Is lead dead?

In an effort to reduce contamination of the environment associated with the disposal of electronic and electrical equipment containing harmful heavy metals and other contaminants and carcinogens, the European Union passed, in February of 2003, the Reduction of Hazardous Substances Directive. Commonly known as RoHS, this Directive requires mandatory compliance in products produced in, or shipped to, the EU beginning in July of 2006. Other countries, including Japan and China, are moving aggressively to adopt the Directive, and similar laws have passed in a number of US states, including California. It will apply to a wide range of electronic and electrical equipment, including:

- Large and small household appliances
- IT, telecommunications equipment, computers, embedded computers, and storage arrays
- Consumer electronics
- Lighting equipment
- Electrical and electronic tools
- Automatic dispensing equipment

Known for mandating lead-free solders, RoHS covers five major categories:

- Lead – found in solders, terminations coatings on components and PCBs, paints, and as a stabilizer in PVC
- Cadmium – used in electroplated coatings, electrical contacts, relays, switches, and some types of solders, pigments, and substrates
- Mercury – used in lamps, sensors, switches, and relays
- Hexavalent chromium – found in corrosion-resistant coatings and passivation coatings on metals
- Polybrominated Biphenyls (PBB) and Polybrominated Duphenyl Ethers (PBDE), which are used as flame retardants in some plastics

To date our indusry's primary concern has been the move towards lead-free solders. These behave, before and after soldering, in somewhat different ways than the tin-lead solders used for the last hundred years. Pure tin is seen to be a cost-effective soldering material. Among several concerns with pure tin is tin's higher melting temperature. With tin's soldering temperature 30-40 degrees Celsius higher than previous tin-lead alloys, a variety of problems can crop up, including:

- Damage to heat sensitive components, including integrated circuits, capacitors, and optoelectronics
- PCB warping that could result in damaged components, misalignments, and cracks
- Delamination of multilayer PCBs
- Thermal fatigue of solder joints
- Damage to plated through holes: Narrow holes in thicker laminates seem to present the worst case. (This is an issue as sophisticated, multilayer high-speed backplane technologies become mainstream.)
- "Popcorn" failures: Rapidly applying heat to molded components causes moisture to gather and when it exceeds 100 ºC, the resultant gas expansion can break the component.
- Reduced solder wetting: Reduced as soldering temperatures increase, it can result in poor joints.
- A requirement for cleaner surfaces prior to soldering

Tin whiskers and dendrites

Pure tin can produce long, thin "whiskers," which can grow to 10 mm in length, come loose, and short out circuits. The causes of these are not well understood. The US Naval Air Warfare Center has documented what they believe to be at least six satellite failures since 1985 due to whiskers. Although this problem has been with us for a while, a recent article in *Aviation Week & Space Technology,* notes that pure tin whiskers grow at a rate of up to 0.09 mm per year, which is about an order of magnitude faster than tin-lead mixtures. This may have serious implications for equipment lifetimes. Dendrites are fern-like growths that develop along a surface rather than outward from it, like tin whiskers. These dendrites, a form of metal migration, can cause shorts and, as with tin whiskers, appear to be a bigger problem with lead-free solders.

There are some exemptions to the RoHS rules, including the somewhat surprising one of lead in batteries. Many industries have applied for a wide range of exemptions, with some granted, especially in the lighting and lamp industries. For lead, most exemptions have come in the form of an extension of the deadline, and the fate of many others is up in the air. RoHS is of great concern to military electronics vendors and customers, and worry particularly that while some exemptions have been granted, the contract manufacturers building so much equipment for a wide range in industries, including the military, won't maintain separate tin-lead and pure tin manufacturing lines. Also, some countries, notably China, are refusing any deadline extensions. No reprieves appear to be available as US manufacturers, especially in the telecom industries, seek to increase their exports to these countries.

Alternative materials are emerging in order to meet RoHS, but many have issues of their own. Silver/tin oxide can be used in electrical contacts, replacing silver/cadmium oxide. It works fine at low voltages but tends to wear out faster at higher voltages. Gold can replace mercury in switches, but only mercury delivers a "bounce-free" contact, and its operational life, measured by number of operations, is significantly longer. Numerous alternatives to chromate passivation exist, but most resist corrosion less effectively.

So, is the sky falling? Key industries, especially the military, have serious and legitimate concerns, especially in the military. Painful and unexpected surprises will occur over the next decade, but I am not joining the Chicken Little Chorus just yet. I have abundant faith in the continuing ingenuity, resourcefulness, and talent of the members of our industry. Collectively we've overcome other mandates in the past, although admittedly most of these have came from customers and not governments. I wonder which is worse.

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