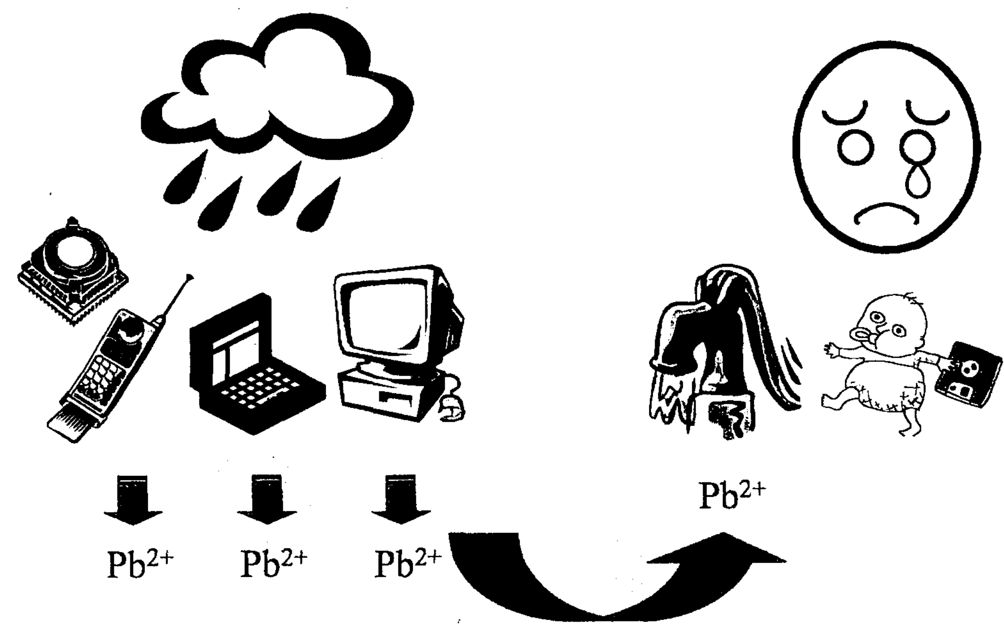
Plating Technology for Lead Free Soldering in Japan

