Department of Mechanical Engineering
University of Massachusetts, Lowell

Lead Free Soldering Materials, Reliability and Process Optimization

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Project Team
UMASS Lowell-Industry Lead Free Consortium

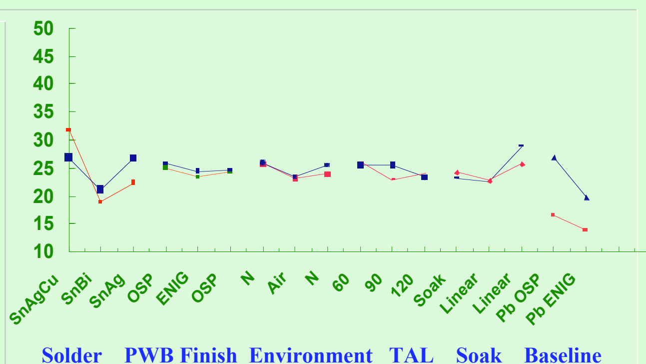
- **Dept. of Mechanical Engineering, University of Massachusetts, Lowell.**
- **L. Harriman, C. Pace, TURI/CEAM**
- **K. Walters, BTU International**, North Billerica, MA.
- **Roberto Pilotto,** Hadco Corporation, Ward Hill, MA.
- **D. Pinsky, Raytheon Corporation**, Lexington, MA.
- **George Wilkish, and Anderson, Richard** , Tyco Electronics, MA/COM, Lowell MA
- **D. Abbott, Texas Instruments**, Attleboro, MA.
- **Richard McCann** , Analog devices, Wilmington MA
- Indium Solders, Air Products and Aim Solder.

Project Team
UMASS Lowell-Industry Lead Free Consortium

Project Accomplishments 2000

- Form the team and plan the project
- Manufacture Lead Free PWB's with Pb Baseline
- Perform Visual Tests to determine best Combo
- Perform Reliability tests to determine Best Combo

Pull Test Before and After 2000 Thermal Cycles (NiPd Lead Finish)



Project Accomplishments-2001

- **Pb-Free soldering can be performed with zero defects**
- **Sn/Ag/Cu and Sn/Ag, Pb-Free solder joints have equal to or greater strength than Sn/Pb joints after 2000 thermal cycles reliability testing**
- ***" This is the most systematic approach to lead free electronics assembly, that I have come across. Work initiated by UMass Lowell team is a positive step towards lead free process optimization."***

Alan Rae, Director of Technology, Cookson Electronics

Project Plan 2002

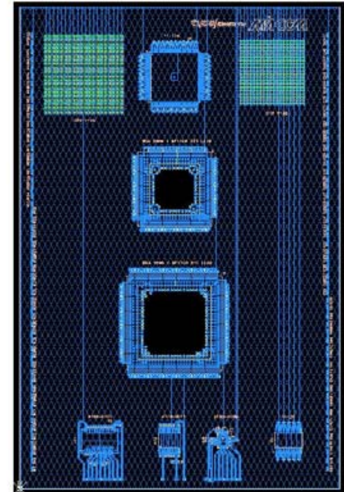
- Form the 2nd phase team and plan the project
- Welcome Schneider, Tyco Electronics, Analog Devices and Air Products
- Leverage NEMI research results
  - Lead free solder composition
  - Reflow Temperatures
  - Expand material selection
- Build on results from 1st phase Consortium Project
  - Manufacturing environments
  - Material Selection

Project Plan 2002

- New Finishes (5 PWB's, BGA Solder balls)
- New Devices (BGA's)
- New Manufacturing processes (Nitrogen Conc.)
- Perform Visual Tests to determine zero defects boundaries for all finishes
- Perform Reliability to determine any deviations within material or process selection

Test Vehicle: (Lead free components) Phase II

2002
•Layout by Tyco Electronics
•Manufacture by Sanmina with 5 finsihes
•Components to be supplied by:
TI components (NiPdAu finish). Components are daisy-chained: 3 x QFP 176 and 3 x SOIC 20
MACOM components:
45 mm BGA. Tin and some Tin lead finish as baseline
Analog Components, Tin finish, 3 x SOIC 20
55 caps and resistors each 0603 Palladium from Schneider



Visual Effect of Nitrogen

- **Nitrogen improves uniformity and hence, the reflow process window.**
- **Nitrogen reduced the clear flux residue and thus will reduce faults in circuit test.**
- **We will experiment with several concentrations of N from Air Products**

Experimental Matrix - 1

PWB Finish	Solder paste	Reflow	Components
.SMOBC/HASL	AIM	Air	Lead Free
.SMOBC/HASL	AIM	Nitrogen	Lead Free
.SMOBC/HASL	Indium	Air	Lead Free
.SMOBC/HASL	Indium	Nitrogen	Lead Free
.SMOBC/HASL	Loctite	Air	Lead Free
.SMOBC/HASL	Loctite	Nitrogen	Lead Free
.SMOBC/HASL	Leaded Solder	Air	Leaded Components
.OSP	AIM	Air	Lead Free
.OSP	AIM	Nitrogen	Lead Free
.OSP	Indium	Air	Lead Free
.OSP	Indium	Nitrogen	Lead Free
.OSP	Loctite	Air	Lead Free
.OSP	Loctite	Nitrogen	Lead Free
.OSP	Leaded Solder	Air	Leaded Components

