Is the Supply Chain Ready for RoHS?

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Common materials and the availability of RoHS-compliant versions.

The EU's RoHS Directive restricts the use of six substances in electrical and electronic equipment: mercury, lead, hexavalent chromium, cadmium, polybrominated biphenyls and polybrominated diphenyl ethers. Manufacturers have made significant investments in new processes that will eliminate these substances -- especially lead. However, in addition to having manufacturing processes in place, they must be assured of a strong supply chain that can provide sufficient replacement materials.

Many electronic system elements will need to be RoHS-compliant, including cables, connectors, plastics and enclosure sheet metal. This article highlights some commonly used materials and the availability of RoHS-compliant versions worldwide.

Printed wiring boards. Manufacturers are concerned about the compatibility of printed wiring board (PWB) materials with Pb-free soldering temperatures of 240 to 260°C. Compatibility is critical for the larger, thicker boards used in high-end computer systems. Some high-temperature PWB materials are becoming available in production quantities, but availability will be constrained through 2006.

In general, PWB boards do not contain any proscribed materials such as cadmium or mercury, and the majority of PWBs do not rely on PBBs or PBDEs for flame retardants. Alternative retardants have been developed and are available worldwide.

All major PWB manufacturers currently offer some version of a RoHS-compliant board finish. RoHS-compliant OSPs are commonly available, but require a high degree of process control for high-yield soldering. Easy-to-solder immersion tin and silver finishes are readily available.

Molding compounds for component encapsulation and connector housings. Most connector suppliers are migrating to housing materials that can handle Pb-free PWB assembly temperature requirements. Component manufacturers are ensuring that moisture is not trapped inside encapsulated components by baking shortly after encapsulation. Most connector and component suppliers are accepting orders for RoHS-compliant parts for delivery before the end of 2005.

Cable insulation materials. Cadmium, hexavalent chromium and lead compounds are often found in polyvinylchloride, which is used for cable insulation. These heavy metal compounds are also used in pigments to mark cable insulation material, and mercury compounds have been used for curing control. Major cable suppliers are implementing substitute materials, such as titanium, for RoHS-compliant cables.

Connector materials. SnPb plating is commonly used on electrical connectors. A pure tin finish meets RoHS requirements, but lead removal increases the potential for tin whisker formation and growth, which can cause problems in high-reliability products. The connector industry is generally moving to Sn/Ni plating, which mitigates tin whiskers.[1] No supply problems should arise.

Compliant pin connectors. Compliant pin connectors, also called insertion force or push-in connectors, are used for high-density PWB connections. The standard compliant pin plating has been tin-lead. Lead acts as a lubricant during insertion/removal from the PWB and, without lead, some compliant pin designs damage the plated-through-holes. The best technical solution appears to be tin-over-nickel plating. However, due to the extreme criticality of high-density compliant pin connections, several companies have been granted a temporary exemption permitting continued use of SnPb coating until 2008.

Electrical components. Plated-through-hole devices typically use SnPb plating over a copper-plated steel wire. Pure tin plating is usually of little concern for PTH devices because of the relatively wide (>1 mm) spacing between adjacent leads. Wire wound resistors, some capacitors and some LEDs are available with PTH connections. Obtaining RoHS-compliant PTH connection devices by the end of 2005 should not be a problem.

Lead-Frames use either a copper or iron-nickel (A42) alloy as strip metal. Some component manufacturers plate strip material with nickel-palladium or nickel-palladium-gold, which is RoHS-compliant and free of any whisker concerns. SMT lead-frame manufacturers have historically used SnPb as a finish coating, and many intend to use a pure tin replacement finish. Tin whiskers are a major reliability concern for components with tight lead-frame spacing (<1 mm) and high-reliability system manufacturers are requiring suppliers to implement one of several whisker mitigation strategies (e.g. annealing or nickel underlay) for lead-frame components with tight spacing.[2] With the exception of some legacy products, RoHS-compliant SMDs should be available.

BGAs with high lead content (>85%) are RoHS-exempt for reliability purposes. However, eutectic SnPb BGAs will have to remove lead. All BGA component manufacturers will provide lead-free BGAs by the end of this year.

Server and storage products are exempted from RoHS until 2008 and can continue to use SnPb solders. However, availability of SnPb BGA components will be problematic because most manufacturers are switching production to lead-free BGAs for high-volume commodities that are not exempt. Mixing lead-free solder balls with SnPb solder paste causes reliability degradation. When SnPb solder BGA balls are no longer available, manufacturers must decide whether to use lead-free solder attach or stay with SnPb solder.

Multi-layer ceramic capacitors are "end-cap" solder connect devices. These components usually have end-caps made from pure tin over an intermediate layer such as nickel or, sometimes, silver. These devices are RoHS-compliant as is and do not require conversion.

Sheet and bulk metal. All electronic hardware needs a mechanical enclosure, meaning that sheet steel must be RoHS-compliant. Additional internal mechanical hardware, such as fasteners and metal heat sinks, use sheet steel and must also be compliant.

There are three exemptions for the use of lead as an alloying element in metals:

1. Lead as an alloying element in steel containing up to 0.35% lead by weight
2. Lead as an alloying element in aluminum containing up to 0.4% lead by weight

3. Lead as an alloying element in copper alloys containing up to 4% lead by weight

Uncoated steels are RoHS-compliant, provided they meet relevant ASTM specifications, with the caveat that mercury must be undetectable (<5 ppm by weight) and cadmium must be < 75ppm. However, steels are typically purchased with a coating, and hexavalent chromium (Cr^{+6}) has been commonly used as a finish. Since RoHS regulations require that Cr^{+6} concentrations in the steel coating be <1000ppm, most system designers have eliminating it as a steel finishing process.