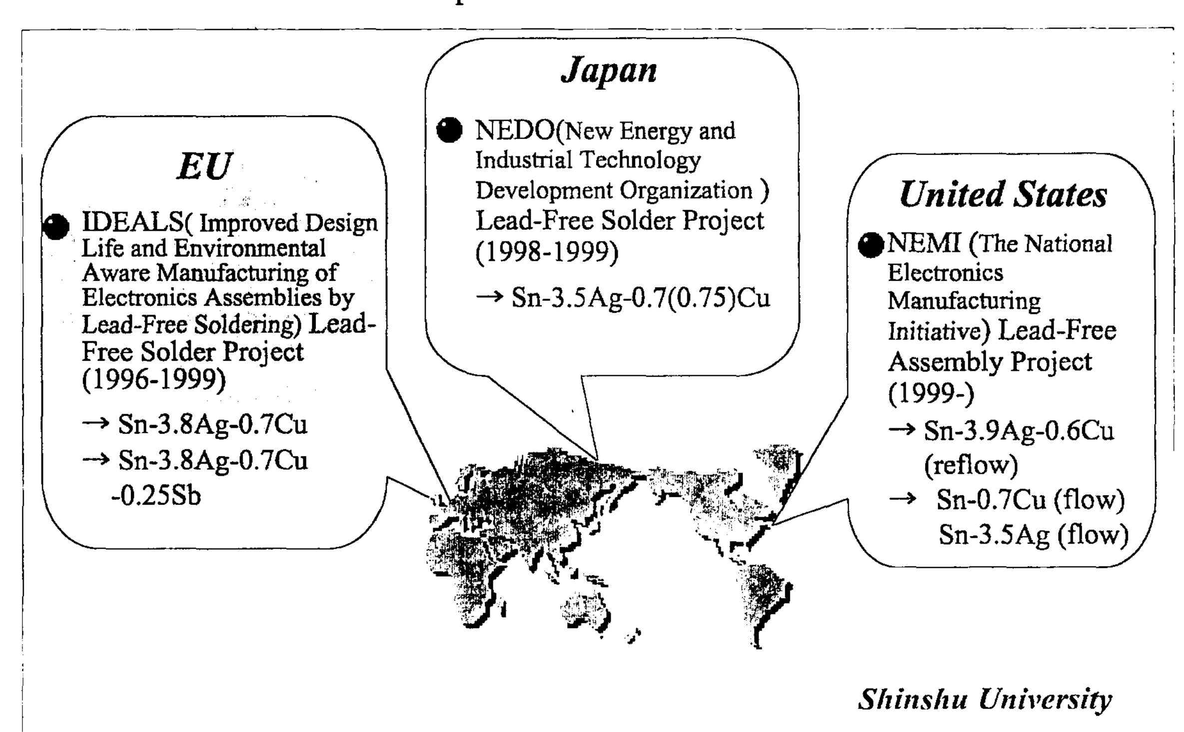
Susumu Arai

Environmental Pollution Issues due to Lead contamination from Electronic Waste such as Printed Circuit Boards

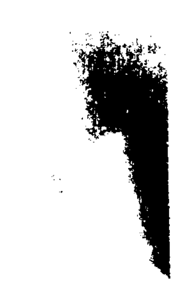


Latest National Projects for Lead-Free Soldering

- Development of Lead-Free Solder –



3rd Korea-Japan Advanced Semiconductor
Packaging Technology Seminar
September 13, 2001 in Seoul



Plating Technology for Lead-Free Soldering in Japan

Faculty of Engineering
Shinshu University
Dr. S. Arai

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- Introduction
- Types of Surface Finishing for Electronic and Semiconductor Parts
- Electroplating Baths for Lead-Free Solder Plating
- Properties of Lead-Free Solder Platings
- Lead-Free Solder Bump Formation Using Electroplating Method
- Conclusion

Electrodes of Parts for Lead-Free Soldering

- A Report of the NEDO Project researched by JEIDA (Japan Electronic Industries Development Association) -

Purpose

The Research of the solderability as follows.

Parts with Lead-Contained Plating ⟺ Lead-Free Solder

Parts with Lead-Free Plating ⟺ Lead-Free Solder

Parts with Lead-Free Plating ⟺ Lead-Contained Solder

Solder

Sn-3.5Ag-0.75Bi-(0〜6)Bi, Sn-37Pb-2Ag(Reference)

Parts

SMD(Seramic condenser etc.), Insert Parts , Semiconductor parts(QFP,DIP etc.)

Platings

Au, Ag, Pd, Sn, Sn-Ag, Sn-Bi, Sn-Cu, Sn-Pb(Reference), etc.

Conclusion

- On the junction reliability, there are no problems on the Parts with Lead-Free Platings.
- There is a probrem between the Parts with Lead-Contained Plating and the Lead-Free Solder containing a lot of Bi
- Lead-Free Plating should be selected from the synthetic viewpoint such as cost, the stability of the quality, etc.

Surface treatment of the Parts

Parts	Plated section	Appearance of the parts
Semiconductor	Outer lead	
Insert parts	Lead	
Chip parts	Electrode	
Substrate	Land ,Pad	

