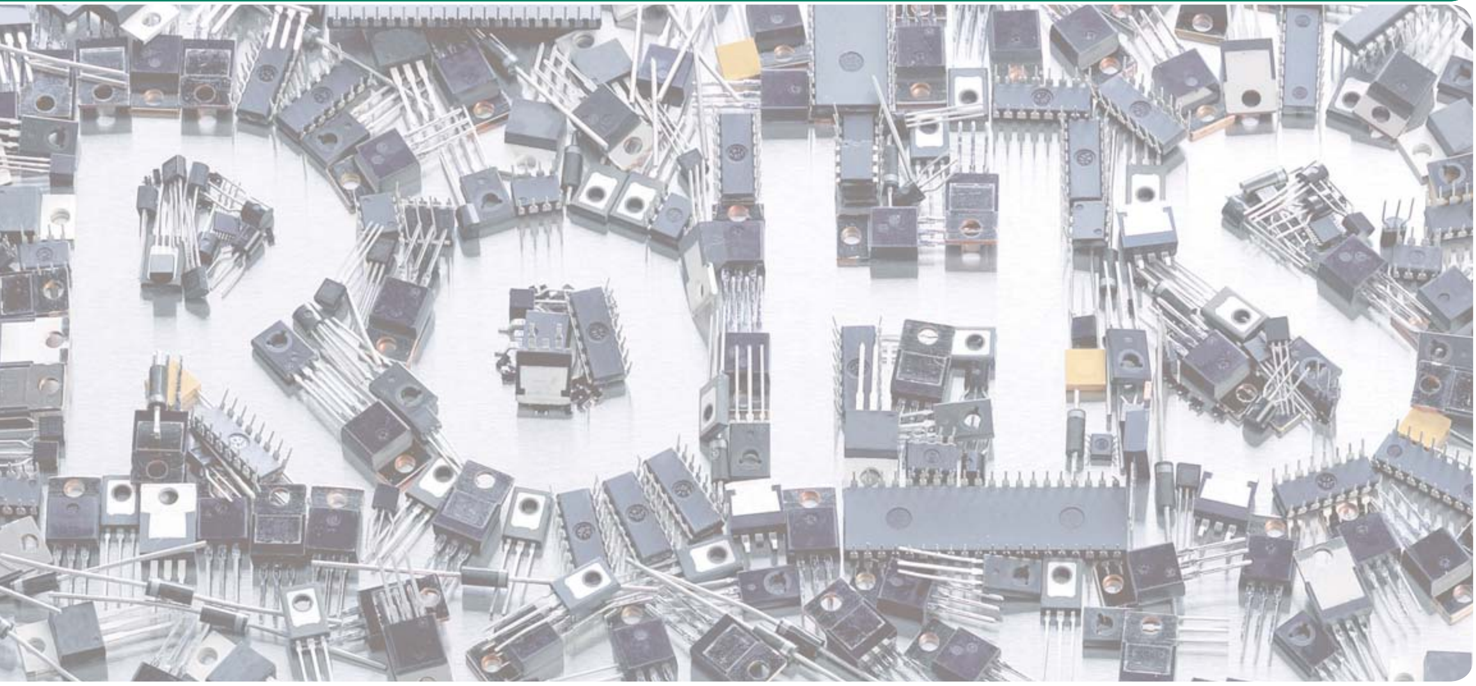
RoHS Directive Technical Guide

May 2008



Introduction to the requirements of the

RoHS Directive 2002/95/EC RoHS

The Restriction of the use of certain Hazardous Substances (RoHS) Directive came into force on 1st July 2006. From this date, producers of certain categories of electrical and electronic equipment will not be able to place on the market products that contain six "banned" substances unless specific exemptions apply.

- Lead - (Pb)
- Mercury - (Hg)
- Hexavalent chromium - (Cr(VI))
- Cadmium - (Cd)
- Polybrominated biphenyl flame retardants - (PBB)
- Polybrominated diphenyl ether flame retardants - (PBDE)

The Directive applies to electrical and electronic equipment that is dependent on electric or electromagnetic fields in order to work properly. Also, equipment for the generation, transfer and measurement of such currents and fields falling within 8 product categories (below) and designed for use with a voltage rating not exceeding 1,000 volts for alternating current and 1,500 volts for direct current

The scope is eight of the ten categories of the Waste Electrical and Electronic Equipment (WEEE) Directive. These are:

1. Large household appliances
2. Small household appliances
3. IT and telecommunications equipment
4. Consumer equipment
5. Lighting equipment (including light bulbs, and luminaires in households)
6. Electrical and electronic tools (except large scale stationary industrial tools)
7. Toys, leisure and sports equipment
10. Automatic dispensers

Categories 8 (medical devices) and 9 (monitoring and control instruments) are expected to fall within scope by 2012

What is a compliant product?

The RoHS Directive applies to equipment that is within the scope of the Directive. None of the "homogeneous materials" within compliant products must contain the six restricted substances at concentrations above the "maximum concentration values".

Who is responsible?

Producers of equipment are held responsible for ensuring that their products do not contain the six restricted substances. The Directive does not cover components or sub-assemblies and so the equipment producers will have to take their own steps to ensure that all parts and materials used in their products do not contain restricted substances.

"Producer" means any person who, irrespective of the

selling technique used:

(i) manufactures and sells electrical and electronic equipment under his own brand;

(ii) resells under his own brand equipment produced by other suppliers; or

(iii) imports or exports electrical and electronic equipment on a professional basis into a member state.

It is clear from this that there will be circumstances in which it is not the actual manufacturer of a product who will assume the "producer" responsibilities.

