Review of Pb-free Activities in Taiwan

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REVIEW OF Pb-FREE ACTIVITIES IN TAIWAN

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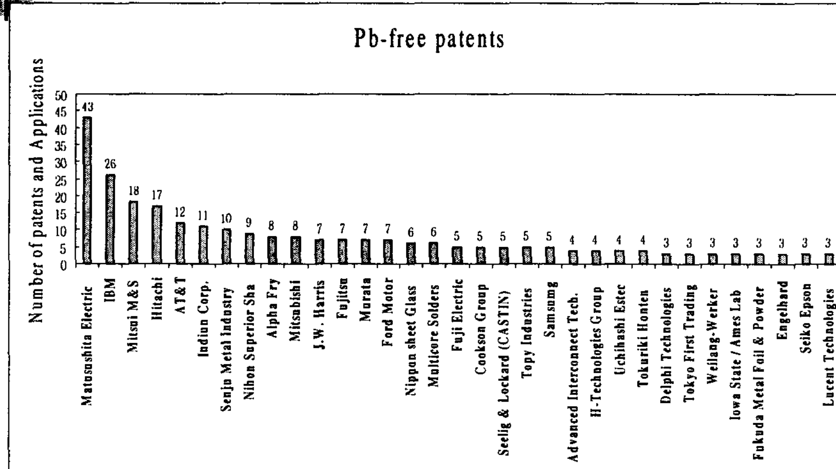
Legislations

- European Draft Directive (WEEE) – ban the use of Pb by July 1, 2006
- Japan: Recycling Law (enacted April 2001)
  - Household Electric Appliances Recycling Law
  - Green Purchase Law
  - Law of Promotion of Utilization of Recyclable Materials
- Major Japanese electronics companies have set time table for Pb-free products.

Patents and Industry



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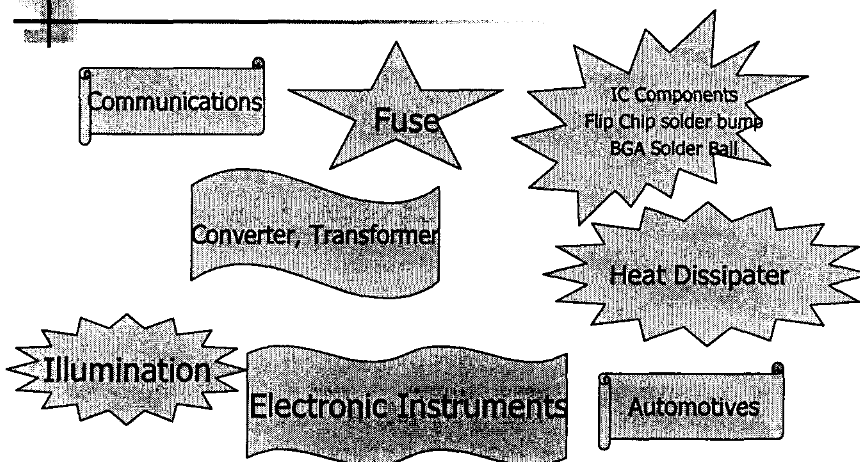
Products Affected due to Pb-removal



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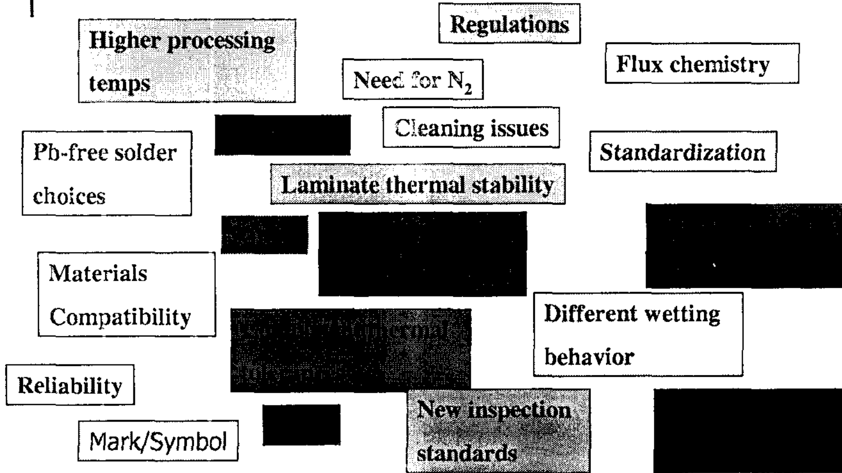
Pb-free Puzzle? Priority?



