Welding Technology Institute of Australia ABN 69 003 696 526	**Lead-free Soldering**	**TGN-MS-05** **Rev: 0** **Date: 21 April 2006** **Pages: 4**

1. INTRODUCTION

The Electrical and Electronic Equipment (EEE) manufacturing industry of is one of the fastest growing industry sectors in the world. New applications of EEE are increasing significantly and this has lead to an important increase in EEE waste, which in turn results in increasing problems in relation to waste management. The EEE waste stream consists of a complex mixture of materials and components.

2. INTERNATIONAL ACTION

The European Commission adopted two proposals in June 2000:

- A directive on Waste Electrical and Electronic Equipment (WEEE), which aims to control the generation of EEE wastes, increase reuse and recycling and to reduce the environmental burden associated with end-of-life treatment. The directive requires producers of EEE to take back end-of-life consumer products.
- Restriction of the use of certain Hazardous Substances in Electrical and Electronic Equipment (RoHS), whereby Member States must ensure that the use of lead, mercury, cadmium, chromium and two flame retardants, polybrominated diphenyl ethers (PBDEs) and polybrominated biphenyls (PBBs) is banned by 2006.

3. LEAD-FREE LEGISLATION

The most controversial issue related to the RoHS directive is the decision to ban lead in solders used for printed circuit boards (PCBs), since all available scientific evidence indicates that the lead used in printed circuit board manufacturing and electronic assembly produces no significant environmental or health hazards. Although medical devices that are implanted, such as that shown in Figure 1, are currently not covered under WEEE or RoHS, it is expected that this will change as the reliability of lead-free soldered connections is developed.

Figure 1: Medical device containing electronic components.

4. SOLDER ALLOY SELECTION

Any prospective replacement solder alloy for SnPb solder must meet certain requirements if it is to become an effective substitute alloy. The required alloy properties include:

- Mechanical properties similar or better than those of tin/lead alloy;
- Electromechanical properties similar or better than those of tin/lead alloy;
- Physical properties similar or better than those of tin/lead solder i.e. density, coefficient of thermal expansion, etc.
- Melting temperature of the alloys, preferably similar to the tin/lead binary eutectic temperature.
- The replacement for lead should be readily available in sufficient quantity to meet demand;
- The replacement alloy should have a low/similar cost to the current solder cost;

- Ability to be prepared into different forms, i.e. paste, bar, cored wire, etc.;
- Adequate wetting capability with common PCB and component finishes;
- Ability to wet materials such as tin, gold, copper, kovar, nickel, etc.;
- No toxic elements should be incorporated;
- Long shelf life (stability of the alloy during storage);
- Ability to operate over a large temperature range;
- Good printing and dispensing ability (rheology of solder paste);
- Solderable using the same equipment as used for Sn/Pb solders;
- Compatibility with flux and plating systems;
- Low dross formation when used in wave soldering operations.

5. CANDIDATE LEAD-FREE SOLDERS

No material has yet been found that meets all of the requirements, and therefore, selection has been based on compromises specific to the particular application needs. Candidate alloys tin-silver-copper (SnAgCu) and tin-copper (SnCu) are generating the most interest. Small quantities of other elements such as Bismuth may be added to improve certain characteristics.

5.1 Characteristics of Tin Lead Solder

63% Tin-37% Lead alloy is eutectic solder because when the temperature is raised to 183°C, its state changes from solid to liquid for the entire volume. On cooling back down to 183°C, a solid alloy joint is formed instantly. The eutectic behaves exactly like a pure metal having a definite solidification temperature and a specific heat of fusion. Eutectic Tin-Lead solder exhibits only small symmetric pasty regions (mix of liquid and solid) even at 5% composition variations.

5.2 Characteristics of Tin Silver Copper Solders

Tin-Silver, Tin-Copper, and Tin-Silver-Copper alloys have eutectics above 217°C but reflow can be performed at 235°C. They can form very large, asymmetric pasty zones for very small deviations from precise percentage composition, making them more susceptible to disturbed solder and other reflow process-related defects. This translates into open (cold) and/or high-resistance joints. The alloy is available at reasonable cost and the properties of this solder are promising. A comparison of pasty zones for various alloys is shown in Figure 2.

