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CHOOSING THE RIGHT LEAD-FREE SOLDER FOR HI-REL PRINTED WIRING ASSEMBLIES

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BACKGROUND

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- The use of lead in electronics has come under increasing scrutiny. Given the trends in both Japan and Europe, it is highly likely that the U.S. will be driven by commercial interests to phase out of lead in electronics usage.
- This paper presents data collected on a recent NASA project to focus on finding suitable alternatives to eutectic tin-lead solders and solder pastes. The first phase of this project dealt with determining the most feasible candidates to replace tin-lead and to determine suitable processing operations in assembling Pb-free printed wiring boards.

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KEY WORDS AND PHRASES

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- Printed wiring assembly (PWA)
- Printed wiring board (PWB)
- Eutectic tin-lead (Sn63/Pb37)
- Lead-free process (LFP)
- Surface mount technology (SMT)
- Solder paste
- Rosin mildly activated (RMA)

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TASK DESCRIPTION

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- 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 level on electronic hardware intended for NASA space applications

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GOALS/OBJECTIVES

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- Make industry contacts and assess work-to-date (done)
- Choose four Pb-free pastes for assembly processing (done)
- Choose and assemble 8 boards* for initial evaluation of solders. (done)
- Based on results of initial processing, narrow down to two pastes (in progress)
- Characterize solder joints on assembled boards using microstructural techniques (in progress)
- Assemble SMT devices onto boards using the two Pb-free solder pastes (4 boards per paste + 4 boards with eutectic Sn-Pb as a control) (next FY)
- Perform temperature cycling followed by a second set of microstructural characterization experiments (next FY)
- Rework selected boards to validate reworkability of pastes (next FY)
- Perform second set of temperature cycling tests followed by characterization (next FY)

* 25 boards procured.

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DELIVERABLES

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- PWBs assembled using lead-free solders
- NASA Technical Report summarizing findings, including results of reliability testing as well as processes used to create reliable Pb-free soldered PWBAs

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Table: Lead-free Solder Alloys for Test

Composition	T_m (°C)	Advantages	Potential Issues
1) Sn96.5Ag3.5 (eutectic)	221	a) Good wetting characteristics and superior joint strength compared to Sn/Pb solder b) Long history of use	a) May exhibit structural weakness at solder connection b) High T_m
2) Sn95.5Ag3.8Cu0.7	217-218	a) Recommended by NEMI b) Virtually no plastic range c) Rapid solidification avoiding formation of cracks d) Formation of intermetallics $Cu6Sn_5$ and Ag_3 Sn provide greater strength and fatigue resistance than Sn/Pb solder	a) High T_m
3) Sn96.2Ag2.5Cu0.8Sb 0.5 (Castin®)	217-218	a) Addition of Sb improves thermal fatigue b) Solder coating offers flatter pads and uniform coat c) Works well with Ni/Au Ag/Pd and OSP boards d) Sb slightly reduces melting temperature and refines grain structure	a) Sb trioxide may exhibit toxicity at higher temperatures b) High T_m
4) Sn77.2In20.0Ag2.8 (Indalloy 227®)	175(T_S)-187(T_L)	a) Compatible T_m to Sn/Pb b) Good ductility, strength and creep resistance c) Low dross in wave solder	a) Supply and cost may be prohibitive factors in its use. b) 118°C eutectic point may deteriorate mechanical properties of solder joint c) Large plastic range

SCHEDULE

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Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

Major Milestones	FY02	FY03	FY04
Identify and characterize best potential candidates for creating lead-free electrical interconnections			
Document assembly-level process for new lead-free solders			
Validate processes through thermal cycling and failure analysis			
NASA technical report that summarizes evaluations and recommendations, based on our test results regarding the use of lead-free alloys for soldering of board level devices.			

- **Deliverables and major milestones shown in Gantt Chart.**

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MAJOR ACCOMPLISHMENTS

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- 4 Pb-free pastes* used to assemble PWBs
- 8 boards assembled; 2 boards per paste
- Bench-top reflow unit (on loan) + perfluorinated liquid for unit received and utilized in assembly
- Ordered 6 lb. of Sn-Ag bar solder for tinning component leads
- Presentations made at NEPP Workshop in Houston and So. CA IMAPS in May
- Scanning acoustic microscopy analysis performed on test boards and components for ascertaining if damage occurs to boards during processing

* (1) Sn96.5Ag3.5 (eutectic T_m 221°C)
(2) Sn95.8Ag3.5Cu0.7 (near eutectic T_m 217-218°C)
(3) Sn96.2Ag2.5Cu0.8Sb0.5 (near eutectic T_m 217-218°C)
(4) Sn77.2In20.0Ag2.8 (solidus 175°C/liquidus 187°C)

COMPONENTS MOUNTED ONTO PWB

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

Double-sided test PWBs with footprints for various chip components and IC packages, including BGAs, were assembled. The BGAs were daisy-chained.

