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Lead-Free Solders: A Status Update for Hi-Rel Printed Wiring Assemblies

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Eutectic Tin-Lead Solder

- Eutectic tin-lead solder (Sn63Pb37-M_p 183°C) has been widely used in electronics for decades
- Its mechanical and electrical properties are well understood
- Reliability issues of this material are also well understood

Problems with Lead (Pb)

- Lead, like other heavy metals, presents toxicological problems and is considered dangerous to human health
- Over the years, its use has been banned in a variety of products
  - Lead pigments in paints and coatings banned in 1977
  - Tetraethyl lead banned completely in 1987

Question?

- It is a fact that the amount of lead used in electronic products is minuscule compared to its use in other products, e.g., batteries
- So, the question is posed:

  Should lead now be banned in electronic products?

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Issues with Lead

- Psychological-sociological: Perception issue-if lead is perceived as detrimental, pressure will grow for its elimination
- Political: Will use of lead in electronics eventually be legislated as ozone depleting chemicals were (e.g., CFCs, TCA)?
- Supply: If production is halted, supply will become limited, necessitating using alternatives
- Human Health and environmental: Are the alternatives to lead as harmful or even more harmful?

Technical Issues

- In addition to the issues alluded to, technical issues also exist regarding the feasibility of using lead-free solder pastes to create electrical interconnections
- Finding a suitable candidate that can create electrical interconnections that are as reliable or more reliable than those made with eutectic SnPb

NASA NEPP Project

- Because of the potential adverse impact on the continued use of lead, the National Aeronautics and Space Administration (NASA) funded a project to search for acceptable candidates as replacements for tin-lead solder
- Presently the project consists of two Phases

Phase I Objectives

- Determine which lead-free solder alloy (paste, bar, and wire form) is capable of providing the most reliable electronic interconnections at the printed wiring board (PWB) level on electronic hardware intended for NASA space applications
- The lead-free solder alloys chosen for this investigation were
  - **Sn96.5Ag3.5**
  - **Sn95.5Ag3.8Cu0.7**
  - **Sn96.2Ag2.5Cu0.8Sb0.5 (Castin®)**
  - **Sn77.2In20.0Ag2.8 (Indalloy 227®)**

Possible Problems

- Processing temperatures (of SnAg(CuSb) alloys) are higher (app. 240-250°C) than those used for Sn63Pb37 (215-220°C), which may lead to
  - Delamination of board materials
  - Detrimental performance of components
- Sn whiskers
  - High Sn content of most Pb-free alloys may result in whiskers
- Interaction with Pb (component finishes, PWB)
  - Possible formation of embrittling phases
- Rework

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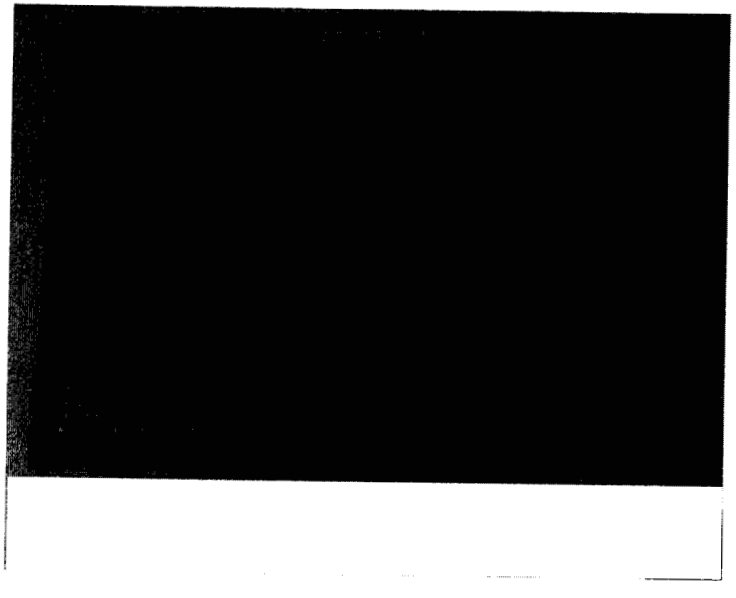
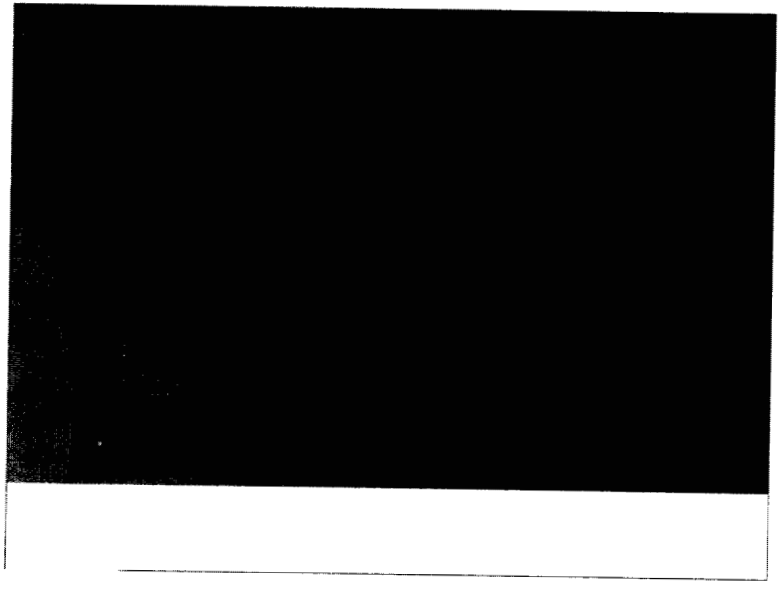
View of Test PWB



