STEP Presentation, 11/3/01

Zero Defects
Lead Free
Soldering

Dr. Sammy Shina
University of Massachusetts Lowell
UMASS Lowell Consortium

The Problem

- Lead is a toxic material: Past major replacements paint, gasoline and joining metal piping
- Tin-Lead eutectic solder (63/37)
  - used in electronics industry for more than 50 years
  - large installed manufacturing base
  - history of reliability data
- Major Companies formed NEMI to share resources and recommend alternatives, $15,000 access to information
- Current Consensus:

There is no drop-in Lead Free replacement for lead soldering

Lead Free Drivers
Environmental

- European Parliament and Council Directive on Waste Electrical and Electronic Equipment Directive (WEEE)
  - Bans lead from certain electronic applications by 2008
- Japan
  - Japanese Electronics Recycling Law - 2001
  - Forbids companies toxic elements that leach into landfills 2/3rd reduction by 2004

Lead Free Drivers
Market Pressure

- German Bluebird
- Proactive stance on lead-free issue by Japanese OEMs
- Hitachi
  - Reduced lead usage by 50% since 1997
  - All products lead-free by 2001
  - current investment US $11.2 million
- Similar stands by Sony, Panasonic, NEC, Toshiba and Fujitsu
- Lead-free green tagged products already in market in Europe and Japan
- Claims of increased market share by 12%
- US market anticipated to be flooded by the end of 2002

Lead Free Project Objectives

- Investigate
  - safe, reliable, non-toxic and cost effective substitute
- Understand
  - material properties
  - compatibility of manufacturing processes and equipment
  - long term availability and solder joint reliability.
- Identify Roadblocks
- Select Test Methods
- Develop a standard guideline
  - SMT Process Optimization
  - Implementation of Lead-Free Process

Project Team
UMASS Lowell-Industry Lead Free Consortium

Project Team

UMASS Lowell-Industry Lead Free Consortium

- **Dr. Sammy Shina; Dept. of Mechanical Engineering, University of Massachusetts, Lowell.**
- **L. Harriman, C. Pace, Toxic Use Reduction Institute**
- **C. Pace, STEP Program**
- **K. Walters, BTU International**, North Billerica, MA.
- **T. Bresnan, Hadco Corporation**, Ward Hill, MA.
- **T. Skidmore, Multicore Solders**, Richardson, Texas.
- **D. Pinsky, Raytheon Corporation**, Lexington, MA.
- **P. Provencal, Solectron Corporation**, Westborough, MA.
- **D. Abbot, Texas Instruments**, Attleboro, MA
- **M. Quealy, Schnieder Automation,** Andover, MA
- **G. Wilkish and B. Anderson, MACOM,** Lowell MA.

UMass Team

" 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

Test Factors (source)

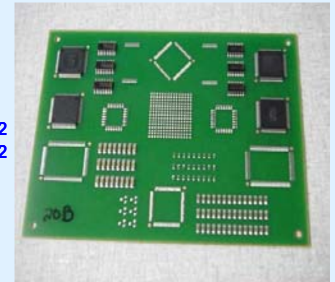
- **Solder Alloys (Multicore solders)**
  - **Sn/Ag/Cu(95.5/3.8/0.7)**
  - **Sn/Ag (96.5/3.5)**
  - **Sn/Bi (57/43)**
- **PWB Surface Finishes (HADCO)**
  - **OSP(Organic Solder Protectants)**
  - **Electroless Nickel Immersion Gold (ENIG)**
- **Thermal Profiles (BTU)**
  - **Soak with 60sec, 90sec, 120sec above liquidus temp.**
  - **Linear with 60sec, 90sec, 120sec above liquidus temp.**
- **Reflow Environment (Solectron)**
  - **Nitrogen vs. Air reflow.**

Test Vehicle: (Lead free components)

Passives
- 1206 - Qty 24
- 0805 - Qty 42
- 0402 - Qty 27

IC/Semiconductor
- LQFP120 - 0.0257 Pitch - Qty 2
- LQFP100 - 0.0157 Pitch - Qty 2
- SO14 - Qty 3
- SO16 - Qty 3

FR-4
size: 5.5”x4.0”



