

Lead Free Backgrounder

LEAD-FREE CONVERSION

Not since the phase-out of CFCs ten years ago has the electronics manufacturing industry faced such a radical change in its assembly processes but, over the next few years, lead-free soldering will have to become a reality following recent activities worldwide.

Such materials are now coming under close scrutiny following concerns over lead ending up in landfill and contaminating land and water supplies, and concerns over lead contamination from recycling operations.

The toxicity of lead has prompted its replacement with more acceptable alternatives in other industries such as here in the UK where lead is no longer used in paints and leaded petrol has been successfully eliminated, as well as lead in domestic water pipes, fishing weights and gun shot etc.

Waste from electronic and electrical equipment is now one of the fastest growing waste streams in the European Union. It is estimated that this waste stream, which constitutes 4% of municipal waste today, will increase by at least 3-5%. Three times as fast as the growth of average municipal waste. Every year, electronic and electrical equipment is one of the largest known sources of heavy metals and organic pollutants in the waste stream. Without proper pre-treatment, the highly toxic components can contaminate soil and groundwater as well as polluting the air.

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European Lead Free Activities

In 1998 the European Union (EU) introduced a draft directive (law) called the WEEE (Waste from Electrical and Electronic Equipment) Directive. The WEEE Directive calls for a ban on lead in all equipment (except automotive) by 1/1/2004. The WEEE Directive intends to ban the selling and/or import of electrical/electronic equipment containing lead interconnect.

The WEEE Directive, based on Article 175 of the Treaty, addresses all electrical and electronic equipment used by consumers and currently not treated before going to incinerators or landfills. It also covers a wide range of professionally used electrical and electronic equipment, such as information technology (IT) and telecommunication equipment, which is not sufficiently recycled today.

ROHS Proposal

It is the restriction on the use of certain hazardous substances in electrical and electronic equipment (ROHS) proposal that promises the greatest impact on the electronics manufacturing industry. The proposal was adopted by the commission on 13 June 2000 and is proceeding in parallel with the WEEE proposal. It requires certain substances (including various heavy metals such as Pb, Hg, Cd, hexavalent Cr) to be phased out of new equipment by 2008. Although there are some exemptions to this ban on the use of lead (in radiation protection, ceramics etc), soldering is not exempt.

The situation is complicated by a separate Directive applicable to the automotive industry i.e. the End-of-Life-Vehicle (EOLV) Directive. Whilst containing the same materials' bans as ROHS, it does specifically exempt lead in solders for automotive electronics.

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Parliament emphasises that the aim of this second directive must be to minimise the risks and the impact on the environment and human health of the production, use, treatment and disposal of WEEE.

Parliament has decided the ban to come into force not in 2008 but on the 1st July 2006. It also says the list of substances should be extended in the light of scientific and technical progress.

EEE Proposal

The proposal for a Directive on electrical and electronic Equipment (EEE) is concerned with minimising overall environmental impact by attention to aspects of design and manufacture, without material bans.

This EEE Directive has now been merged with the EER Directive into the new EuE Directive, Eco-Design of End Use Equipment. This focuses on equipment which is dependant on energy input so is wider than WEEE/RoHS.

EuE has still to go through EC consultation, commission adoption is hoped for in May. It will then be put forward to the European Council.

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Japanese Lead Free Activities

There are no impending legislative material bans although there is an emphasis on recycling. However, in Japan, impending legislation is no longer the driver. In Japan, public preferences for “green” goods and product differentiation provide the incentive for going lead-free. Many Japanese companies are already successfully using a green image to promote lead-free products. Many have strategies for eliminating lead timescales in a few years – well within that of the proposed EU Directive. The JEITA Roadmap indicates that full use of lead-free solder in all new products will be achieved in 2003. However, companies in other parts of the world have generally yet to show the same commitment.

JEITA Roadmap

Japan Electronics and Information Technology Industries Association

First adoption Pb-free solders in mass-produced goods	1999-2000
Adoption of Pb-free components	2000
Adoption of Pb-free solder in wave soldering	2000
Expansion of use of Pb-free components	2001
Expansion of use of Pb-free in new products	2001
General use of Pb-free in new products	2002
Full use of Pb-free solders in all new products	2003
Pb solder used only exceptionally	2005

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US Lead Free Activities

National Electronics Manufacturing Initiative (NEMI) is a partnership of the North American electronics manufacturing industry including commercial and consumer electronics manufacturers, semiconductor manufacturers, substrate suppliers, materials' suppliers, equipment manufacturers and electronics service providers.

NEMI called for a "Lead-Free Initiative Meeting" in February 1999 at Anaheim, CA, to review the situation and, since then, rolled out a series of action items to establish lead-free direction for the US electronic industry. The second NEMI meeting was held in May 1999 at Northbrook, IL. This meeting effectively motivated many manufacturers to get involved in lead-free development.

NEMI has been actively involved in providing the industry with recommended alternative alloys through the NEMI lead-free assembly project. The following are the objectives of this project:

- To have the capability for North American companies to produce lead-free products by 2001, with an eye toward total lead elimination by 2004
- To demonstrate production-ready parts, materials and processes for lead-free assemblies
- To co-operate with component, PWB and equipment manufacturers to allow for the smooth transition to manufacturing processes that may require temperatures up to 260°C
- To develop criteria for the industry to evaluate lead-free processes
- To modify or develop appropriate JEDEC, IPC, or other related standards for lead-free electronic manufacturing.

This team has recommended Sn-3.9Ag-0.6Cu (+/- 0.2%) as the recommended alloy for surface mount assembly.