Bottom view



Top view

Fabrication Test Plan

- 2 PWBs were assembled using each of the solders
  - **Vapor phase reflow (2 reflows performed)**
  - **Due to the higher melting point of the Pb-free alloys, a perfluorinated liquid having a boiling point of 240°C was utilized**
  - **PWBs were acquired with a NiAu finish (ENIG)**
  - **Most components had a SnAg finish. The BGAs had a eutectic SnPb finish**
- SAM (performed before and after surface mount assembly) used to determine whether there were delamination problems within the boards due to the higher processing temperatures

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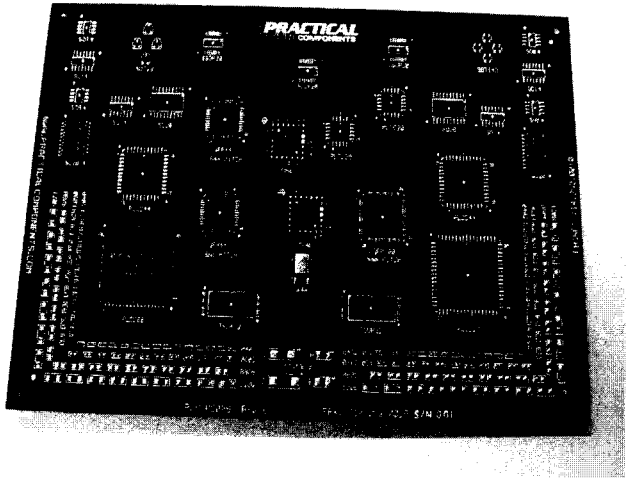
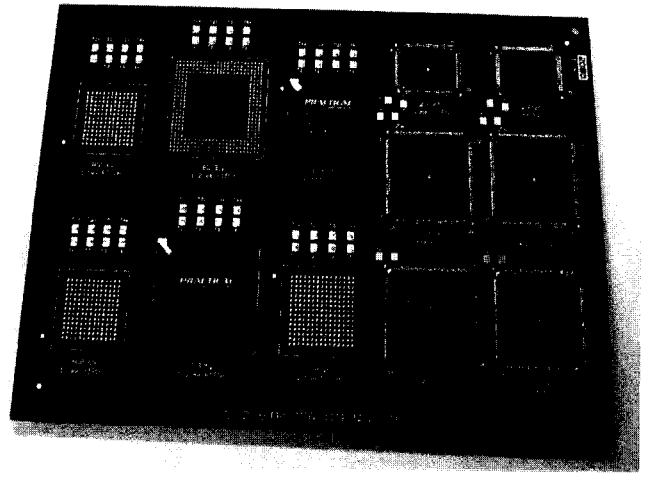
View of Assembled PWB*



Bottom view



Top view

*** Assembled with Sn95.5Ag3.8Cu0.7**

Phase II Objectives

- Two lead-free solder pastes selected for Phase II
  - Sn95.5Ag3.8Cu0.7
  - Sn96.2Ag2.5Cu0.8Sb0.5 (Castin®)
- Four PWBs per paste were assembled + four using eutectic SnPb as controls
- Subject the PWAs to thermal cycling using the military cycle –55 °C to 125°C
- Monitor the PWAs for continuity

Results to Date (1)

- Visual inspection and x-ray
  - The solder flow appeared good except that lead-free solder joints appear grainier than SnPb joints
  - The solder joints containing indium appeared even more grainy

Results to Date (2)

- Scanning acoustic microscopy (SAM) showed
  - No signs of PWB delamination after exposure of PWBs to higher processing temperatures (240°C)
  - Some of the plastic BGAs did show signs of delamination

Conclusions

- The lead-free pastes had no printing problems
- Grainy solder joints will necessitate training QA/inspectors to become accustomed to these new solder joints
- Very low levels of ionic cleanliness levels on all printed wiring assemblies processed with lead-free pastes (acceptability limit is 1.55 $\mu g/cm^2$ per total assembly area)
- No opens after reflow per daisy-chain continuity measured in the BGAs after reflow

Summary

- Use of lead-free pastes to assemble PWBs is feasible notwithstanding the higher processing temperatures
- During Phase II thermal cycling will be used to further assess the reliability of solder joints created with lead-free solders
- Technically, it appears feasible to find a suitable alternative to replace SnPb in hi-rel applications