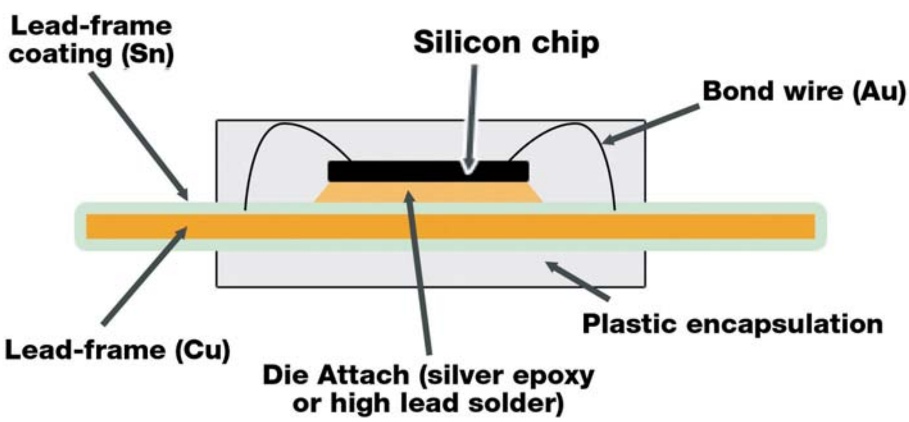
What are the maximum concentration values (MCV)?

These are 0.1 percent by weight of lead, mercury, hexavalent chromium, PBB and PBDE and 0.01 percent by weight cadmium in homogeneous materials.

What is a homogeneous material?

A homogeneous material cannot be mechanically broken down (by cutting, grinding, crushing etc) into different materials - examples would be plastic, ceramic, glass, metal etc. A semiconductor package, for example, will contain several, see below

Homogeneous material – semiconductor package example



What Product Categories need to comply

The list of products below each category heading is illustrative and not exhaustive.

1. Large household appliances

(Such as large cooling appliances; refrigerators; freezers; other large appliances used for refrigeration, conservation and storage of food; washing machines; clothes dryers; dish washing machines; cooking; electric stoves; electric hot plates; microwaves; other large appliances used for cooking and other processing of food; electric heating appliances; electric radiators; other large appliances for heating rooms, beds, seating furniture; electric fans; air conditioner appliances; other fanning, exhaust ventilation and conditioning equipment)

2. Small household appliances

(Such as vacuum cleaners; carpet sweepers; other appliances for cleaning; appliances used for sewing, knitting, weaving and other processing for textiles; irons and other appliances for ironing, mangling and other care of clothing; toasters; fryers; grinders, coffee machines and equipment for opening or sealing of containers or packages; electric knives; appliances for hair-cutting, hair drying, tooth brushing, shaving, massage and other body care appliances; clocks, watches and equipment for the purpose of measuring, indicating or registering time; scales)

3. IT and telecommunications equipment

(Such as centralised data processing; mainframes; minicomputers; printer units; personal computing; personal computers, including the CPU, mouse and keyboard; laptop computers, including the CPU, mouse and keyboard; notebook computers; notepad computers; printers; copying equipment; electrical and electronic typewriters; pocket and desk calculators; other products and equipment for the collection, storage, processing, presentation or communication of information by electronic means; user terminals and systems; facsimile; telex; telephones; pay telephones; cordless telephones; cellular telephones; answering systems; other products or equipment of transmitting sound, images or other information by telecommunications)

4. Consumer equipment

(Such as radio sets; television sets; video cameras; video recorders; hi-fi recorders; audio amplifiers; musical instruments; other products or equipment for the purpose of recording or reproducing sound or images, including signals or other technologies for the distribution of sound and image than by telecommunications)

5. Lighting equipment, (including electric light bulbs and household luminaires)

(Such as luminaires for fluorescent lamps; straight fluorescent lamps; compact fluorescent lamps; high intensity discharge lamps, including pressure sodium lamps and metal halide lamps; low pressure sodium lamps; other lighting equipment for the purpose of spreading or controlling light)

6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)

(Such as drills; saws; sewing machines; equipment for turning, milling, sanding, grinding, sawing; cutting; shearing; drilling; making holes; punching; folding; bending or similar processing of wood, metal and other materials; tools for riveting, nailing or screwing or removing rivets, nails, screws or similar uses; tools for welding, soldering or similar use; equipment for spraying, spreading, dispersing or other treatment of liquid or gaseous substances by other means; tools for mowing or other gardening activities)

7. Toys, leisure and sports equipment

(Such as electric trains or car racing sets; hand-held video game consoles; video games; computers for biking, diving, running, rowing, etc.; sports equipment with electric or electronic components; coin slot machines)

8. Automatic dispensers

(Such as automatic dispensers for hot drinks; automatic dispensers for hot or cold bottles or cans; automatic dispensers for solid products; automatic dispensers for money; all appliances which deliver automatically all kind of products)

Note:
Categories 8 (medical devices) and 9 (monitoring and control instruments) are expected to fall within scope by 2012

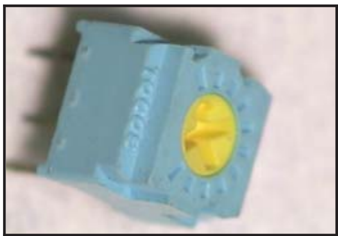
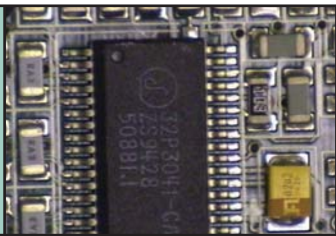
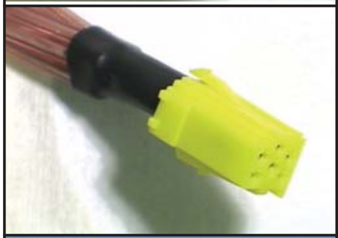
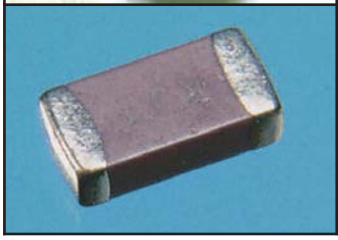
Exemptions to the RoHS Directive