The sheet steels most commonly used for electronic enclosures (and their coatings) are discussed below.

Zinc-coated sheet steel. Zinc coatings are the most widely used sheet steel finish due to low cost and good sacrificial corrosion protection. The three primary types are: galvanneal (a heat-treated hot-dip zinc alloy sold with an oil finish and then usually painted), galvanized (a hot-dip zinc coating typically sold with a hexchrome finish, unless specified otherwise) and electro-galvanized (E-Gal) coatings (electrolytically plated zinc films).

Galvanneal is RoHS-compliant and available globally. Galvanized and electro-galvanized may be RoHS-compliant, depending on the finish coating, but are not as readily available. RoHS-compliant galvanized steel that meets typical electrical hardware specifications is just becoming available worldwide. Sources were established in Asia-Pacific in early 2005, and European and U.S. sources for RoHS-compliant galvanized are expected mid-year. E-Gal steel with an RoHS-compliant organic (anti-fingerprint) coating has been available in the Far East for several years, but supply is limited and the sources will not, at this time, accept new customers outside of the Asia-Pacific market.

Aluminized sheet steel. Aluminized sheet steel is made by immersing sheet steel into molten aluminum, and it usually runs about 4-10 cents more per pound than zinc-coated steel. Aluminized steel is highly corrosion resistant and conductive, making it an ideal metal for electrical chassis applications. However, it should not be used where abrasion resistance is a concern because it tends to gall quite severely. ASTM standards require that aluminized steel be sold with an oil coating unless a special order requires some other finish. However, aluminized steel manufacturers have commonly used hexchromated finishes for marketing purposes. It may be necessary to negotiate with mills making aluminized steel to obtain oil-coated aluminized steel. RoHS-compliant aluminized steel is available in the U.S. and Europe, but is not yet available in Asia.

Electroless nickel coatings on sheet steel. Electroless nickel, a post-fabrication operation, has very good corrosion resistance, good hardness, very good surface conductivity, an attractive appearance, good edge corrosion resistance and worldwide availability. However, some electroless nickel chemistries contain cadmium in amounts greater than 75 ppm, which could potentially exceed RoHS guidelines (<100 ppm) as well as the requirements of additional environmental regulations adopted by a few European countries. All major coating companies now provide chemistries that do not contain any cadmium. Electronics manufacturers must be sure that nickel plating shops do not utilize a post-plate hexchrome finish and that they select a nickel plating chemistry without cadmium.

Sheet and bulk stainless steel. Stainless steels are RoHS-compliant. Stainless steel fasteners are commonly used where outstanding corrosion resistance and an attractive visual appearance are required. Stainless is available worldwide, but the user must ensure that hexavalent chromium passivation is not used by the manufacturer.

Sheet and bulk aluminum. Aluminum is available in sheet form and is used for some electrical enclosure applications. Sheet aluminum with an oiled or trivalent chromate finish is RoHS-compliant. Anodized aluminum is also RoHS-compliant, provided the manufacturer does not add a hexchrome finish after anodization. Aluminum is available worldwide.

RoHS-compliant metal coatings. Trivalent chromate passivation finishes for zinc-coated steel are RoHS-compliant and offer good (24-72 hours) salt spray corrosion resistance and reasonably high electrical conductivity. Trivalent coatings are usually good enough for most electronic assembly applications and are available in the U.S and Europe. Anti-fingerprint (AFP) coatings are thin organic films providing both corrosion resistance and some measure of electrical conductivity. The process window for AFP thicknesses that provide acceptable corrosion and electrical requirements is extremely tight. Some Asia-Pacific manufacturers have developed outstanding AFP coatings on zinc-coated E-Gal steel. Attempts to develop AFP coatings on galvanized (hot-dipped zinc) steel have been minimally successful to date. Users should require stringent quality control on AFP-coated galvanized steels to ensure all specifications are met.

Steel is typically purchased by its ability to withstand a salt spray test. **Table 1** summarizes the various options for RoHS-compliant sheet steel finishes and their availability as of June 2005.

Table 1: Options and Current Availability

Salt Spray Requirement	Qualified Sheet Steel Finishes (1 milliohm sheet conductivity) (>24 hour salt spray)	Availability
24 hours	Zn with trivalent passivation	Available in US and Europe
	Galvanneal E-coat (a painted Zn)	Available globally
48 hours	Zn with trivalent passivation	Available in US and Europe
72 hours	E-Gal Zn with anti-fingerprint (AFP)	Available in Far East from Japanese sources
96 hours	3 microns of electroless nickel	Available globally
105 hours	Aluminized steel	Available in US only
	5 microns of electroless nickel	Available globally

Designers must ensure that suppliers provide replacement materials that meet the manufacturer's RoHS definition. In many cases, the RoHS Directive is vague and open to interpretation. When looking at RoHS compliance, it is necessary to consider other materials beyond lead, since the directive deals with six substances. Also remember that restrictions apply to more than the electronics. They include other parts of the

product, such as enclosures and accessories.

References

1. G. T. Galyon and R. Gedney, "Avoiding Tin Whisker Reliability Problems," *Circuits Assembly*, August 2004, pp. 26-32.
2. Recommendations on Lead-Free Finishes for Components Used in High-Reliability Products (updated May 2005), iNEMI Tin Whisker User Group. **User_Group_mitigation_May05.pdf**

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