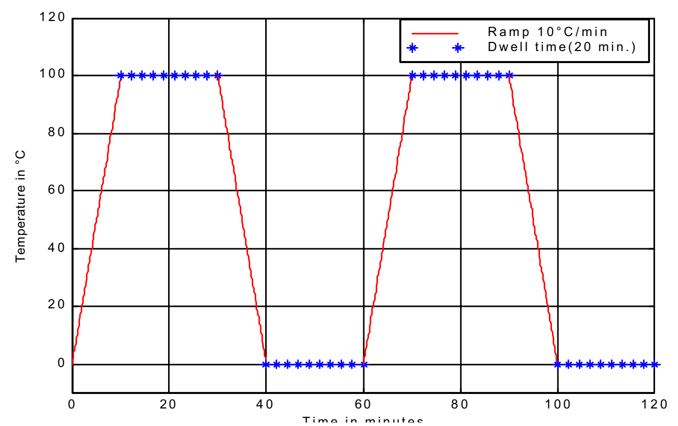
Visual Inspection

Lead Free Defect Results

Sl.no.	Paste	S. Finish	TAL	Soak	Nitrogen	Board Label		Profile No.	Board Faults Visual		Total	Average
1	Sn/Ag/Cu	OSP	60sec	Yes	yes	1A	1B	1	797	944	1741	870.5
2	Sn/Ag/Cu	OSP	90sec	No	No	2A	2B	8	1213	1146	2359	1179.5
3	Sn/Ag/Cu	OSP	120sec	No	yes	3A	3B	6	874	890	1764	882
4	Sn/Ag/Cu	ENIG	60sec	No	No	4A	4B	7	544	594	1138	569
5	Sn/Ag/Cu	ENIG	90sec	No	yes	5A	5B	5	0	0	0	0
6	Sn/Ag/Cu	ENIG	120sec	Yes	yes	6A	6B	3	0	0	0	0
7	Sn/Ag/Cu	OSP	60sec	No	yes	7A	7B	4	828	819	1647	823.5
8	Sn/Ag/Cu	OSP	90sec	Yes	yes	8A	8B	2	902	960	1862	931
9	Sn/Ag/Cu	OSP	120	No	No	9A	9B	9	1182	1164	2346	1173
10	Sn/Bi	OSP	60sec	No	yes	10A	10B	13	1134	963	2097	1048.5
11	Sn/Bi	OSP	90sec	No	yes	11A	11B	14	875	1136	2011	1005.5
12	Sn/Bi	OSP	120sec	Yes	No	12A	12B	12	967	1146	2113	1056.5
13	Sn/Bi	ENIG	60sec	No	yes	13A	13B	13	1024	960	1984	992
14	Sn/Bi	ENIG	90sec	Yes	No	14A	14B	11	1016	1002	2018	1009
15	Sn/Bi	ENIG	120sec	No	yes	15A	15B	15	843	560	1403	701.5
16	Sn/Bi	OSP	60sec	Yes	No	16A	16B	10	1148	1067	2215	1107.5
17	Sn/Bi	OSP	90sec	No	yes	17A	17B	14	781	606	1387	693.5
18	Sn/Bi	OSP	120sec	No	yes	18A	18B	15	765	882	1647	823.5
19	Sn/Ag	OSP	60sec	No	No	19A	19B	7	1212	1279	2491	1245.5
20	Sn/Ag	OSP	90sec	Yes	yes	20A	20B	2	1131	988	2119	1059.5
21	Sn/Ag	OSP	120sec	No	yes	21A	21B	6	1027	933	1960	980
22	Sn/Ag	ENIG	60sec	Yes	yes	22A	22B	1	0	0	0	0
23	Sn/Ag	ENIG	90sec	No	yes	23A	23B	5	0	0	0	0
24	Sn/Ag	ENIG	120sec	No	No	24A	24B	9	180	240	420	210
25	Sn/Ag	OSP	60sec	No	yes	25A	25B	4	796	829	1625	812.5
26	Sn/Ag	OSP	90sec	No	No	26A	26B	8	1205	1146	2351	1175.5
27	Sn/Ag	OSP	120sec	Yes	yes	27A	27B	3	868	935	1803	901.5