Component package types used were as follows:

- Chip resistor, 0603 package (24 each per board)
- Chip resistor, 1206 package (18 each per board)
- SOT 23 package (2 each per board)
- SOIC20 package, 50 mil pitch part (2 each per board)
- PLCC68 package, 50 mil pitch part (1 each per board)
- QFP100, 25 mil pitch part (1 each per board)
- QFP208 package, 20 mil pitch part (1 each per board)
- BGA225 full array package, 1.5 mm ball pitch (1 each per board)
- BGA352 area array package, 1.27 mm ball pitch (1 each per board)

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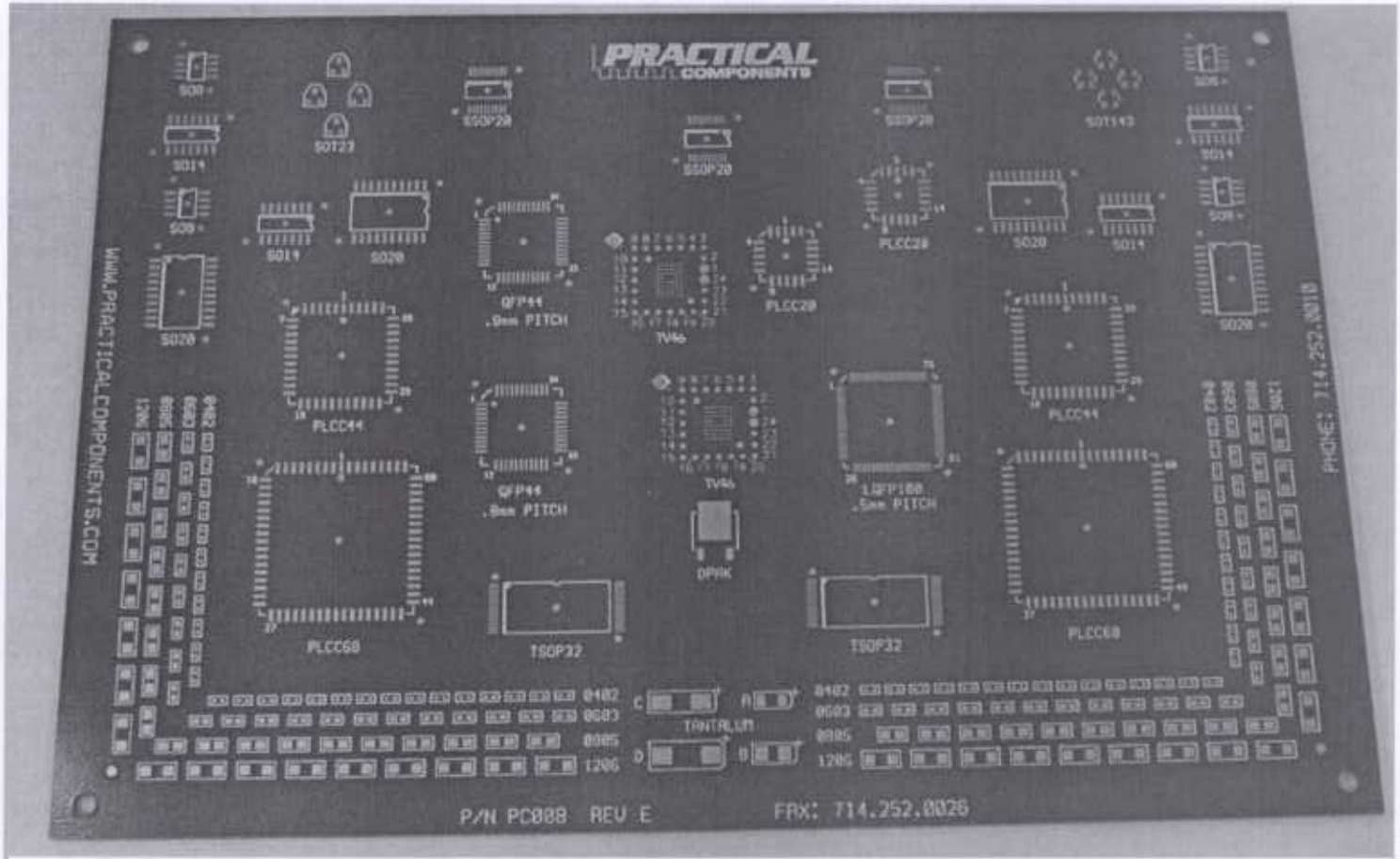
TEST PWB-SIDE 1