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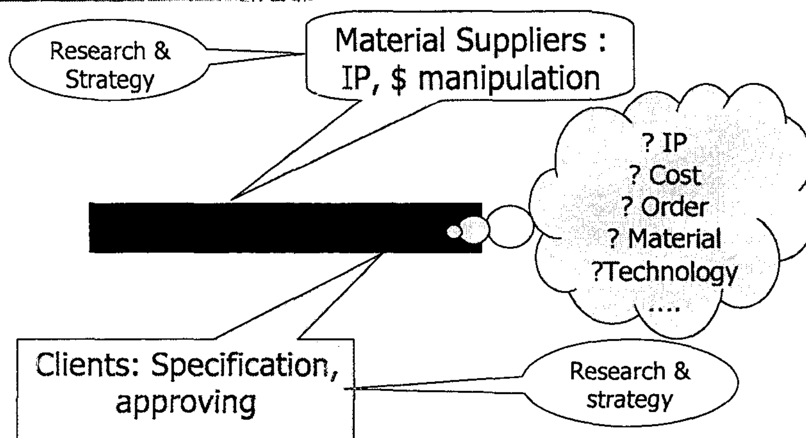
Status of Taiwan in Pb-free Transition



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Pb-free Promotion Activities

- The Bureau of Industry – Ministry of Economy
  - Workshop
- Green Industry Association
  - Workshop
- The Printed Circuit Association
  - Workshop
- Academics
  - Workshop, Consulting

Pb-free Consortium

- Pb-free Packaging Consortium - Leaded by ITRI :
  - Participants: most major electronic industry
  - Activities:
    - workshops
      - Invite worldwide renown lecturers
    - joint research projects
      - At least two on-going projects
    - testing services
      - Reliability facilities

Pb-free R & D in Industry-1

- ITRI-Academic-Industry (System and Packaging) joint research
  - Project 1: with leading notebook/PCB Companies
    - SMT process developments
  - Project 2: with leading PC/Packaging/Component Companies
    - Component packaging

Pb-free R & D in Industry-2

- Packaging industry independent research
  - Most small to medium industry attempted to develop individually needed process independently
  - May consult with ITRI or academics

Pb-free Materials Status -1

- Solders being adopted
  - Sn- 3.0~4.0 Ag- 0.5~0.7 Cu
    - Paste, ball
  - Sn-0.7Cu
    - Wave soldering
  - Sn-Ag-Cu-Sb (CASTIN®)
    - Wave soldering, paste

Pb-free Materials Status -2

- Solders being under consideration
  - Sn-Ag-Cu-Ni-Ge (patented JPN)
    - paste
  - Sn-Zn-Al (patented JPN)
    - paste, ball
      - Paste for SAC ball attachment
  - Sn-Zn-Bi (not intend to accept)
    - Paste
- Sn-Cu-Ni
  - Wave soldering
- Sn-Zn-Ag-Al-Ga (patented TWN, pending JPN, US)
  - ball

Pb-free Materials Status -3

- Solder Venders
  - Sub-licensed:
    - Sn-Ag-Cu-Sb
    - Sn-Ag-Cu-Ni-Ge
  - Agent/branch office
    - Sn-Ag-Cu
  - Samples supplied (to industry directly)
    - Sn-Zn-Al (ball and paste)
    - Sn-Zn-Bi (paste)

Academic Involvements in International Activities

- Co-organizing Pb-free symposium
  - TMS Pb-free symposium
  - IEEE-CPMT Pb-free symposium
- Universities having aggressive Pb-free research activities
  - Taiwan U, Central U, Tsing-Hua U, Chiao-Tung U, Cheng Kung U, Chung-Shan U
- International Journal publications:more than 50 publications/presentations annually

Pb-free Research in Academics

- IMC formation mechanism
  - SAC/Cu-Ni-Au; SAC/Cu
  - SAC/UBM
  - Sn-Zn/Cu-Ni-Au; Sn-Zn/Cu
- Electromigration
  - SAC/UBM
  - Sn-Zn/Cu
- Thermodynamics
  - Ternary phase diagram establishment
- Interfacial Interaction
  - Wetting behavior

Pb-free Research in Academics

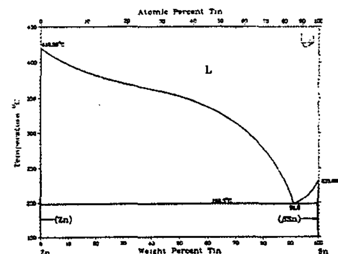
- Pb-free solder alloy development
  - Sn-Zn system: Sn-Zn-Ag-Al-Ga
    - Eutectic temperature: 198°C
    - Form layer, instead of columnar, IMC with Cu and Au – no Cu-Sn or Au-Sn IMC
    - Higher UTS and greater ductility than Sn-37Pb
    - Solder ball (Ø 0.3mm~0.76mm being successfully produced)
    - Improved oxidation resistance over Sn-9Zn
    - At least a commercial flux works well for ball attachment
      - Good shear strength (as reflowed, 5 cycle reflow)
  - Cost lowers than SAC

