

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)

FR-4

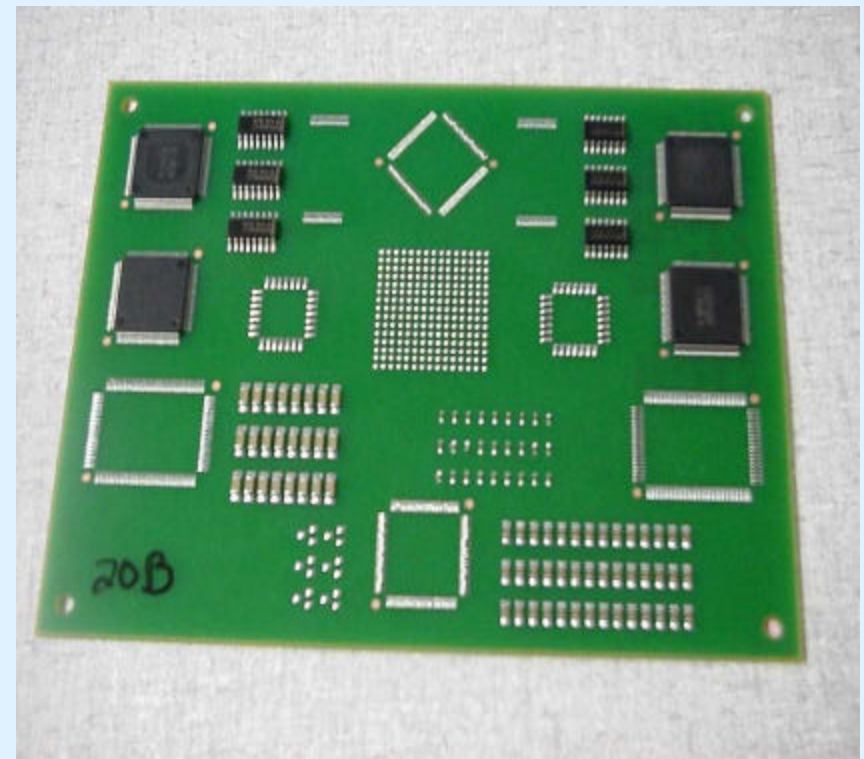
size: 5.5''x4.0''

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



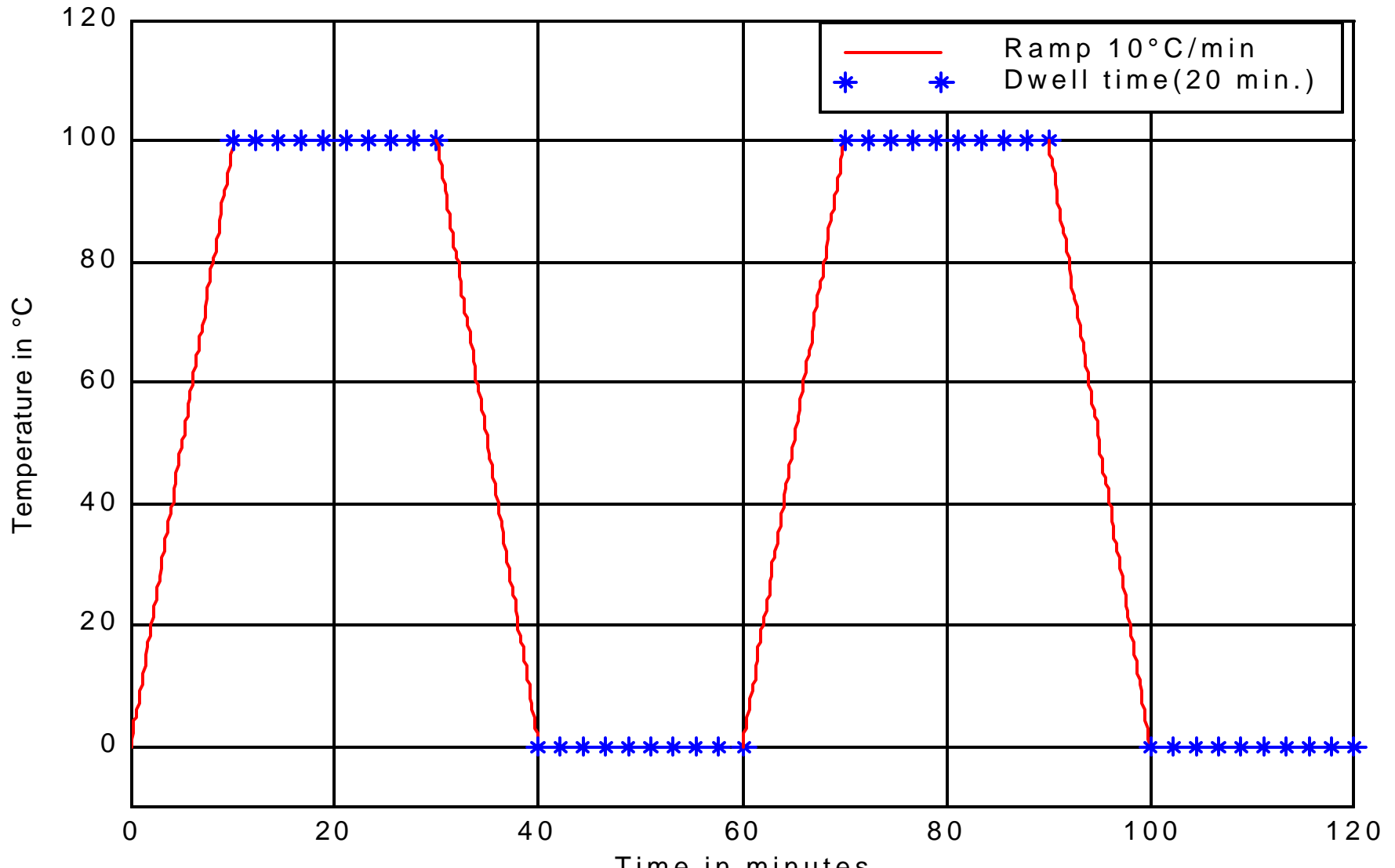
Visual Inspection

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