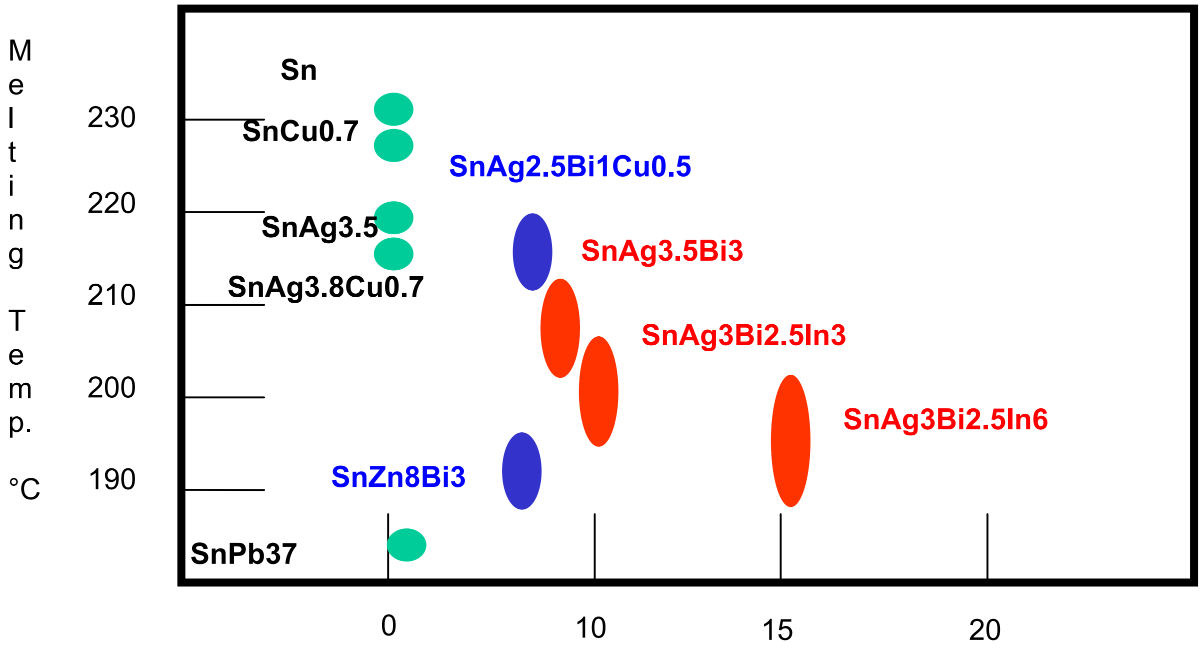


Figure 2: Apparent pasty ranges of alloy solders

6. FLUXES

The flux has an effect on the printability and shelf life of solder pastes. Most fluxes are compatible with lead-free soldering processes, although further development may be required for fluxes that start to react at higher temperatures. “No-clean fluxes” are one of the most popular options to save the cleaning step. This option can save substantial money, but some damage to boards may occur due to residual flux.

7. LEAD-FREE FINISHES ON BOARD AND COMPONENT

Most component and board suppliers can now supply products with lead-free finishes. For boards the most common are based on:

7.1 Metallic finishes

Precious metal based
- AuNi or PdNi
- Ag

Pure Sn
- Immersion Sn

Sn based alloys
- SnBi
- SnAg
- SnCu

7.2 Organic coatings

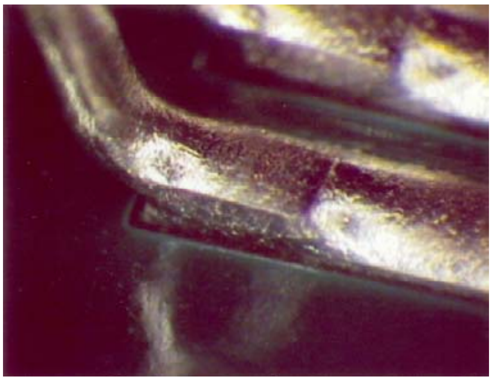
Immersion Sn is emerging as the most likely replacement. However when a long shelf life is required, it is advisable to use gold flash over nickel plating. Some of the finishes or solders may have improved results when processed under nitrogen. One of the major problems for lead-free soldering was the lack of availability of lead-free finishes on components. This has changed over time with most suppliers now offering Sn based or NiPd finishes. Differences between finishes on components and boards are of concern. Incompatibility of finish and solder may be responsible for metallurgical problems, resulting in failures such as dewetting or formation of unwanted intermetallics due to diffusion. An example is the low melting point eutectic (~95°C) that may be formed between bismuth and lead.

8. LEAD-FREE PROCESSING ISSUES

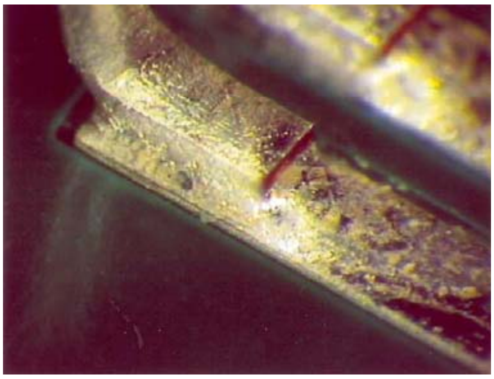
The higher temperature of the soldering process that may be necessary for lead-free soldering may be incompatible with some board materials, components and equipment. Process temperatures will be increased (e.g. 20-40°C) due to the higher melting point of the lead-free solders.

8.1 Inspection

Wetting – lead-free solders have higher contact angle (poorer wetting) as shown in Figure 3.



Weaker flux nitrogen



Stronger in air

Figure 3: In comparison to Sn/Pb solder (LHS), Pb-free alloy solder (RHS) exhibits a dull, rough surface

Void levels can be significantly higher in Pb free joints, Figure 4, although there does not appear to be any loss in mechanical strength.

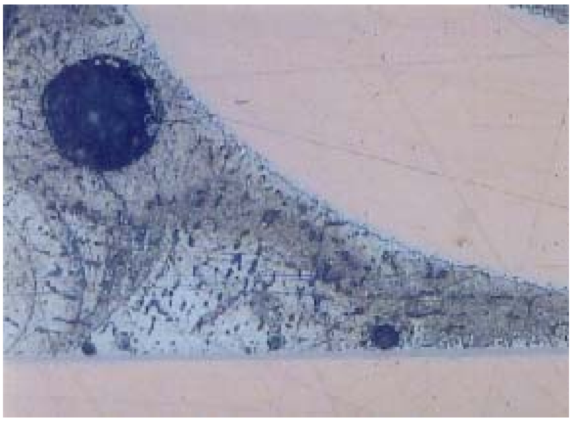


Figure 4: Typical void in Pb-free soldered joint

8.2 Tin Whiskers

A large area of concern with the use of tin-plated or pure tin component finishes is the occurrence of tin whiskers. This condition arises when tin begins to grow tiny filaments known as whiskers, as shown in Figure 5. A tin whisker is a spontaneous columnar or cylindrical filament, which can branch, of mono-crystalline tin emanating from the surface of a plating finish. Tin whiskers generally have a high aspect ratio (length/width); whiskers have been found to be over several mm in length. The whiskers can be kinked, bent, or twisted and may be surrounded by striations/rings. These whiskers are very brittle therefore can lead to intermittent or permanent electrical shorts when broken and re-deposited upon the circuit's surface.

