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Feasibility of Restricting Lead From Electronic Products

The current trend to restrict lead in electronics is predicated on the premise that discarded electronic products are finding their way into landfills, dissolving and/or entering groundwater. Environmental impact studies and leaching tests, however, which are representative of actual conditions within landfills, suggest a more likely explanation—lead is extremely corrosion resistant and exacts a low solubility in a landfill environment.

Solder alloys and tin/lead surface finishes on printed wiring boards (PWBs) are not the only lead-containing elements in electronic devices. Surprisingly, the major source of lead in electronics exists in monitor tubes. Tin/lead coatings are the preferred surface finish on component leads. They provide corrosion protection and preserve solderability. Tin is also capable of this function, but concern over whisker growth limits its use for most applications. Tin alloys with more than two percent lead eliminates this problem.

The campaign to restrict the use of lead in electronic products is strongest in Europe and Japan. The population density and lack of landfill space mobilizes the issue. The momentum of this crusade is such that legislation may occur without a comprehensive environmental impact study. A sharp increase in cost and decrease in reliability could result without any environmental, health or safety improvement.

The use of a green label indicating that the product is environmentally friendly has been successful in increasing market share of certain consumer products in Japan. The fine print on the label usually states only that lead-free solder was used to attach the components to a PWB with a lead-free surface finish. Because many components contain lead, the green decal does not automatically guarantee a lead-free product.

The U.S. EPA and OSHA regulations on lead—first imposed in 1970—have been an environmental and public health success story. Data from the National Health & Nutrition Examination Surveys (NHANES) show that the average blood-lead levels in the U.S. have been lowered significantly among both children and the general population.*

	Children, age 1-5	**Gen. Population**
NHANES II, 1976-81	15.0 ug/dl	12.8 ug/dl
NHANES III		
• Phase I (1988-91)	3.6 ug/dl	2.8 ug/dl
• Phase II (1991-94)	2.7 ug/dl	2.3 ug/dl

Most sources of lead contamination have been removed:

- In 1930, coal, which can contain up to 50 ppm of lead, was used to heat most homes in the U.S. Today, electric-generating plants and steel mills using coal have efficient pollution control equipment to remove lead.
- In 1970, tetraethyl lead was used as an additive to prevent knocking in gasoline engines. This accounted for 30 percent of the lead production in the U.S., which currently approaches zero.
- Early on, paints were the main source of lead as a health hazard. The use of household paint containing lead began being limited in 1960, and was completely banned in 1978.
- OSHA regulations in lead industries have been very successful in reducing blood-lead levels of the workforce to approximate levels acceptable to the general population.

During the past year, there have been numerous conferences and technical papers concerning alternatives to the use of lead in printed circuits. The general consensus is that there is no drop in replacement for lead and, further, that a vast expenditure in research will be required if legislation is passed restricting the use of lead on printed circuits.

Successful Lead-free Solder Applications

Successful production of lead-free circuit boards have thus far been limited to consumer electronic products, such as mini-disc players, television boards, computer boards and domestic appliance circuits.

* *Center for Disease Control & Prevention (CDC Report), 2/21/97, Vol. 46, No. 7.*

Lead-free Alternatives to 63/37 Sn/Pb

Alloy	Melting range, °C	Patent	Cost/Kg, $ *as of 2/3/00*	Density, g/cc
63Sn/37Pb	183	No	5.21	8.4
52Sn/58Bi	139	No	7.57	8.8
77.2Sn/20In/2.8Ag	179-189	Yes	66.13	7.4
91Sn/9Zn	199	No	7.11	7.2
91.8Sn/3.4Ag/4.8Bi	208-215	Yes	13.73	7.5
90Sn/7.5Bi/2Ag/0.5Cu	186-212	No	11.20	7.6
96.2Sn/2.5Ag/0.8Cu/0.5Sb	213-219	Yes	12.06	7.4
95.5Sn/4Ag/0.5Cu	217-218	No	14.41	7.3
95Sn/3.5Ag/1.5In	218	No	17.93	7.5
93.5Sn/3.5Ag/3Bi	216-220	No	13.02	7.5
96.5Sn/3.5Ag	221	No	13.90	7.4
99.3Sn/0.7Cu	227	No	7.66	7.3
95Sn/5Sb	232-240	No	7.41	7.3

Component selection and board design were vital elements for success.

These products do not involve complex circuitry and were carefully selected and designed to utilize "lead-free" as a marketing tool. For more complex circuitry, cost and reliability are valid concerns that must be carefully addressed.

Concerns

Lead-free solders do not wet as well as tin/lead alloys. To compensate, the following may be pre-required:

- New flux formulations
- A nitrogen atmosphere
- Post-soldering cleaning

High tin alloys tend to dissolve more copper, causing:

- Fast buildup of copper in wave soldering
- Erosion of fine lines in high-density circuits

Lower density alloys may mandate:

- New solder past formulations to achieve desired properties (print quality/slump/tack time)

Higher soldering temperature may impose:

- More costly laminate material with superior thermal properties
- Elimination of components containing volatiles (*e.g.*, electrolytic capacitors and polymer encapsulated components)

Limitation to ball grid array (BGA) attachment for high I/O components:

- The large temperature differential (125 °C) between 5/95 Sn/Pb and 63/37 Sn/Pb essential for BGA attachment is not available in lead-free alloys

Lead-free alloys are not as ductile, causing problems in:

- Silicon attachment, where tin/lead brings the necessary ductility that allows relaxation of stress over time

Self-centering during reflow is decreased with non-eutectic alloys. To compensate:

- Optimize pick and place precision and pad design

Summary

Soldering has been the preferred technique for component attachment to printed circuit boards. The industry has come far in 40 years, reducing solder defects to where they are now measured in parts-per-million, rather than percent. This has been achieved by utilizing data collected over the years to upgrade materials, improve equipment, perfect techniques and control parameters. This data is based on tin/lead solders. Tin/silver alloys were limited to applications where leaching of silver thick film on hybrid circuits presented a problem.

With few technical advantages and the anticipatory expenditures to develop techniques/operating parameters/equipment for efficient manufacturing, the feasibility of eliminating lead is being tested in consumer electronics, where marketing is a driving force. The degree of success will determine if it is practical to pursue this into other sectors where reliability is a major issue, such as the aerospace, automotive, communications, defense and medical fields. P&SF