Experimental Matrix- 2

PWB Finish	Solder paste	Reflow	Components
ENIG	AIM	Air	Lead Free
ENIG	AIM	Nitrogen	Lead Free
ENIG	Indium	Air	Lead Free
ENIG	Indium	Nitrogen	Lead Free
ENIG	Leaded Solder	Air	Leaded Components
.ENIG	Loctite	20 ppm O2-228' C	Lead Free
.ENIG	Loctite	20 ppm O2-240 C	Lead Free
.ENIG	Loctite	5000 ppm O2-228' C	Lead Free
.ENIG	Loctite	5000 ppm O2-240 C	Lead Free
.ENIG	Loctite	Air- 228' C	Lead Free
.ENIG	Loctite	Air-240' C	Lead Free

Experimental Matrix- 3

PWB Finish	Solder paste	Reflow	Components
.Matte Sn	AIM	Air	Lead Free
Matte Sn	AIM	Nitrogen	Lead Free
Matte Sn	Indium	Air	Lead Free
.Matte Sn	Indium	Nitrogen	Lead Free
.Matte Sn	Loctite	Air	Lead Free
Matte Sn	Loctite	Nitrogen	Lead Free
Matte Sn	Leaded Solder	Air	Leaded Components
AG	AIM	Air	Lead Free
.AG	AIM	Nitrogen	Lead Free
.AG	Indium	Air	Lead Free
.AG	Indium	Nitrogen	Lead Free
.AG	Loctite	Air	Lead Free
.AG	Loctite	Nitrogen	Lead Free
.AG	Leaded Solder	Air	Leaded Components

Reliability Test

- **Predict the failures and life of the Process**
- **Depict real time stresses in a Lab by inducing Thermal stresses and cyclic loading**
- **Selection of Thermal cycle**
  - **Creep: High ramp rate and dwell time**
  - **Fatigue: Cyclic loading**
- **Thermal Cycle range selected 0-100°C**
- **Ramp rate 10°C/min**
- **Dwell time 20 minutes on each peak**
- **Raytheon Reliability Analysis Lab utilized for testing**

2000 Presentations/Publications

- **Lead Free Electronics Workshop** hosted by Lucent Technologies Merrimack Valley Works, North Andover, MA, **April 13, 2000**.
- **Lead Free Electronics Workshop**, Session, C2, Best Western Royal Plaza and Trade Center, Marlborough, **April 25th 2000.**
- **State of Massachusetts Legislative committee on education policy**, UMASS President Office, Boston, MA, **May 4th, 2000.**
- **IMAPS New England, 27th annual symposium and exhibition**,, Boxborough, **May 9th 2000.**
- **CEAM /TURI Colloquy University Research in Sustainable Technologies Program, June 2nd 2000**.

2000 Presentations/Publications

- **2nd Workshop on Lead-Free Electronics**, **Technical Issues and Challenges in the Transition To Lead-Free Technologies**,, at BTU North Billerica, MA, **June 29, 2000.**
- **Design Of Experiments For Lead Free Materials, Surface Finishes And Manufacturing Processes Of Printed Wiring Boards**, **Karen Waters, SMTA International Conference** at Rosemount trade center, Chicago, IL, September 2000
- SMTA paper above **translated into Chinese** for PRC EE Journal**.**

2001 Presentations/Publications

- Selecting Material and Process Parameters for Lead Free SMT Soldering Using Design of Experiments Techniques, Apex Conference, San Diego, CA, 1/ 2001 .
- Reliability Testing Techniques For Lead Free SMT Technology, ETRONIX Conference; Anaheim, CA, March 2001 .
- Above paper translated into **Japanese Journal ANBE**, SMT, Kanagawa, Japan, July 2001
- **SMTA Atlanta Conference** Atlanta, GA, **April 19th 2001**,
- **IMAPS New England, 28th annual symposium and exhibition**, Holiday Inn Conference Center, Boxborough, **May 8th 2001.**
- **Shina** Invited to research summary in the **Workshop on Modeling and Data Needs for Lead-Free Solders** ***sponsored by NEMI, NIST, NSF, & TMS, 2/2001, New Orleans, LA***

2001/2002 Presentations/Publications

- Process and Material Selection for zero defects and superior adhesion Lead Free SMT soldering", SMTA International Conference, Chicago, IL., September 2001.
- Shina, "Design Of Experiments", chapter 25 to "**Environment Friendly Electronics: Lead-Free Technology**" by J. Hwang, Electrochemical Publications Ltd, November, 2001.
- ."Lead Free UMASS Consortium", conference sponsored by the Strategic Envirotechnology Partnership (STEP), Boston MA , November 2nd, 2001
- **Lead Free Electronics Workshop** hosted by Schnieder Electric Wilmington, MA, **April 10, 2002**.
- TURA Coordinators Conference, Best Western Royal Plaza and Trade Center, Marlborough, April 23th 2002.