Sn-Ag-Cu Solders

Alloys	MP (°C)
Sn-3.5Ag	221
Sn-0.7Cu	227
Sn-2.5Ag-0.8Cu-0.5Sb (CASTIN®)	215~217
Sn-(3.5~4.0)Ag-(0.5~0.7)Cu	216~220
Sn-(2.5~2.8)Ag-0.5Cu-1Bi	214~217

Sn-Zn Alloys

- Eutectic: Sn-9Zn
- Eutectic T: 199°C
- Good Mech Strength
- Low cost
- Stable supply



- Oxidation
- Special Flux
- Lacks Reliability Study
- Uneasy to Plate

Dissolution of Metals in Solders (NCKU)

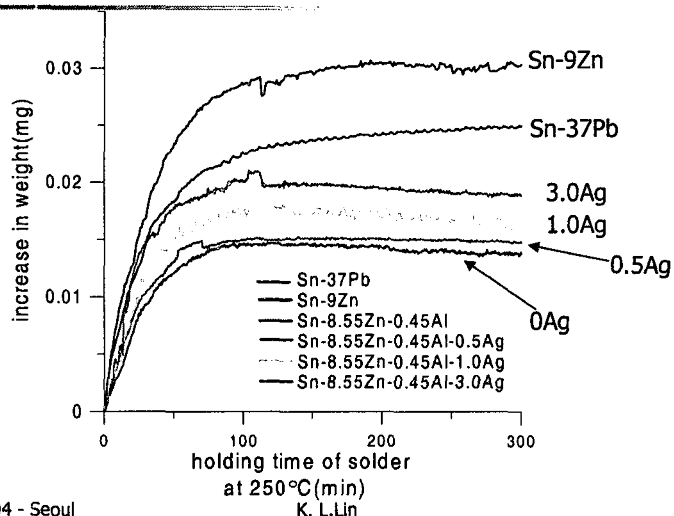
Sn-9Zn

Sn-4.0Ag-0.5Cu

Dissolution rates of Cu and Ag in solders (NCKU)

Solder / V(μm/s) / T	Sn-4Ag-0.5Cu		Sn-37Pb		Sn-9Zn	
	Cu	Ag	Cu	Ag	Cu	Ag
300℃	0.6	0.9	0.2	0.9	0.02	0.1
350℃	1.4	2.7	0.9	3.7	0.3	1.8
400℃	2.4	3.7	1.4	6.7	1.1	4.4

Oxidation Comparison at 250°C, under Oxygen Atmosphere(NCKU)



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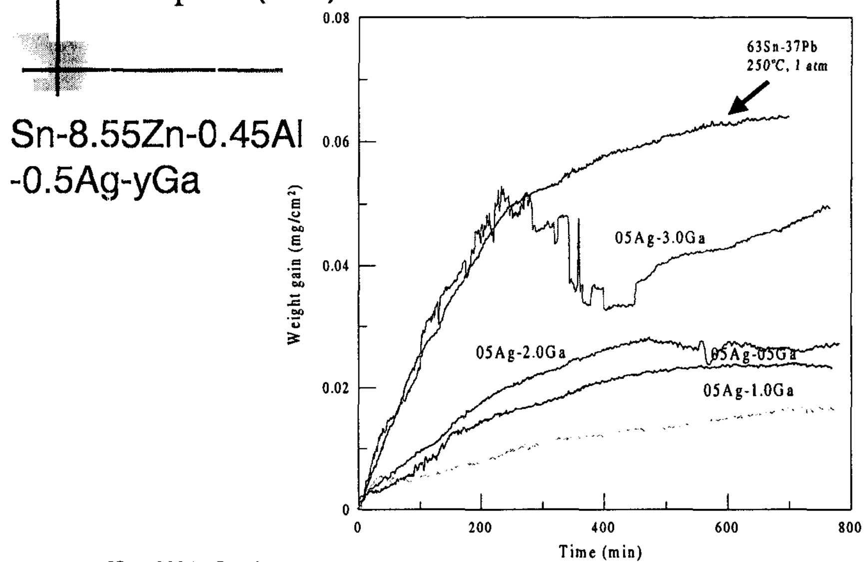
Oxidation Comparison at 250°C under Oxygen Atmosphere(NCKU)

