

## LEAD-FREE SOLDER ALLOYS

Finding an acceptable substitute for traditional tin-lead solder is not a simple matter. Several things must be considered: toxicity, availability, price, worldwide distribution, wetting ability, reliability, to cite a few. The two main alloys being considered, and marketed with great fanfare, are variants of tin-silver-copper and tin-copper. These alloys have higher melting temperatures, and wet metal surfaces more slowly, than does our old friend tin-lead; cosmetic appeal is reduced, too, as the joints have a dull appearance compared with tin-lead joints. The fluxes that worked well with traditional processes do not work well with lead-free soldering and we will treat this in turn. Specialty solders using indium,<sup>1</sup> bismuth, antimony &c will not be treated here due to space considerations; rest assured they will be addressed in future.

The characteristics of lead-free solder causing problems (or difficulties, or challenges, or opportunities, depending upon how one chooses to look at them) involved in changing to such alloys for manufacturing or reworking electronic components are:

1. Lead-free alloys usually have higher solidus and liquidus temperatures than does the traditional 63-37 tin/lead solder. This means one may be required to solder at higher temperatures; the exact temperature, of course, depends upon the alloy chosen but in general the operating temperature will be 50°F. (28°C.) higher than that used with tin/lead. The use of a soldering station with fast thermal recovery may limit the need for higher soldering temperatures. Most proposed lead-free solders are rich in tin. This is good in one respect because tin does all the work anyway; even the old 63-37 solder just used lead as a carrier for the tin. It helped that lead and tin in those proportions formed an eutectic alloy.

Tin is an active metal and forms the intermetallic layers with copper or other base metals that allow solder joints to be made. You would think, then, that tin would 'wet' the surface of a soldering tip or a candidate for a solder joint but you would be wrong. What the tin wants to do is devour the base metal - rapidly in the case of copper, a bit slower in the case of iron - by detaching the molecules from the base metal and dispersing them amongst the tin. (The subjects of molecular attraction, molecular adhesion, and crystalline structure formation are worth studying, if you haven't anything else to do.)

2. Lead-free alloys do not 'wet' - do not adhere to the soldering iron or the surface being soldered - as well as tin/lead. This has to do not only with the chemistry of the metals involved but also with physical characteristics, primarily molecular adhesion and attraction, and thus requires the use of more active, or corrosive, fluxes. For example, water wets any surface with which it comes in contact, because its surface tension is weak; mercury, on the other hand, does not wet at all because its surface tension is very strong. Because lead-free solders do not wet as well as tin/lead, this also increases the dwell time. In order for one material to 'wet' another, the surface tension of the wetting material must be low enough to allow it to flow into the material being

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<sup>1</sup> For example, indium is a ductile metal with a low melting point that wets metallic and non-metallic surfaces; it will weld under relatively low pressure. Indium alloys have a wide range of melting points, depending upon the metals with which they are combined; the lowest is the eutectic indium/tin alloy that with a liquidus of 118 C°. Indium alloys perform very well when operating temperatures do not exceed 120 C°.

Indium forms intermetallic compounds at temperatures above ~200°C., though not as actively as tin, and most indium solders are used at much lower temperatures to avoid these compounds. It is all a matter of chemistry and temperature.

wetted or, to put it another way, the molecular attraction of whatever is being wetted must exceed the molecular adhesion of the wetting agent. Tin-lead solder wets much better than pure tin; this is because the presence of the lead in the alloy acts to reduce the molecular bonding of the tin.

3. Most lead-free alloys are not eutectic, i. e., the alloy does not change from solid to liquid or back again all at once but passes through a mushy stage. All melt at the lowest possible temperature, but over a range of temperatures. This means that dwell times will increase.