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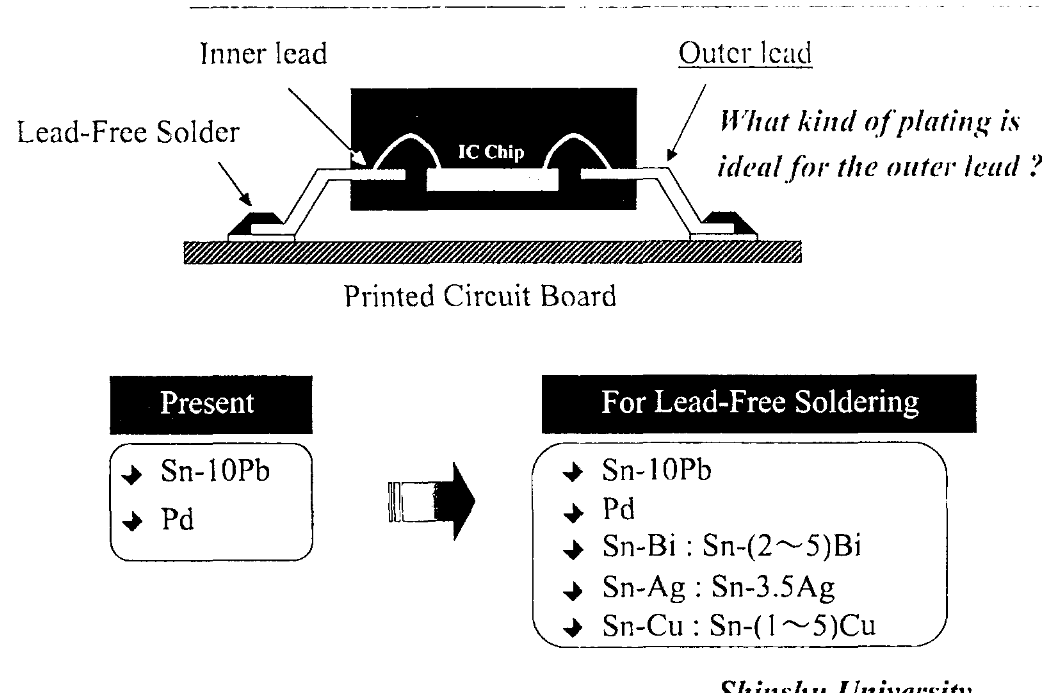
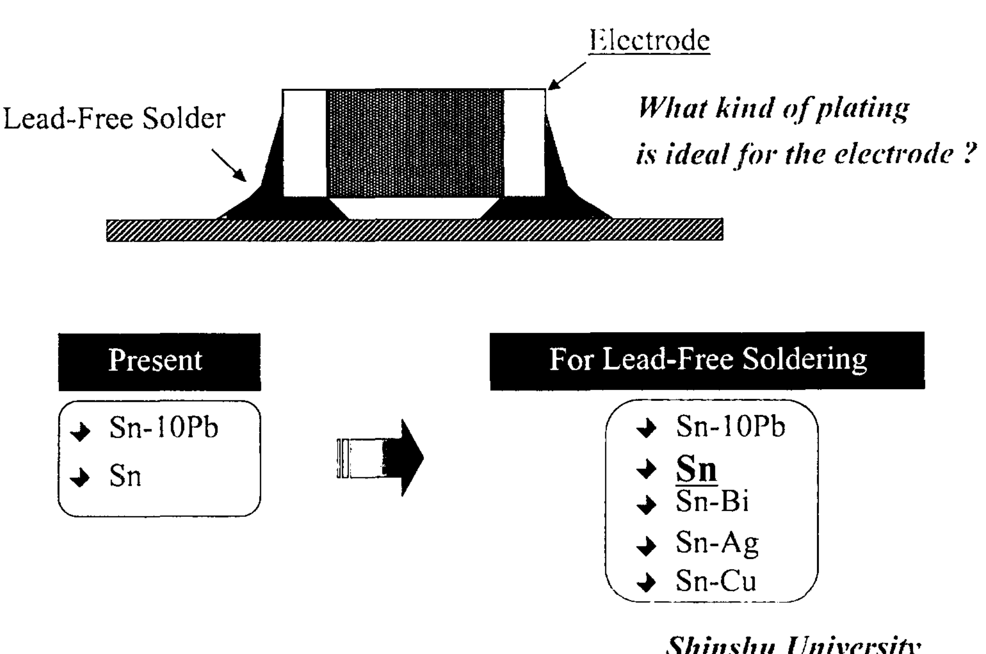
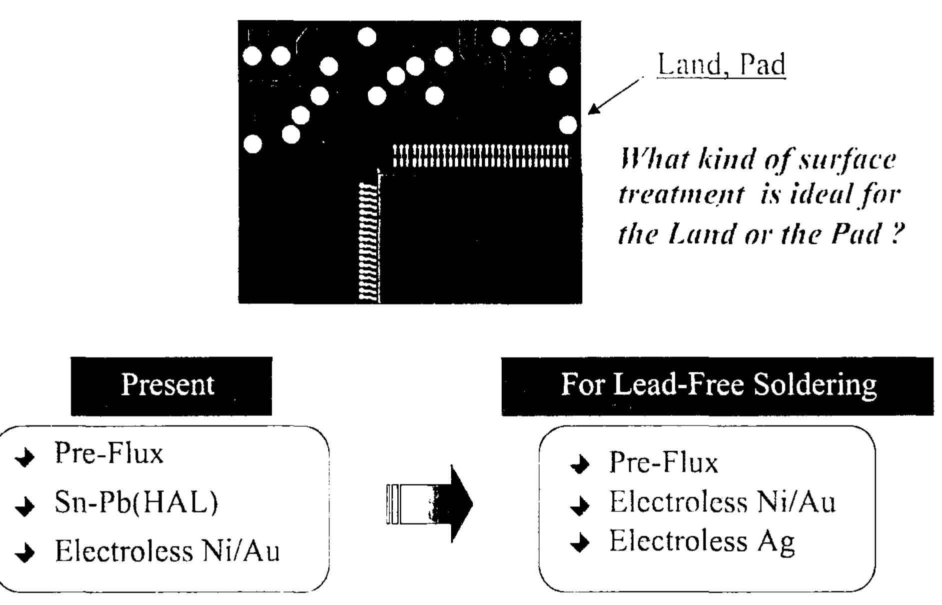
Plating of Semiconductor Parts (Outer Lead) for Lead-Free Soldering