No.	Description
1.	Mercury in compact fluorescent lamps not exceeding 5 mg per lamp.
2.	Mercury in straight fluorescent lamps for general purposes not exceeding: — halophosphate 10 mg — triphosphate with normal lifetime 5 mg — triphosphate with long lifetime 8 mg.
3.	Mercury in straight fluorescent lamps for special purposes.
4.	Mercury in other lamps not specifically mentioned in this Annex.
5.	Lead in glass of cathode ray tubes, electronic components and fluorescent tubes.
6.	Lead as an alloying element in steel containing up to 0,35 % lead by weight, aluminium containing up to 0,4 % lead by weight and as a copper alloy containing up to 4 % lead by weight.
7.	— lead in high melting temperature type solders (i.e. lead based alloys containing 85 % by weight or more lead) — lead in solders for servers, storage and storage array systems, network infrastructure equipment for switching, signalling, transmission as well as network management for telecommunications — lead in electronic ceramic parts (e.g. piezoelectronic devices).
8.	Cadmium and its compounds in electrical contacts and cadmium plating except for applications banned under Directive 91/338/EEC (1) amending Directive 76/769/EEC (2) relating to restrictions on the marketing and use of certain dangerous substances and preparations.
9.	Hexavalent chromium as an anti-corrosion of the carbon steel cooling system in absorption refrigerators.
9a	DecaBDE in polymeric applications **DELETED 1 JULY 2008**
9b	Lead in lead-bronze bearing shells and bushes
11.	Lead used in compliant pin connector systems.
12.	Lead as a coating material for the thermal conduction module c-ring.
13.	Lead and cadmium in optical and filter glass.
14.	Lead in solders consisting of more than two elements for the connection between the pins and the package of microprocessors with a lead content of more than 80% and less than 85% by weight.
15.	Lead in solders to complete a viable electrical connection between semiconductor die and carrier within integrated circuit Flip Chip packages.
16.	Lead in linear incandescent lamps with silicate coated tubes.
17.	Lead halide as radiant agent in High Intensity Discharge (HID) lamps used for professional reprography applications.
18.	Lead as activator in the fluorescent powder (1% lead by weight or less) of discharge lamps when used as sun tanning lamps containing phosphors such as BSP (BaSi2O5:Pb) as well as when used as speciality lamps for diazo-printing reprography, lithography, insect traps, photochemical and curing processes containing phosphors such as SMS ((Sr,Ba)2MgSi2O7:Pb).
19.	Lead with PbBiSn-Hg and PbInSn-Hg in specific compositions as main amalgam and with PbSn-Hg as auxiliary amalgam in very compact Energy Saving Lams (ESL).
20.	Lead oxide in glass used for bonding front and rear substrates of flat fluorescent lamps used for Liquid Crystal Displays (LCD).
21.	Lead and cadmium in printing inks for the application of enamels on borosilicate glass.
22.	Lead as impurity in RIG (rare earth iron garnet) Faraday rotators used for fibre optic communications systems.
23.	Lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with NiFe lead frames and lead in finishes of fine pitch components other than connectors with a pitch of 0.65 mm or less with copper lead-frames.
24.	Lead in solders for the soldering to machined through hole discoidal and planar array ceramic multilayer capacitors.
25.	Lead oxide in plasma display panels (PDP) and surface conduction electron emitter displays (SED) used in structural elements; notably in the front and rear glass dielectric layer, the bus electrode, the black stripe, the address electrode, the barrier ribs, the seal frit and frit ring as well as in print pastes.
26.	Lead oxide in the glass envelope of Black Light Blue (BLB) lamps.
27.	Lead alloys as solder for transducers used in high-powered (designated to operate for several hours at acoustic power levels of 125 dB SPL and above) loudspeakers.
28.	Hexavalent chromium in corrosive preventive coatings of unpainted metal sheetings and fasteners used for corrosion protection and Electromagnetic Interference Shielding in equipment falling under category three of Directive 2002/96/EC (IT and telecommunications equipment). Exemption granted until 1 July 2007.
29.	Lead bound in crystal glass as defined in Annex 1 (Categories 1, 2, 3 and 4) of Council Directive 69/493/EEC
	Agreed by TAC but not yet published in Official Journal
30	Cadmium alloys as electrical/mechanical solder joints to electrical conductors located directly on the voice coil in transducers used in high-powered loudspeakers with sound pressure levels of 100 dB (A) and more.
31	Lead in soldering materials in mercury free flat fluorescent lamps (which e.g. are used for liquid crystal displays, design or industrial lighting).
32	Lead oxide in seal frit used for making window assemblies for Argon and Krypton laser tubes.

Restricted substances

-where they might be found

Substance	Application
Lead	Solders
	Termination coatings on components
	Paints as pigments and as driers
	PVC as a stabiliser
	Batteries (not covered by RoHS Directive)
Cadmium	Electroplated coatings
	Special solders (e.g. in some types of fuse)
	Electric contacts, relays, switches
	PVC stabiliser
	Plastics, glass and ceramic pigments
	In some glass and ceramic materials
Mercury	Lamps
	Sensors
	Relays
Hexavalent chromium	Passivation coatings on metals
	In corrosion resistant paints
PBB and PBDE	Flame retardants in plastics.