Reliability Test

Theoretical Thermal Cycling



Pull Test on Ni/Pd SO14

Lead-Free Results after Thermal Cycling

	Paste	S. Finish	TAL	Soak	N2	Board Label		Force (lbs)		Force (N)		Average
1	Sn/Ag/Cu	OSP	60sec	Yes	yes	1A	1B	9.686	10.59	43.103	47.126	45.1141
2	Sn/Ag/Cu	OSP	90sec	No	No	2A	2B	10.65	10.18	47.393	45.301	46.34675
3	Sn/Ag/Cu	OSP	120sec	No	yes	3A	3B	10.46	10.18	46.547	45.301	45.924
4	Sn/Ag/Cu	ENIG	60sec	No	No	4A	4B	10.32	9.89	45.924	44.011	44.96725
5	Sn/Ag/Cu	ENIG	90sec	No	yes	5A	5B	10.54	7.388	46.903	32.877	39.8898
6	Sn/Ag/Cu	ENIG	120sec	Yes	yes	6A	6B	7.989	8.462	35.551	37.656	36.603475
7	Sn/Ag/Cu	OSP	60sec	No	yes	7A	7B	10.99	8.548	48.906	38.039	43.47205
8	Sn/Ag/Cu	OSP	90sec	Yes	yes	8A	8B	9.052	10.48	40.281	46.636	43.4587
9	Sn/Ag/Cu	OSP	120	No	No	9A	9B	8.913	9.342	39.663	41.572	40.617375
10	Sn/Bi	OSP	60sec	No	yes	10A	10B	7.925	6.174	35.266	27.474	31.370275
11	Sn/Bi	OSP	90sec	No	yes	11A	11B	8.837	6.722	39.325	29.913	34.618775
12	Sn/Bi	OSP	120sec	Yes	No	12A	12B	5.766	3.705	25.659	16.487	21.072975
13	Sn/Bi	ENIG	60sec	No	yes	13A	13B	5.412	9.632	24.083	42.862	33.4729
14	Sn/Bi	ENIG	90sec	Yes	No	14A	14B	3.297	8.623	14.672	38.372	26.522
15	Sn/Bi	ENIG	120sec	No	yes	15A	15B	8.827	3.436	39.28	15.29	27.285175
16	Sn/Bi	OSP	60sec	Yes	No	16A	16B	5.133	5.756	22.842	25.614	24.228025
17	Sn/Bi	OSP	90sec	No	yes	17A	17B	4.897	8.354	21.792	37.175	29.483475
18	Sn/Bi	OSP	120sec	No	yes	18A	18B	6.776	8.569	30.153	38.132	34.142625
19	Sn/Ag	OSP	60sec	No	No	19A	19B	9.632	8.719	42.862	38.8	40.830975
20	Sn/Ag	OSP	90sec	Yes	yes	20A	20B	10.12	10.19	45.034	45.346	45.18975
21	Sn/Ag	OSP	120sec	No	yes	21A	21B	9.492	9.31	42.239	41.43	41.83445
22	Sn/Ag	ENIG	60sec	Yes	yes	22A	22B	9.697	9.815	43.152	43.677	43.4142
23	Sn/Ag	ENIG	90sec	No	yes	23A	23B	9.224	8.709	41.047	38.755	39.900925
24	Sn/Ag	ENIG	120sec	No	No	24A	24B	9.707	6.142	43.196	27.332	35.264025
25	Sn/Ag	OSP	60sec	No	yes	25A	25B	9.031	10.08	40.188	44.856	42.521975
26	Sn/Ag	OSP	90sec	No	No	26A	26B	8.666	6.883	38.564	30.629	34.596525

Pull Test - MIN Before and After Thermal Cycling

Conclusions

- For Zero Defect lead Lead Free Soldering and superior long term Joint Strength, use the following:

Materials

Lead Free Solder :	Sn/Ag/Cu
Surface Finish for PWB:	ENIG
Components Finish:	Ni/Pd

Processes

Reflow Profile:	Linear
Reflow Environment:	Nitrogen
Time Above Liquidus:	120 seconds

Dissemination

- 17 Presentations, including
  - 4 TURI Sponsored Workshops in MA
  - 2 State of MA committees
  - 6 Society Conferences: IMAPS, SMTA, APEX, TMS
  - 2 Electronics Conferences: APEX, ETRONIX
  - 1 book chapter
- 2 Papers Translated into Chinese and Japanese
- Presentations in MA, GA, IL, CA, LA.

Future Work

- Consortium Working on 2nd phase:

Materials

New flux combinations with Sn/Ag/Cu
More component types (BGA, QFP's)
More Component finishes (Sn, SOP, Immersion)
More lead free PWB surface finishes

Processes

Reflow Environment: %Nitrogen or Air

Benchmarked with Sn/Pb Lead materials Base

Cross Section of Zero Defect Test PWB 6A @ 10X Mag