Plating of Chip Parts for Lead-Free Soldering



Surface Treatment of Substrate (Pad, Land) for Lead-Free Soldering



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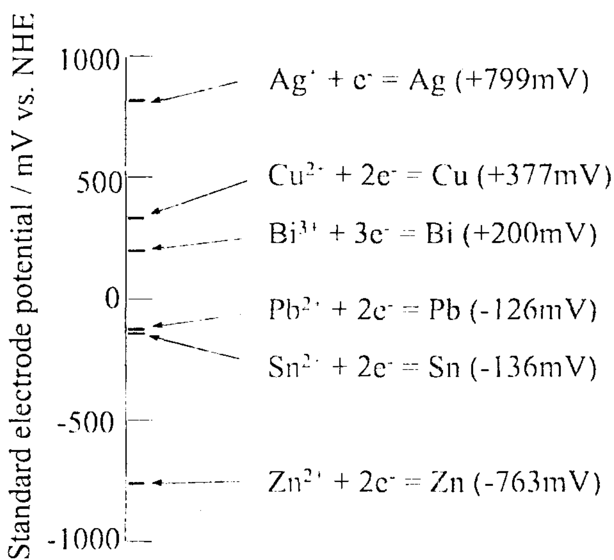
Standard electrode potentials of Metals used as Lead-Free Solder Alloy Plating Materials