	Potentiometer, may contain cadmium internally		Lead in solder or termination coating
	Lamp, glass and solder may contain lead		Plastic housings, PBB, PBDE, cadmium and lead
	Plastic connector and cable insulation may contain lead or cadmium		Electrolytic capacitor; lead in termination coatings and in plastic cover if PVC
	MLCC, lead in ceramic is exempt but lead in termination is banned		Cadmium or lead in plastic and lead in electroplated coatings

Limitations of alternatives

Material or component	Alternative	Limitations of alternative
Tin/lead solder	Lead-free solders	All different to tin/lead, see next section
Silver/cadmium oxide contacts	Silver/tin oxide	OK at low voltage, wears faster at high voltage
Chromate passivation	Various	Most are less effective as corrosion inhibitors on bare metals.
Mercury switches	Gold contacts	Only mercury gives bounce free contact and life is significantly longer
Tin lead electroplated terminations	iTn, tin alloys	Risk of tin whiskers. Wetting characteristics different
PBDE flame retardants	Other flame retardants	Characteristics may be different. Need to comply with fire regulations

Note that manufacturers may request exemptions for some of these applications.
Where alternatives are available, in some cases they may be more expensive.

The EU RoHS Directive restricts the use of six hazardous substances in eight product categories of electrical equipment.

Typical examples of products currently in scope:

External hard drives, memory cards, bluetooth adapters, digital cameras, keyboards, IT cables, mouse, printers, Ethernet switches, routers, PCI cards, calculators, clocks, laser pointer, telephones, headphones, 2-way radios, modem adaptors, electric grinders, electric drills, soldering irons, vacuum cleaners, battery chargers (may be regarded as tools), torch, etc.

Medical equipment and monitoring and control instruments are currently excluded from RoHS but this is likely to change following a review of scope driven by the European Commission.

A hypothetical example of an electrical product is used here as a case study to illustrate what manufacturers need to do to comply with RoHS.

Actions required:

- First set up a team to implement the changes required. This should include production, quality, R&D and purchasing. One of the roles of this team should be to monitor RoHS legislation world-wide. This is constantly developing and changes could affect new product design.
- Contact suppliers to determine if RoHS compliant components are available – if any have been withdrawn then a re-design of the product may well be required.
    - New circuit layouts are relatively straightforward but rewriting software for newer types of microprocessor, for example, can be very time consuming.
- Contact PCB sub-contractors if these are not made in-house to determine if lead-free soldering is available – if not an alternative sub-contractor will be required
- If soldering is carried out in-house, this will need to be changed to lead-free.
    - Lead-free soldering is very different to tin/lead. The higher temperatures required can damage some types of components and laminates so alternatives may need to be used. A sufficiently high temperature is needed to form good solder joints but this should not be any higher than necessary to avoid heat damage to components or the laminate. To achieve this compromise, new soldering equipment may be required.
    - Lead-free prototype products will need to be made in sufficient numbers to validate the production process and to provide samples for quality and reliability testing. Both of these can be compromised when changing to lead-free soldering if this is not carried out correctly.
- If any aluminium or galvanised steel parts are treated with passivation chemicals, these are likely to be hexavalent chromium based and an alternative will be required. Suppliers of sub-assemblies will also need to be informed of this requirement.
    - Find a suitable sub-contractor who is able to coat parts with one of the relatively new passivation materials. The substitutes that are available are suitable for most applications but are not as easy to apply as hexavalent chromium, therefore prototype testing is advisable.
- Set up a RoHS compliance procedure. This will be required to assess and audit suppliers, check incoming parts and test any high risk materials such as bright yellow plastic (cadmium or hexavalent chromium) and PVC cable insulation (lead). This procedure will need to be followed and documented to ensure that non-compliant parts are not used and to provide evidence of due diligence if the RoHS enforcement body requests this information.
- Staff training will be required; for optical inspection, rework, assessing whether parts are RoHS compliant, etc.

Changing products to comply with RoHS is not straightforward. Manufacturers who have already changed found that the process took up to four years and costs can be considerable. Having eliminated the six RoHS substances, this is not the end. The EC is reviewing the RoHS Directive and may add additional product categories and substances to the current lists and they may also delete certain exemptions.

Glossary of terms

What are Tin-Whiskers?

Tin-whiskers are single crystal, electrically conductive, hair-like structures that grow from lead-free, pure tin surfaces.

What are Dendrites?

Dendrites are fern-like or snowflake-like patterns growing along a surface (x-y plane) rather than outward from it, like Tin-whiskers. The growth mechanism for dendrites is well understood and requires some type of moisture capable of dissolving the metal (e.g., tin) into a solution of metal ions that are then redistributed by electro-migration in the presence of an electromagnetic field.

What is surface Insulation Resistance?

Metal migration between isolated conductors on a completed assembly may produce electrical shorts. These occur when the space between the conductors is bridged by dendrites formed by re-deposited metal ions.

What is a "popcorn" reaction?

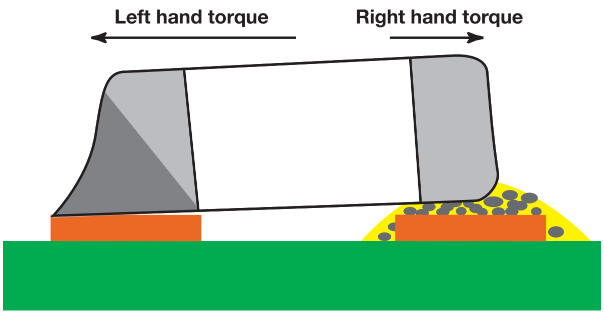
When heat is rapidly applied to moulded components moisture can gather. Above 100°C it expands, turns to gas and tries to escape and when it can't it tends to break or “pop” the moulded compound like a “popcorn effect”.

What is Wetting?

The ability of a liquid to flow across a surface as opposed to sticking to itself. Wetting occurs when the attractive surface energy of the pad, or lead, is greater than the surface energy of the solder drawing a molecularly thin layer of solder across itself. Heating solder adds to the surface energy in the solder, so the cooler the solder the better the wetting.

What is Tomb-stoning?

Defined as the raising of one end, or standing up, of a leadless component from the solder paste. This phenomenon is the result of an imbalance of the wetting forces during reflow soldering.



Initial stages of tomb-stoning due to the force of imbalance caused by temperature differences

What is Kneading?