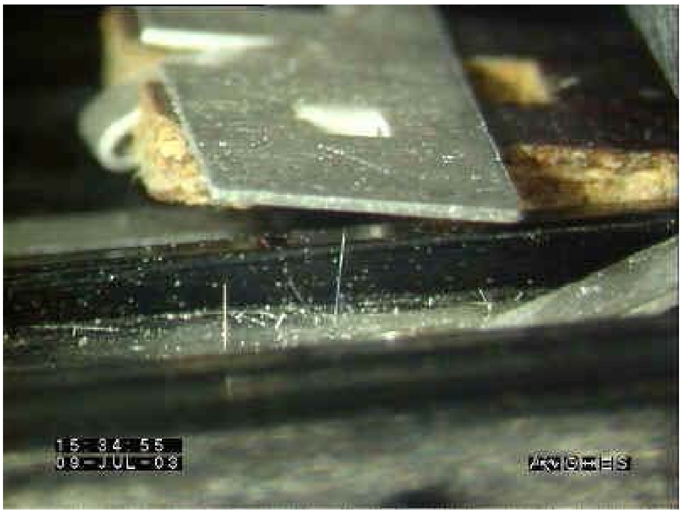


Figure 5: Tin whiskers on circuit breaker (Source NASA)

Ways of avoiding whiskers in actual field applications include:

- Not using pure tin, especially in a 'brightened' format;
- Reflow of the tin plating to re-fuse/re-crystallize and stress-relieve the deposit;
- Using barrier materials (over-plating or organic post-coatings) to encapsulate any whiskers which have formed since completion of the plating.

9. ACKNOWLEDGMENT

WTIA wishes to acknowledge the contribution of the WTIA Medical Devices and Sensors Industry Specific Group.

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NDNP TECHNOLOGY DIFFUSION ACTIVITY # 27	WTIA Welding Technology Institute of Australia ABN 69 003 696 526 **NATIONAL DIFFUSION NETWORKS PROJECT TECHNOLOGY QUESTIONNAIRE** **Medical Devices and Sensors Group** **"Lead-free soldering"**	**Document No:** 9.4.7QR-0001 **Revision No:** Rev 0 **Page 1 of 2** **Date:** 24 April 2006

As part of the WTIA National Diffusion Networks Project, the Medical Devices and Sensors Industry Sector has identified the need to understand the transition to reliable lead free soldering. The WTIA has prepared a Technical Guidance Note "Lead-free soldering" to explain the legislative changes occurring with regard to lead-tin solders and requirements for the selection of suitable alternative solder alloys. As a valued technology expert in this area we would like you to be part of the Technology Expert Group to review this Note. Please complete this questionnaire so that we can gauge the success of meeting this need.

Objective 1: Identify the need to identify reliable lead free solders

Traditionally electrical solders have been based on lead and tin. With international legislation currently phasing out lead for such applications there exists a need to guide the electrical industry in the selection of alternative alloys that provide the same ease of application and reliability of operation as the traditional lead-tin solders. This guidance note is intended to provide the Medical Devices and Sensors Industry with such knowledge. How well does the document explain tack welding of reinforcement bar?

poor ☐ average ☐ good ☐ very good ☐

Comments: ______________________________

Objective 2: Identify appropriate technology receptors in the Medical Devices and Sensors Industry

This document was written for designers and engineers in the Medical Devices and Sensors Industry. Are these people the appropriate individuals we should be targeting?

yes ☐ no ☐

What other types of companies and/or personnel do you suggest we target? ______________________________

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Objective 3: Identify current best practice for tack welding of reinforcement bar

The document was written to reflect current best practice for lead free soldering. Do you envisage opportunities for the use of this technology in the industry?

yes ☐ no ☐

If yes, what and where, if no why not? ______________________________

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Objective 4: Is the information provided clear, concise and accurate?

yes ☐ no ☐

If not, why? ______________________________

Objective 5: Broad dissemination of technology to the Medical Devices and Sensors Industry

Please indicate how best to disseminate this Technical Guidance Note to the appropriate Medical Devices and Sensors Industry Recipients

Free Website Download ☐ Poster ☐ Pocket Guide ☐ Pamphlet ☐

If poster, what size? A1 ☐ A2 ☐ A3 ☐ Laminated ☐ What selling price? $

If a pocket guide, what selling price? $

Other format? ______________________________

Objective 6: Continuous Improvement

Please Identify areas where the document can be improved or return the document with your recommended additions/amendments. Alternatively, please use the area below to provide any additional comments.

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