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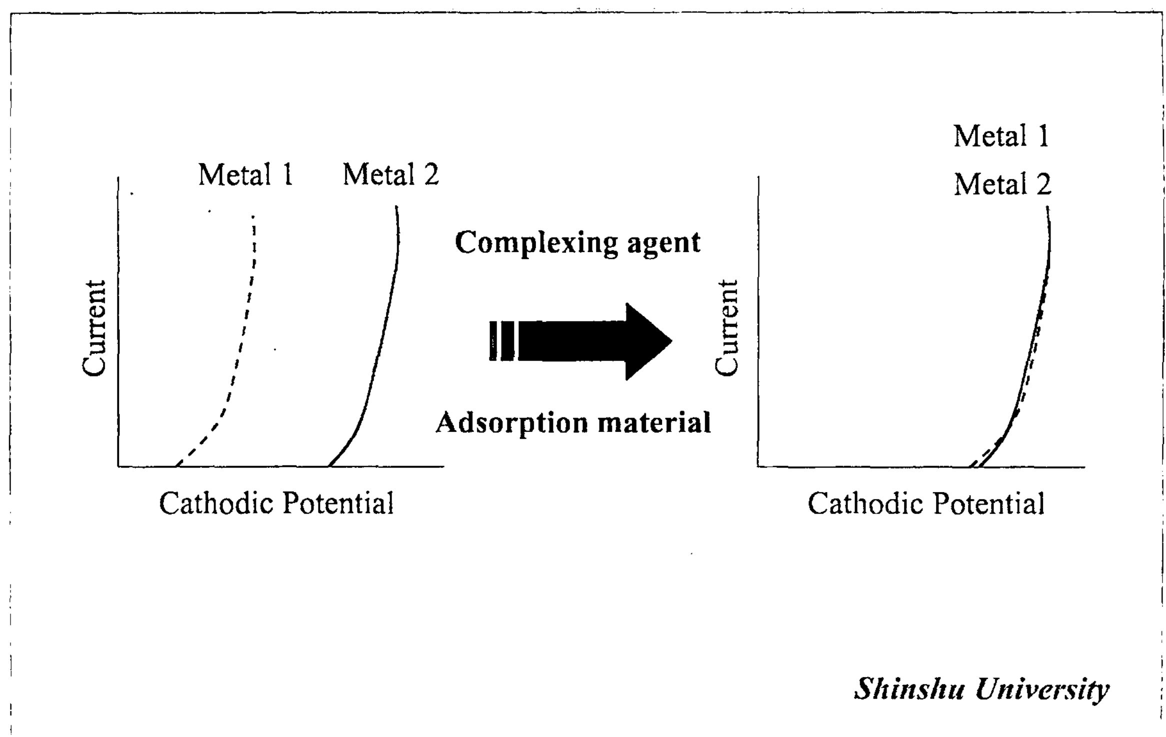
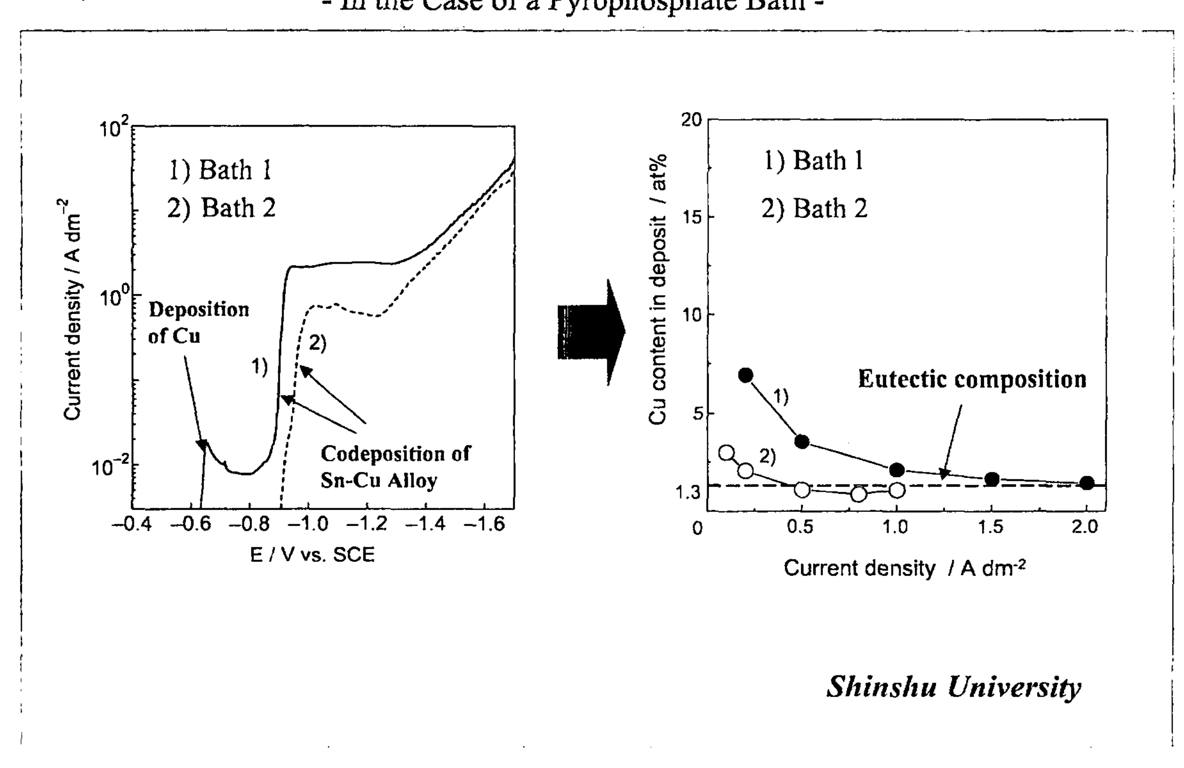
Development of Alloy Plating Bath