The process of mixing solder powder to solder flux to form solder paste

What is Drossing?

The formation of oxides and other contaminants upon molten solder.

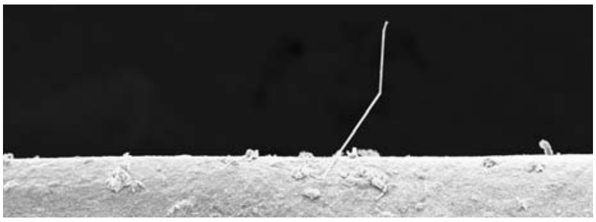
Tin Whiskers

What are they?

- Whiskers are thin fibres of tin that grow apparently spontaneously from electroplated tin surfaces
- Tin whiskers can cause short circuits and have caused several satellites, missiles, heart pacemakers and a nuclear power station to fail
- Electroplated tin coatings are used on most component terminations to aid soldering and to provide corrosion resistance
- Whiskers of several mm are possible although ~ 100µm is more common.
- Only long whiskers cause failures.

Causes of Tin Whiskers

- Whiskers are caused by compressive stresses in tin coatings
- Stresses are induced by:
  - Irregular intermetallic crystals that grow at copper / tin interfaces
  - Due to stress induced by thermal expansion mis-match between layers of coatings
  - Due to formation of bulky oxides between tin grains in humid environments



SEM image of tin whiskers taken by ERA Technology Ltd

Prevention of Tin Whiskers

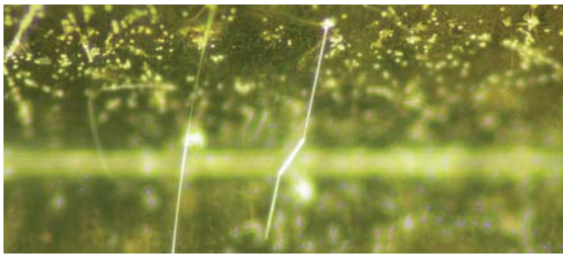
- A lot of research has been carried out into the causes and prevention
- iNEMI has published guidance
  - http://thor.inemi.org/webdownload/projects/ese/tin_whiskers/Pb-Free_Finishes_v4.pdf
  - Risk should be small if this is followed but:
- Equipment manufacturers buy pre-plated components from suppliers and have no influence over production process
  - Test methods are available but
- These take at least 3 months – no use for QA
- Equipment manufacturers need a whisker mitigation strategy:
  - Approved supplier list for COTS components
  - Document coating specification for custom made parts
  - Design requirements
  - Conformal coatings

Measures to avoid Tin Whiskers

- Whisker risk very low if the following are used:
  1. Use Ni/Pd/Au termination coatings (no risk but an uncommon coating)
  2. Use tin/lead terminations (extremely low risk but infrequently available)
  3. Thin matte tin on copper with a non-porous nickel barrier layer (very low risk)
  4. Bake matte tin on copper at 150°C for 1 hour within 24 hours of plating (no good later than this). Very low risk but only a few component manufacturers do this
  5. Melt electroplated tin – this usually prevents whiskers but the high temperature may cause heat damage. Hot dipped terminations are OK

How to avoid Tin Whiskers

- Do not use SnCu plating but SnAg is OK
- Avoid alloy 42 lead-frame components or other low TCE materials if there is a choice
- Whisker resistant matte tin plating processes are new, not all electroplaters use them, check that they do and that operating procedures are followed
- Matte tin is usually less susceptible to whiskers although whisker resistant bright tin is available
- SnBi termination coatings are OK but ensure <6% Bi to avoid reliability problems with PbBiSb phases



Unusually long tin whiskers photographed by ERA Technology Ltd

Design to avoid Tin Whiskers

- Follow iNEMI guidelines as far as possible
- Avoid components from sources you do not trust
- Avoid fine pitch terminations (if possible) – most whiskers are up to ~150µm in length
- Consider conformal coatings – even if whiskers form and break-through, they are unlikely to re-penetrate the coating on an adjacent termination
- Choose components that have been tested by the manufacturer
  - JEDEC test results should be freely available
- Remember that silver and zinc plating also produce whiskers
- If custom parts are to be plated with tin for corrosion resistance – use nickel barrier layer & matte tin

Replacements for Standard Solder

There is no "drop-in" replacement for standard tin/lead solder.
All lead-free alloys are different. (M.pt. = melting point)

Alloy composition	M.pt. °C	Comments
Eutectic tin/lead solder	183	Included for comparison. Good wetting and low melting temperature
Sn0.7Cu	227	Used for wave soldering applications (known as 99C), high melting temperature and wetting inferior to SnAg
Sn3.5Ag	221	Used as high temperature solder, wetting inferior to SnAgCu
Sn3.5Ag0.7Cu (and variations on this)	217	Most widely used lead-free alloy. Various percentages of silver and copper are used. Melting temperature 34°C higher than tin/lead and inferior wetting
SnAgBi alloys (some with Cu)	Ca. 210 -215	Better wetting properties than SnAgCu but must not be used with lead. Mainly used as solder pastes but has been used for wave soldering, mainly in Japan. Wire not available
Sn9Zn	198	Needs special flux and is susceptible to corrosion
Sn8Zn3Bi	Ca. 191	Used by several Japanese manufacturers where heat sensitive components are used. Difficult to use
58Bi42Sn	138	Low melting point, hard, brittle alloy

Reliability issues with lead-free solders

The main differences between lead-free and tin/lead alloys that need to be understood to avoid reliability issues are:

Higher melting temperature

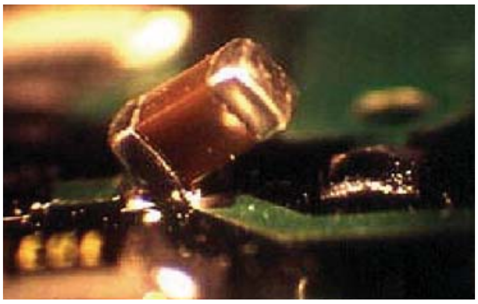
Lead-free alloy soldering temperature is higher (30°C - 40°C), which can lead to a variety of defects such as:

- Thermal fatigue of solder joints - not well understood, research is on-going
- Tin-whiskers from electroplated tin termination coatings - research is on-going
- Delamination of multi-layer PCBs
- Damage to plated through holes - especially with narrow holes in thicker laminate
- PCB warping - can damage components, cause open circuits, misalignment
- IC packages are more susceptible to “pop-corn” failure. The IPC/JEDEC-020B Moisture Sensitivity Level for components with lead-free soldering can be 1 or 2 levels lower.
- Damage to heat sensitive components. Processes improving but check upper temperature limit in manufacturers datasheet

Wetting

of most lead-free solders is inferior to tin/lead.

- Tin coatings behave differently to tin/lead, even with tin/lead solder
- Correct choice of flux important.
- It is more important with lead-free that component terminations and solderable surfaces are clean and oxide-free
- Use the correct temperature profile. If the temperature rises too slowly due to poor temperature control or insufficient power, surfaces will oxidise making solder wetting more difficult. Beware of too rapid temperature rise as this can damage some components and PCBs due to thermal shock.
- The surface tension of lead-free solders is higher than tin/lead solders. This limits solder spread as well as increasing the risk of “tomb-stoning”.



Example of tomb-stoning

Tomb-stoning can be prevented by alignment of the component perpendicular to the direction of the conveyer, using a paste with a wider pasty range, ensuring all surfaces have good solderability

Components: **Typical maximum temperatures**	
Aluminium electrolytic capacitor - max. temp. depends on size	240°C -250°C
Tantalum capacitor - various types	220°C -260°C
MLCC ramp rate more important	240°C -260°C
Film capacitor	230°C -300°C
Surface mount relay	226°C -245°C
Crystal oscillator	235°C -245°C
Connector - depends on type of plastic used	220°C -245°C
LED - may function but light output affected	240°C -280°C
Ball Grid Array & Chip Scale Packaged devices	220°C -240°C
Other ICs	245°C -260°C

Hand soldering

- This is relatively straightforward and trials with samples of wire are easy to carry out.
- Greatest difficulty is with large thermal mass components.
- Many lead-free SnCu, SnAgCu, SnAg wire products available.
- Alloys with bismuth not generally available as it is brittle and difficult to make into wire (can be made as “specials” but more expensive).
- Need slightly higher soldering iron tip temperature.
- More aggressive solders and fluxes will shorten tip life - 10°C rise could halve tip life.
- Longer pre-heat needed and wetting will take longer unless very high temperature is used.
- Older style soldering irons have poor temperature control - can result in overheating (large temperature cycle).
- New soldering iron equipment has much better temperature control
- “Lead-Free” iron tips available.
- Frequently too-high a temperature is used with SnPb for fast wetting - operators in these cases may be able to use the same temperature with lead-free wire.
- To find optimum tip temperature:- start at 350°C, reduce temperature until poor results occur then increase by 10°C (or increase until good results are obtained).

Wave soldering

- Lead-free solders can damage steel parts - contact machine supplier for advice.
- Higher temperature required.
- Need to choose suitable flux.
- Some components may be damaged if they pass through the wave.
- Drossing rate higher - consider using nitrogen over wave.
- Check bath composition initially, especially if some tin/lead terminated components used.

Surface mount

- Forced air convection heating needed for better temperature control.
- Minimise peak temperature with good temperature control and many heat zones. Ovens may need to be longer with throughput lower to achieve good results.
- A controlled cooling rate is advisable as some component coatings can crack if cooled too slowly. Too rapid cooling can damage certain brittle components such as MLCCs.
- Nitrogen helps but is not essential.
- Choose optimum paste by comparative testing with realistic test PCBs. Test each paste over an eight-hour shift. This can be carried with 12 PCBs:
- Print 4 (no kneading), then place components, measure tack on 2 of these.
- 1 PCB wait 1 hour then reflow.
- 1 PCB wait 3 hours then reflow.
- Wait 6 hours, then place components, measure tack, then reflow.
- Repeat with 4 more after 1 hour.
- Repeat tests.
- Repeat with 4 more after 1 hourRepeat tests.

Note:

Soldering iron tips have a shorter life with lead-free than tin-lead for three reasons:

1. Higher temperature increases tip coating dissolution rate
2. Lead-free uses more corrosive fluxes
3. The tip coating is iron and this reacts with tin faster (to form on intermetallic) than with tin-lead

PCB coatings

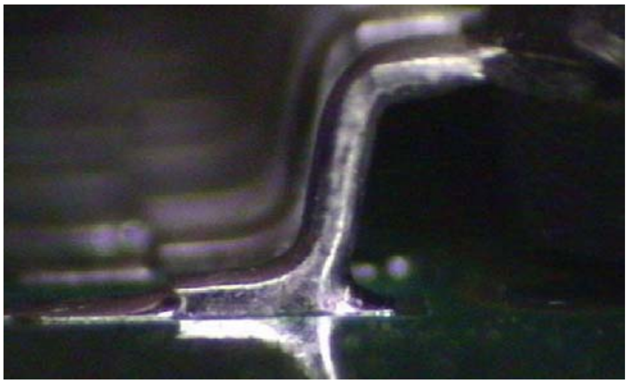
- traditional tin/lead hot air level (HASL) coatings cannot be used.