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies



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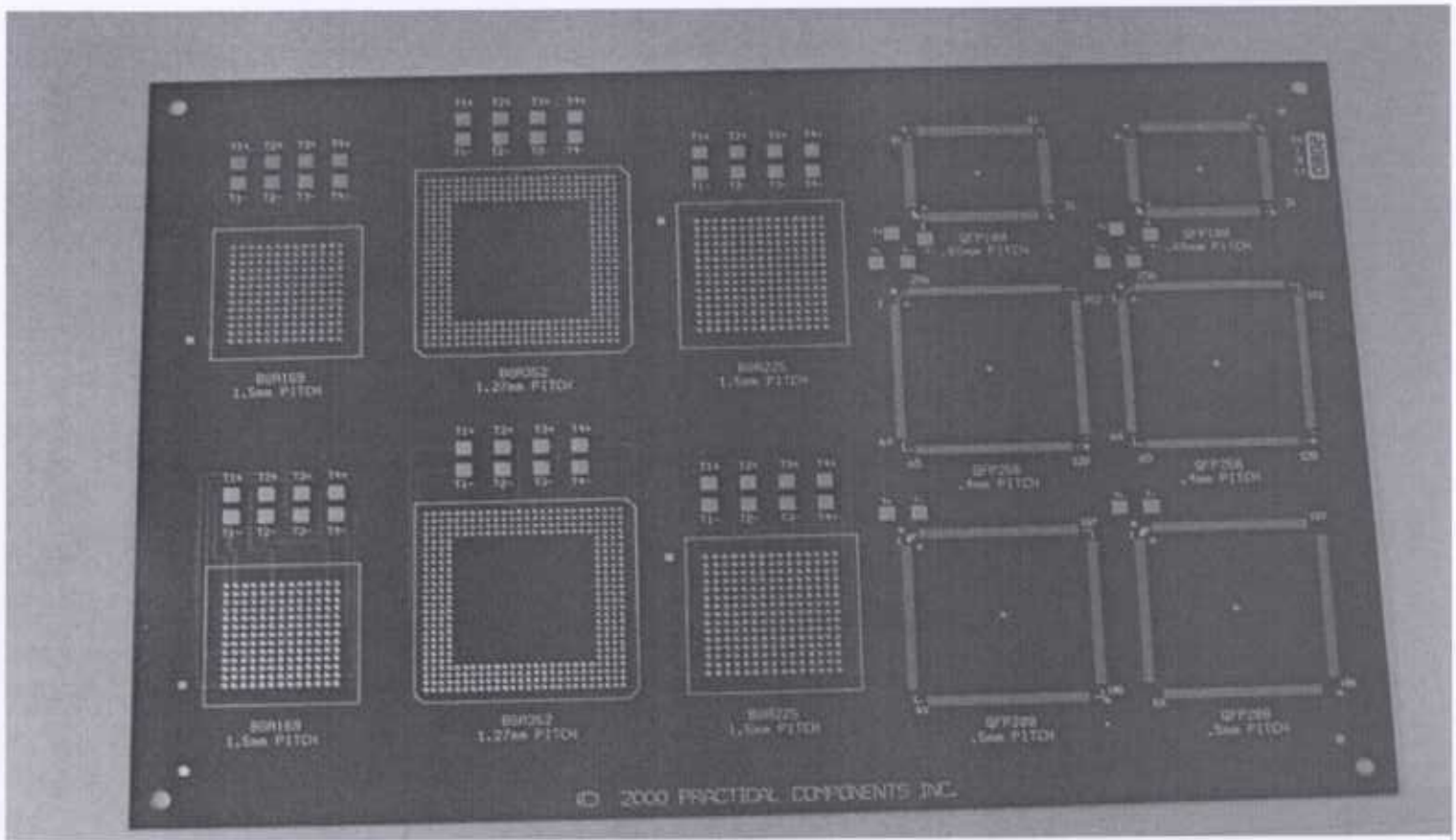
TEST PWB-SIDE 2

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies



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CONCLUSIONS

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- No problems were encountered during the printing process with lead free paste. The printing was uniform for all PWBs.
- A longer delay was required for the first three pastes during the reflow process. This was due to the higher melting temperature of the solders.
- Although the solder fillets appeared to be generally good, the solder joint appeared grainier than those formed by Sn63/Pb37 solder.
- The daisy-chain continuity measured after reflow was same as that prior to the reflow, meaning there was no opens after reflow.
- In the upcoming Phase II tests, several PWB assemblies will be built using the Pb-free pastes and the PWAs will be subjected to thermal cycling and vibration tests.

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PLANS FOR NEXT FY

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- Scanning acoustic microscopy analysis to check for board delamination (which may occur due to 30°C higher processing temperatures)
- Continue investigating tin-whisker issue with the four selected alloy materials
- Begin steps to down select to two alloy candidates
- Present a paper at the SMTA Conference in Rosemont, IL in Sept. and present at the UC SMART Workshop at UCLA on Pb-free Solder for Electronics in Sept.
- Most likely candidates are:

  (1) Sn96.5Ag3.5 (eutectic T_m 221°C)

  (2) Sn96.2Ag2.5Cu0.8Sb0.5 (near eutectic T_m 217-218°C)

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PROBLEMS AND CONCERNS

Pb-Free Solder for Hi-Rel Printed Wiring Assemblies

- Lack of adequate reliability database for Pb-free solders
- Will Pb-free solders provide same level of reliability as eutectic tin-lead?