— Current-Potential Curve —



Current-Potential Curves and the Relationship between Current Density and Composition of Sn-Cu Alloy

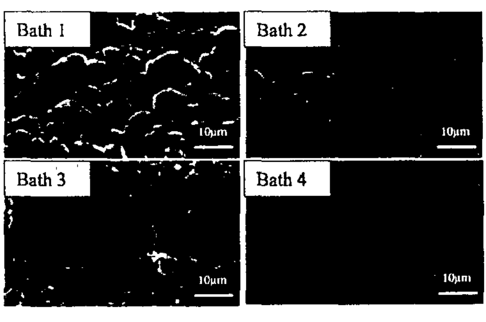
- In the Case of a Pyrophosphate Bath -



Effects of Organic Compounds for Surface Morphologies of Electroplating Sn-Cu Alloy Films

Composition of Sn-Cu electroplating bath

Compound	Bath 1	Bath 2	Bath 3	Bath 4
$K_4P_2O_7$	1	1	1	1
KI	2	2	2	2
$Sn_2P_2O_7$	0.25	0.25	0.25	0.25
$Cu_2P_2O_7$	0.005	0.005	0.005	0.005
PEG600			0.002	0.002
HCHO		0.05		0.05



Surface morphologies of Sn-Cu alloy films (Cu:1～2at%)

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Electroplating Baths for Lead-Free Solder Plating

	Electroplating baths
Sn-Bi	oAlkanesulfonate Bath o Sulfate Bath
Sn-Ag	o Pyrophosphate-Iodide Bath o Alkaline Bath(5,5-Dimethylhydantoin) o Pyrophosphate-Acetyl Cystein Bath o Gluconate-Iodide Bath o Citrate-Iodide Bath o Alkanesulfonate Bath (+ sulfur compound) o Mercaptoalkanecarboxylic acid Bath o Tartrate Bath o Tris(3-hydroxypropyl)phosphine Bath o Ag particle Composite Bath
Sn-Cu	o Alkanesulfonate Bath o Pyrophosphate Bath o Sulfate Bath
Sn-Zn	o Alkaline Bath o Citrate Bath o Sulfosuccinate Complex Bath o Pyrophosphate Bath

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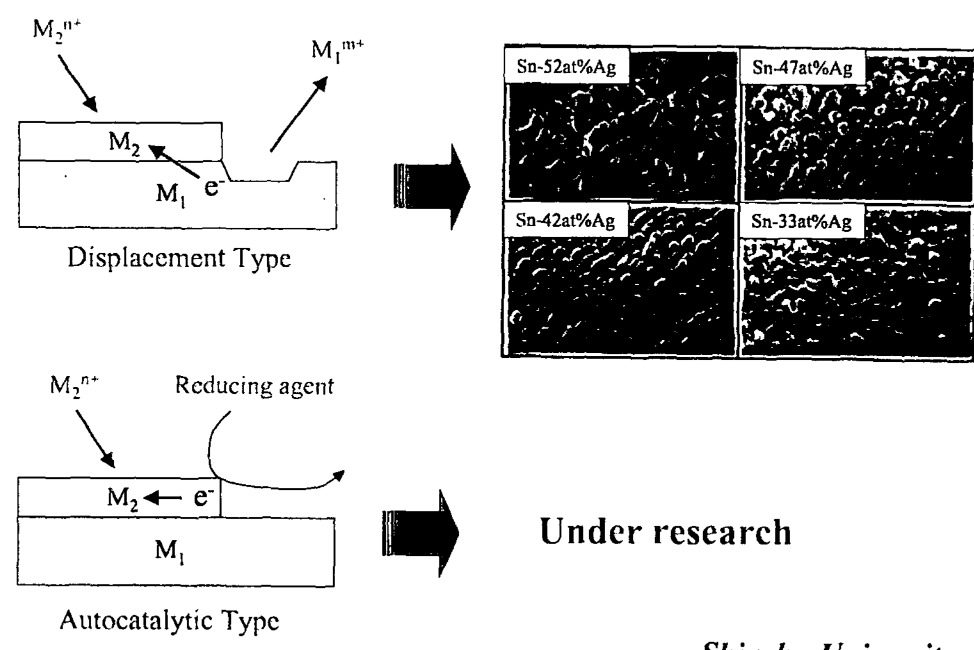
Electroless Lead-Free Solder Plating