Sn-8.55Zn-0.45Al -0.5Ag-yGa



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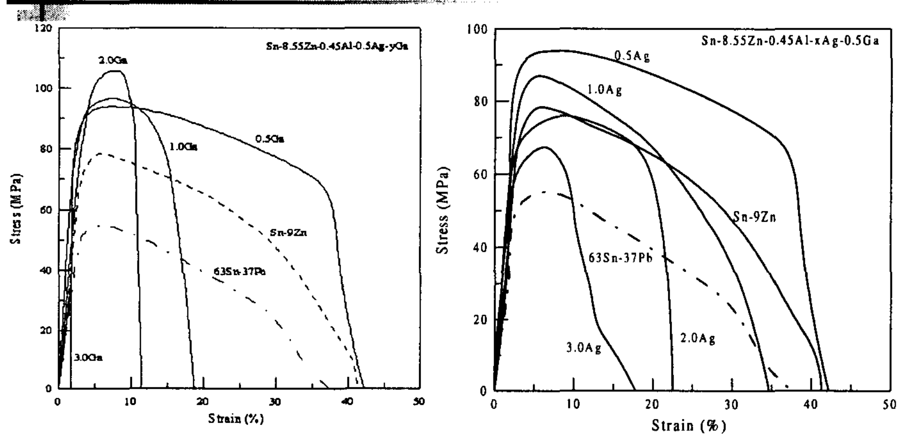
The solidus and liquidus temperatures of different Al (wt%) content solders

"The Thermal Property of Lead-Free Sn-8.55Zn-1Ag-X Al Solder Alloys and its Wetting Interaction with Cu," **J. Electronic Materials**, 31(9) September, 940-945 (2002), K. L. Lin et al.

Solders (wt%)	Solidus (℃)	Liquidus (℃)
Sn-9Zn	198.4	200.8
Sn-8.55Zn-1Ag	199.6	205.9
Sn-8.55Zn-1Ag-0.01Al	198.2	205.6
Sn-8.55Zn-1Ag-0.1Al	198.3	207.2
Sn-8.55Zn-1Ag-0.25Al	197.1	207.9
Sn-8.55Zn-1Ag-0.45Al	198.3	206.7

Stress-Strain Behaviors

K. I. Chen and K. L. Lin, **J. Electronic Mat.**, 32(10) 1111-1116(2003).
K. I. Chen and K. L. Lin, **J. Electronic Materials**, 31(8) 861-867 (2002).



Wetting behaviors: (by wetting balance)

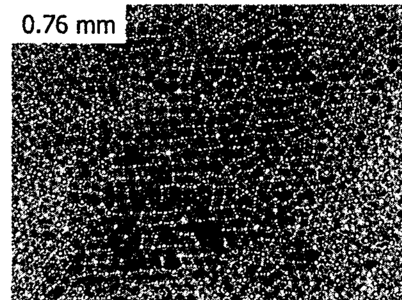
Sn-8.55Zn-0.45Al-0.5Ag-0.5Ga on Cu (NCKU)

Temperature (°C)	220	235	250
Wetting time(s)	1.35~ 1.58	1.05~1.5	0.8~0.98
Wetting force(mN)	0.4	0.58~0.9	0.52~0.9

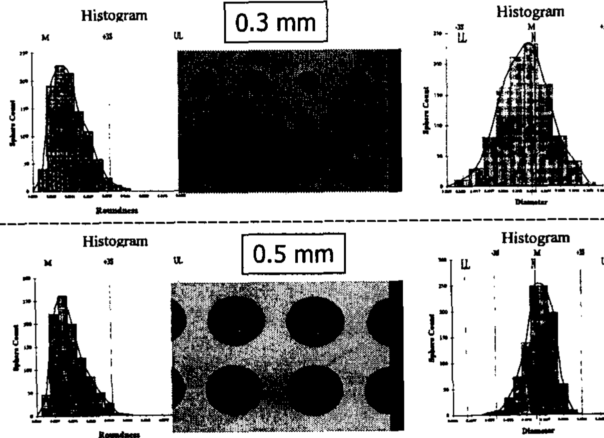
Sn-Zn-Ag-Al-Ga Solder Balls

NCKU/ACCURUS Inc.

Solder ball produced: 0.3, 0.5, 0.76 mm



Sn-Zn-Ag-Al-Ga Solder Balls-ball size distribution NCKU/ACCURUS Inc.



Shear Strength (gf) of Sn-Zn-Ag-Al-Ga Solder Balls, 0.76mm (NCKU)

Reflow Temp (°C)	220	240	250
Commercial Flux A (common for Sn-Pb)			1139.6
Commercial Flux B			1726.2
Commercial Flux C			1788.3
Lab Flux (NCKU)	2053.7±206.5	2073.9±81.6	

Summary

- The industry activities incorporating with research institute in developing manufacturing process
- Academics are quite active in fundamental studies, alloy development, as well as international activities
- Government, Associations, and Academics assist in knowledge spreading and training