japanese manufacturers have started to voluntarily produce lead free products. These are generally limited to consumer/personal use products that have a short life span and are likely to end their life in public landfills. Currently less than 5% of all electronic products are made with lead free solder. The European Union has adopted the WEEE (Waste Electrical and Electronic Equipment) directive that currently calls for the elimination of lead from electronics manufacturing by 2008 (pushed back from 2004).

Issues that need to be addressed

There is overwhelming research that clearly suggests that the use of lead free solder is inherently more expensive and is less reliable that leaded solders. The increase in material expense comes from the cost of the alloy constituents. For example, Silver is 212 times more expensive than lead and Indium is 194 times more expensive than lead. Additionally, all of the likely lead free candidates contain Silver, Indium, Bismuth or Antimony. If all electronics manufacturing were to become lead free to the worldwide supply of these materials would be stressed, further increasing costs. Many of the other metals that are used in lead free solders are also heavily regulated, as many of them are not suitable for landfill disposal. For example, the most likely Sn/Pb replacement alloys all contain silver which is a known environmental contaminate. This could mean that once the Electronics Industry moves away from lead it could once again face having to change/reformulate the solder being used to eliminate a hazardous metal containing solder.

Further, because lead free solder joints are less reliable than leaded solder joints, it is unlikely that leaded solder will go away entirely as it is clearly the material of choice for high reliability applications. At best, lead free, if required, will find its niche in personal/consumer products and most likely will not meet the requirements for high reliability PCBs found in telecommunications, military, aerospace, and transportation industries. This means that even though PCB manufacturers may be able to build some of their products lead free, it is unlikely that the lead will ever be gone for good.

Lead Free Alloys and Rework

On the surface it appears that hand-soldering utilizing lead free alloys should be fairly straightforward with little adjustment necessary from current procedures. However, if we dig deeper, there are a number of factors to consider some of which could potentially create major problems for the rework process. Consider first, the alloy itself. Despite the countless hours of research into lead free alloys, a single, drop in replacement for standard tin/lead has yet to be identified. While several alloys have emerged as potential front-runners, most notably Sn/Ag/Cu, the industry in general has not yet settled on the wide spread use of such an alloy. While the Sn/Ag/Cu alloy clearly is receiving the most attention, the exact percentage of each metal within this alloy is still a topic of debate. The percentages of each metal effects wetting angles, tensile strength and other joint characteristics.

Without standardization of an alloy, we are likely to see various alloys in use as companies come into compliance with lead free initiatives. The problem this creates from a rework standpoint is twofold. First, the potential compatibility issues between alloys. It will be impossible for a rework technician to visually tell which alloy has been used on any given PCB. Solder alloys used in initial manufacturing, on the bench-top as well as component lead plating, tip tinning, etc will all need to be compatible with one-another in order to avoid creating an uncontrolled alloy, the result of mixing several unknown solder alloys in unknown quantities.

It has been suggested that PCB's and components be labeled to allow quick determination of the alloy in use. In reality, this would be a huge undertaking and likely would not solve the problem. It should be noted that research continues on the compatibility issue and the effects seen by mixing different alloys. In general, lead free alloys have been grouped into three melting point ranges, low, medium and high for lack of better terms. Melting points of the potential alloys being tested have ranged from roughly 140°C to roughly 280°C. Each alloy and melting point provides different joint characteristics and requires different tip temperatures and potentially, different flux chemistries. Adjusting an alloy even a half a percent changes the joint wetting and strength characteristics as well as melting points. Most of the low melting point alloys have either strength or cost related issues so it is likely that the eventual replacement for Sn/Pb will fall into the mid-range category and have a melting point roughly 30° – 50°C higher than that of the current Sn/Pb eutectic. For instance, the alloy 95.5Sn/3.8Ag/0.7Cu has a melting point of 217°C. While variations in the percentages of each metal will in fact have an impact on the quality of the joint, these impacts are proving to be minimal. From a hand-soldering standpoint this means only slightly higher operating temperatures than we are using today. It has always been recommended that iron tip temperatures stay below 400°C and most applications can be handled at much lower temperatures than that. If tip temperature is increased only slightly and tips are maintained per manufacturers recommendations and the same fluxes are used, we wouldn't expect to see significant changes in tip life or performance.

Flux Chemistries

The next issue to consider is that of flux. As we all know, flux is absolutely required for the soldering process be it convective or conductive, machine or by manual. Flux development seems to be progressing at a much faster rate than that of lead free solder and as a result has stayed ahead of the curve. Flux chemistries specific for lead free soldering are readily available. New flux technologies are focusing more on rosin free and VOC free products, which are of course environmentally sound. Even still, tests have shown that even though the Sn/Ag/Cu alloy has a higher melting point than its Sn/Pb counterpart, existing flux chemistries are still applicable. However, it seems that many companies already employing a lead-free process are using more aggressive fluxes to help counter potentially higher oxidation rates at these higher operating temperatures. It should also be noted that the use of nitrogen reduces the need for more aggressive fluxes and has been shown to reduce the wetting angle disparity and improve solder spread. The use of nitrogen, however, is not as commonly found on the rework bench as it is in the manufacturing environment. Like the alloy discussion above, while flux chemistries are available for lead free alloys; it appears that standard existing chemistries are also effective which could mean minimal variance from current procedures.

Due to the high tin content in lead free solder alloys, there will clearly be an increase in the likelihood of common defects that have been well under control for years. Tin whiskers (a common cause of bridging) will become common and will create an increased demand for rework. Lead free solder alloys will also hamper the inspection process as the industry has been trained to look for clean, shiny solder joints. Even in an N2 environment lead free solder has a dull and sometimes grainy finish.

Reworking BGAS

One of the greatest challenges with Lead free solder is related to reworking BGAs. BGAs are usually reflowed using convective heating methods, which N2 can be easily incorporated. However, the problem is that plastic BGAs have a maximum component temperature in the range of 220 ºC. With a melting temperature of 217 ºC, the width of process window is decreased significantly. This will either mean that BGA rework with lead free solder spheres will become a specialty operation and will not be easily achieved by most technicians increasing the costs of rework, or more advanced, specialized rework equipment will be required to control a process to within ± 3-5 ºC. Again, this will significantly increase the cost of rework. Array packages also tend to exhibit excessive solder ball voiding with lead free solder.

Conclusion

In conclusion, while the intent behind the lead free movement is well intended, it is clear that the electronics industry is not ready to make such a move. As a minimum a single alloy needs to be identified and agreed upon to replace Sn/Pb eutectic. Additionally, reliability issues are still a major concern and until an alloy is developed that can be proven to be as reliable as Sn/Pb eutectic, the possibility of lead going away completely is unlikely. While the electronics industry consumes less than .5% of the lead in the world, it seems that the lead free initiative will at best reduce lead consumption to .2 or .3%. If the goal is to eliminate lead, legislative activities should begin with the largest users, not the smallest who do not have a viable replacement. It appears that electronics manufacturers who produce or sell products in Europe will ultimately be given a choice of going lead free or instituting reclamation programs that will recycle PCBs and other electronic assemblies that contain lead. Recycling is a better alternative because it addresses waste volume and prevents other hazardous materials that can be found in today's electronics from reaching landfills as well. Let us all hope that we end up having to pay a $10 recycle deposit on our next cell phone and can continue to use the solder that works the best!