Alternatives include:

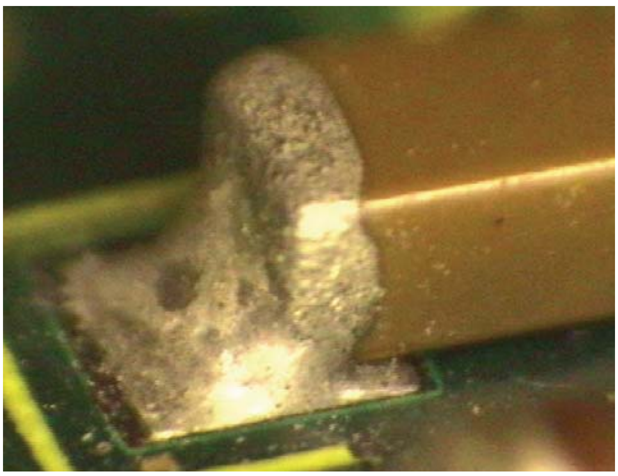
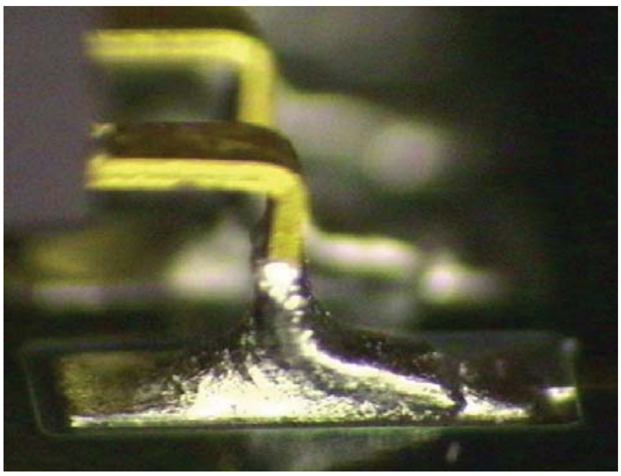
PCB Coating	Limitations
Lead-free HASL	Need new equipment, pre-bake boards
Nickel/gold (ENIG)	Gives good protection and solderability for up to 1 year but most expensive option
Organic solderability preservative	Low cost option, protection for up to 6 months, very easily damaged
Immersion silver	Good compromise but tarnishes (sulphides)
Immersion tin	Good compromise but deteriorates in warm or humid conditions

Inspection

Lead-free solder joints appear different to tin/lead and therefore training may be required so that operators can recognise good and poor solder joints. The criteria in IPC - 610C, although originally written for tin/lead should also apply to lead-free solder



Examples of tin lead solder joints

Examples of Tin/Silver/Copper solder joints

Rework and repair

Spare parts for the repair of equipment put onto the market before 1st July 2006 are not within the scope of the RoHS Directive. Therefore these spares may legally contain the six restricted substances. By inference therefore, spare parts used for the repair of equipment put onto the market after this date, must not contain restricted substances.

The same types of rework tools that are used for tin/lead can be used for lead-free solders. It is advisable however to avoid mixing alloys so wherever possible, repair using the same solder as was originally used. Some combinations can give very poor reliability, in particular lead and bismuth.

The temperature will need to be high so there is a greater risk of damage to heat sensitive components and the PCB, including high aspect ration plated through holes.

More aggressive fluxes may be required. These can cause SIR, corrosion and dendrites problems.

No.	Defect	Cause	Solution
1	Poor wetting	i. Unsuitable flux ii. Surfaces oxidised or contaminated	i. Use different flux ii. Ensure surfaces are clean and oxide free - do not use parts beyond their use-by dates Rotate stocks of components and PCBs iii. Use equipment with better temperature control
2	No wetting	Part not hot enough Insufficient heating power for part to reach solder melting temperature in a short enough time.	Use equipment with good temperature control and sufficient power
3	PCB delamination	Moisture within laminate and incorrect temperature profile	Increase pre-heat time/temp. to dry PCB before reflow
4	PCB warping	High reflow temperature	Reduce reflow temperature Use high Tg laminate Re-design to eliminate stresses during reflow
5	Pop-corning	Moisture within package	Check moisture sensitivity level of component for lead-free processes. May need to store in dry environment or bake before use.
6	Cracked PTH	Stresses on copper due to high TCE of laminate. Drilling defects increase risk	Re-design with thinner laminate, larger diameter PTH, increase copper thickness, use low z-axis TCE laminate. Replace drill bits more frequently
7	Damaged components	Exceeded maximum temperature	Use alternative components if available Re-design to avoid heat sensitive components Use lower reflow temperature (may need new equipment)

Trouble shooting guide continued

No.	Defect	Cause	Solution
8	Shorts on PCB (bridging)	Lead-free solders have higher surface tension than lead solder	Use hot-air knife after reflow Increase time above solder melting temperature Use different flux
9	Excessive number of solder balls	Incorrect solder reflow profile, incorrect flux	Modify profile, use more active flux
10	Voids in solder joints	Trapped gas from coatings or flux	Increase time of pre-heat and time above solder melting temperature.
11	Solder bonds fracture easily after reflow	Thick and brittle intermetallic layer formed	Decrease maximum temperature and time above solder melting temperature. Use nickel barrier layer under solderable coating
12	Short circuits occur in field	i. Tin whiskers form after period in service ii. Dendrites	i. Specify coatings with low susceptibility to tin whiskers ii. Use less active flux or clean to remove flux residues.
13	Open circuits occur in field due to thermal fatigue	i. High strain on solder joints ii. Poor solder wetting	i. Redesign to minimise joint strain. ii. Improve wetting - see 1.