– Electroless Sn-Ag Solder Plating by Displacement Reaction –



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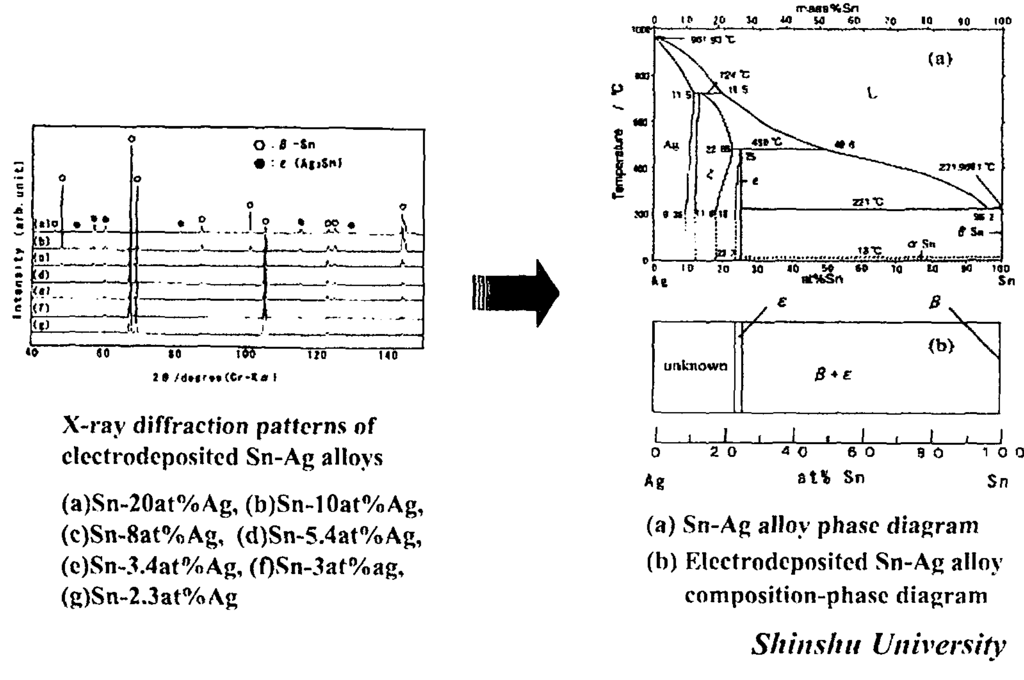
Phase Structure of Lead-Free Solder Plating

– Sn-Ag Binary Alloy Electrodeposited from Pyrophosphate-Iodide Bath –



X-ray diffraction patterns of electrodeposited Sn-Ag alloys

(a)Sn-20at%Ag, (b)Sn-10at%Ag, (c)Sn-8at%Ag, (d)Sn-5.4at%Ag, (e)Sn-3.4at%Ag, (f)Sn-3at%ag, (g)Sn-2.3at%Ag

(a) Sn-Ag alloy phase diagram
(b) Electrodeposited Sn-Ag alloy composition-phase diagram