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The Environment Protection Agency (EPA) in the US has taken regulatory action to remove lead from common consumer products such as gasoline, plumbing and paint products, and to impose strict management requirements on lead-acid batteries to prevent disposal in the solid waste stream. These actions have successfully resulted in the average blood lead levels of people in the US dropping 78% from 12.8 to 2.8 micrograms per deciliter during the last decade.

The EPA has also proposed reducing the Toxic Release Inventory (TRI) reporting threshold for lead and lead compounds from 25,000 pounds to 10 pounds which, if enacted, would increase reporting burdens for facilities that age lead.

No federal lead legislation is pending in the US congress. Some States (e.g. New Jersey), however, are exploring legislation or programs that would require the recycling of consumer electronic products to reduce lead-content in landfill leachate. Consumer electronics have been targeted because they represent a large portion of the municipal solid waste stream. For example, more than 12 million computers are discarded each year, resulting in as much as 600 million pounds of waste⁷.

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LEAD-FREE CHOICES

Although it is now widely agreed that there is no drop-in replacement for Sn/Pb solder, there is a range of possible alternatives readily available.

However, there has been significant progress towards agreement for using one family of alloys, at least for many applications. The European IDEALS programme concentrated on Sn/Ag/Cu alloy for its trials. This prompted Soldertec at ITRI to recommend Sn/Ag/Cu alloy range for most processes. Importantly, agreement was also achieved between a number of major solder suppliers such as IPC, ITRI and NCMS, as to the viability of this option. Subsequently, NEMI (National Electronics Manufacturing Initiative) in the US have also chosen an alloy from within this range for further evaluation and recommendation for reflow soldering.

The Sn/Ag/Cu system is the preferred alloy system of Europe, Japan and the United States. All are in agreement that the Sn/Ag/Cu system offers a reduced melting temperature and provides enhanced mechanical properties to the Sn/Pb systems; however, there is no agreement in exact composition. Table 1 illustrates the preferences of alloy composition of the three countries:

Region	Organisation	Composition
USA	NEMI	Sn – Ag 3.9 - Cu 0.6
Europe	IDEALS	Sn – Ag 3.8 - Cu 0.7
	ITRI	Sn – Ag 4.0 - Cu 0.5
Japan	JEITA	Sn – Ag 3.0 - Cu 0.5

Table 1. Recommended Alloy Compositions

It has been determined by the DTA that alloys have an onset (initial melting temperature) of 217°C with difference of 3-4°C and the Sn-Ag3.0-Cu0.5 displaying the

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highest final temperature at 220°C. Although none of these are true eutectic (Sn/3.42%Ag/0.67%Cu) composition, all alloys display similar melting behaviour.

NEMI hopes that the lead-free solder it has endorsed will become the standard for the electronic industry, suggested for solder reflow applications and for wave soldering.

The Semiconductor Assembly Council, which comprises of semiconductor manufacturers, assembly/test service providers, material manufacturers, and end-user companies established to standardise, certify and compare quality systems and process practices also endorse the Sn/Ag/Cu alloy and refer to it as the SAC lead-free mix.

The Lead-Free Choice for Plating

The question of what happens to a lead-free solder joint if it becomes contaminated with lead is important because during the transition to lead-free soldering it is very likely that Sn/Pb parts will still be used in a great deal of production. In other words, just because one implements a lead-free solder alloy does not mean that Sn/Pb coated components and boards will disappear immediately.

Unfortunately, in the past, the presence of lead in lead-free alloys has been presumed to be acceptable. The logic behind this was that tin and lead are soluble in a lead-free system. However, what has been overlooked is that the intermetallic crystalline structures in lead-free systems are not soluble and will precipitate at lead boundaries. Therefore, when using a lead-free alloy to solder to Sn/Pb coated component leads, Pb can actually create voids in the solder joint that can result in joint failure. In other words, when a company implements a lead-free solder alloy, it should also implement lead-free component terminations. If this is not followed, the reliability of the solder joint is risked.

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The Lead Finish Requirements Needed

- Good electrical, mechanical and wetting properties;
- No electrolytic corrosion potential;
- No dendritic growth;
- Cost, including material, equipment, yield and rework, also availability;
- Compatibility with current processes such as SMT;
- Ability to withstand temperatures such as 260°C IR re-flow;
- Reliability and long-term effects.

The Lead Finish Options

SnCu	Tin/Copper	Cost effective and readily available, with good solderability and solder joint strength, but has a high reflow temperature with a melting point of 227°C and has poor wetting and mechanical properties. It needs a tight %Cu control ⁹ .
SnAg	Tin/silver	Readily available with good mechanical properties, solder joint strength and better solderability than eutectic tin/copper but has a high cost, a melting temperature of 221°C and has potential Whisker growth.
SnB	Tin/Bismuth	Good solderability but poor solder joint strength. It is a by-product of Pb mining and is more expensive. It has poor mechanical properties, with poor solder joint strength and a low melting point.
SnZn	Tin/Zinc	Corrosion of the zinc phase.
100%Sn	Matte Tin	The easiest lead-free solution as it has good solderability and good solder joint strength, although it has a higher reflow temperature.

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The Matte Tin Choice

Historically, leads of semiconductor packages have been plated with a 90% Sn 10% Pb finish to aid solderability. Pure tin offers excellent solderability and wetting at a low cost. The fact that it is a single metal alloy increases the desirability from a manufacturing viewpoint. Some plating solutions containing more than one metal can create problems regarding compositional drift.

An advantage for choosing straight tin is that it can be slotted into existing production lines easily, which could not be done with copper etc. If the straight tin bath is put on the line, it can be used by stepping over the lead/tin baths. Skipping baths means that no special dedicated production line is needed.

Wolfson has chosen to use Matte Tin as its preferred lead-free solder material.