EU RoHS and the so-called China RoHS legislation have a number of similarities and differences. These are summarised in the following table:

Characteristic	EU RoHS	China RoHS
Legislation adopted	13th February 2003	26th February 2006
Entry into force	1st July 2006	1st March 2007
Scope	Eight broad categories of finished products. Individual product types are not specified and legislation leaves interpretation to producer	All Electronic Information Products (EIP). Extensive list published which includes many products not covered by EU RoHS such as radar attached to aircraft or ships, medical equipment, measurement instruments, some production equipment, batteries and most types of components
Main requirements	Six RoHS substances must not be present in homogeneous materials, at above the maximum concentration values, unless covered by an exemption	Two levels of requirements: All EIPs must be marked to indicate whether any of the six substances are present. Products that will be specified in a catalogue – substance restrictions will be specified and these may be some or all of the six EU-RoHS substances and possibly others
Restricted substances	Lead, cadmium, mercury, hexavalent chromium, PBB and PBDE	As for EU RoHS, with the possibility of others being added
Marking requirements	None. Related WEEE Directive requires use of the crossed wheelie bin symbol to indicate to users that product should be recycled at end of life.	Pollution control mark (also indicates recyclability). If no RoHS substances present (same six as EU RoHS except Deca-BDE), use: If a RoHS substance present in at least one material, use: The number within the mark is Environment Friendly Use Period (in years) Table is also required if a RoHS substance is present; this constituent lists “parts” and which RoHS substances each contains
Sources of details of legislation	Published EC and member state guidance and some Commission Decisions	Chinese Standards to be published by Chinese Government and some Q & A from MII (Ministry of Information Industry)
Maximum concentration values	In-scope products must contain less than: 0.1% for all except Cd which is 0.01%. All are by weight in homogeneous materials (unless covered by exemptions)	Marking with a table and the orange logo if concentrations of Pb, Hg, Cr(6), PBB or PBDE are >0.1 % or >0.01 % of Cd by weight in homogeneous materials, except for metal coatings where RoHS substances must not be intentionally added and parts of 4 mm^3 or less regarded as single homogeneous materials
Exemptions	29 so far and will continue to grow	All EIPs – none Will be specified in catalogue for listed products
Approach to compliance	Self declaration, third party testing not required	Self declaration for marking of all EIPs Testing by authorised laboratories in China of catalogue listed products
Packaging	Not included as covered by the Packaging Directive	Must be marked to show materials content, not contain toxic substances and be recyclable
Batteries	Not included as covered by Batteries and Accumulators Directive	Included as these are EIPs
Non-electrical products	Excluded if the finished product sold to user does not depend on electricity for its main function	Included if listed as EIPs. Includes CDs and DVDs
Military and national security use only	Excluded from scope	Excluded from scope
“Put onto the market”	When individual item is available for sale within EU and transferred to distribution	Applies to production on or after 1 March 2007. It must be marked thereafter

China:

China has legislation widely referred to as "Chin-RoHS" which came into effect on 1st March 2007 and applies to a very wide range of electrical equipment sold in China. There are similarities with EU-RoHS but also significant differences. China RoHS has two main phases.

Phase 1 - this started on 1st March 2007 and requires all electrical information products (EIPs) to be marked. There are no substance restrictions in phase 1 but the following information is required:

- Pollution control label which indicates if any RoHS substances are present at concentrations above the maximum concentration limit. If none are present, the symbol (normally green) has "e" in the centre. If at least one is present then a number is printed in the centre of the label (normally orange) which is the "environmentally friendly use period" or EFUP. This is effectively the "safe use" life of the product, in years, including time following repairs and refurbishment.
- If a RoHS substance is present, then a table of hazardous substances needs to be printed in the instruction manual. This must be in Chinese and indicates which RoHS substances are present and in which part of the equipment. This is to help with the recycling process at end-of-life.
- The product packaging requires a label that lists the codes for all of the main packaging materials used.
- Phase 2 – will start when the Chinese authorities publish a catalogue of products that will be subject to substance restrictions (initial product listing expected late 2008). The catalogue will specify:
- The specific products that will have restrictions imposed and the date when these take effect
- The substances that are restricted (could be the EU-RoHS 6, or others) and any exemptions (likely to be similar to EU-RoHS)
- Procedure for demonstrating compliance. All catalogue listed products must be certified by approved Chinese test laboratories before they can be sold.

South Korea:

Korea has adopted the "Act for Resource Recycling of Electrical & Electronic Products and Automobiles". This legislation is the Korean equivalent of EU-RoHS, EU-WEEE and the EU-ELV directives, but there are differences.

- Revised date of enforcement is now 1st July 2008 for new products manufactured after that date. Products manufactured prior to that date will be subject to duty, but not until 1st January 2011.
- The Korea RoHS scope will initially be restricted to consumer and some office equipment made in large quantities such as mobile phones, air conditioning, computers and refrigerators.
- The Korean Government recently announced that the substance restrictions will be the same as EU-RoHS, with similar exemptions.
- As in the EU, Korea-RoHS compliance is by self-declaration, but manufacturers and importers will be required to make declarations of compliance on a Korean Government website.

Australia:

The Australian Government has sponsored several studies into the possibility of RoHS legislation. The consultants used have considered three approaches. These were a choice of no government intervention, a voluntary code of practice plus some associated legislation, or national legislation.

They found that no government intervention would be the cheapest and about half of manufacturers will become RoHS compliant anyway. Interestingly, the consultants found that the reduction in levels of hazardous substances would be similar for the voluntary approach as with national legislation.

There is no certainty that Australia will impose legislation although, if it does, it is likely to be similar to EU-RoHS.

Meetings late in 2007 concluded that there was a general agreement on a voluntary approach without government legislation.

Taiwan and Thailand:

Taiwan was one of the first countries to adopt electrical recycling legislation but has no substance restrictions at present. However, this is being considered and although no drafts are available yet, it could well be similar to EU-RoHS.

Please note:

The information contained in this guide is of a general nature and is not intended to address the circumstances of any particular individual or entity. Although we endeavour to provide accurate and timely information, there can be no guarantee that such information is accurate as of the date it is received or that will continue to be accurate in the future. No one should act on such information without appropriate professional advice after a thorough examination of the particular situation.

Written in collaboration with ERA Technology Ltd - (www.era.co.uk/rfa)

May 2008