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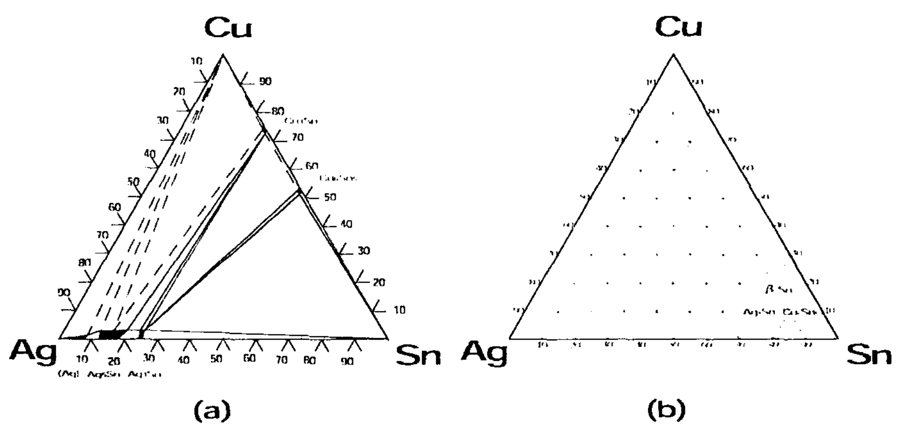
Phase Structure of Lead-Free Solder Plating

- Sn-Ag-Cu Ternary Alloy Electrodeposited from Pyrophosphate-Iodide Bath -



(a) Sn-Ag-Cu ternary alloy phase diagram at 37℃
(b) Electrodeposited Sn-Ag-Cu ternary alloy composition-phase diagram at room temperature

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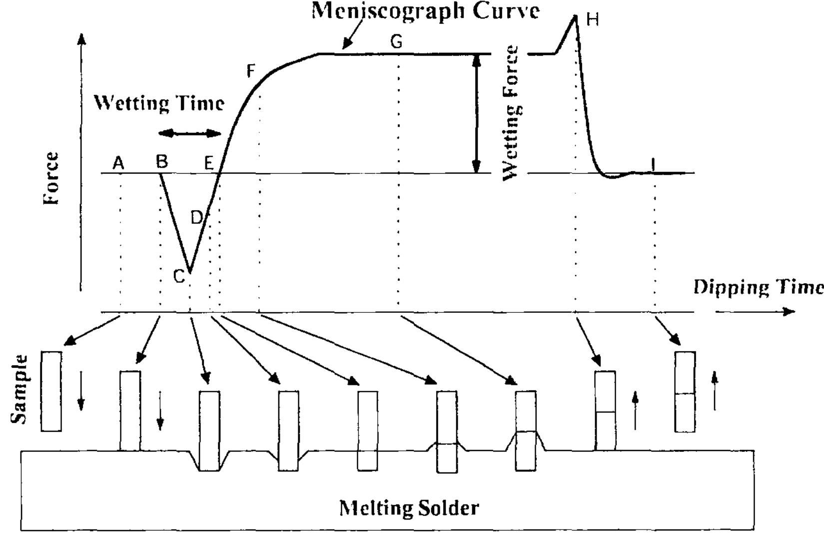
Wettability of Lead-Free Solder Plating

- Wetting Balance(Meniscograph) Method -



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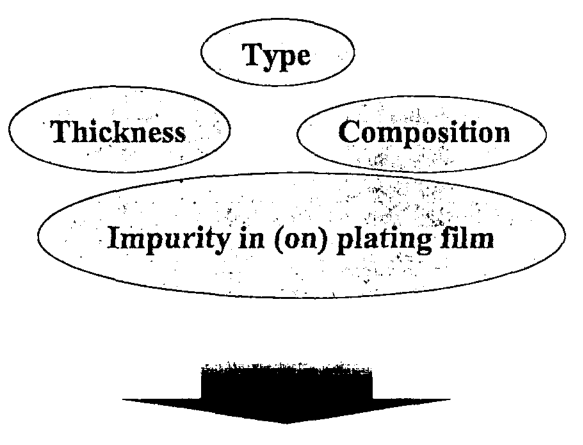
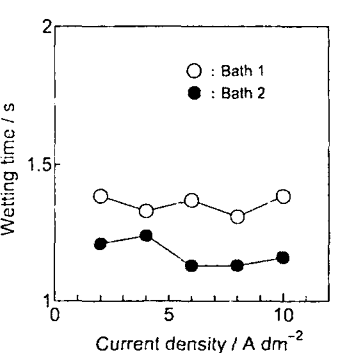
Wettability of Solder Plating

Solder plating films which are the same type, the same composition and the same thickness often show different wettabilities



Wettability of plating film



Wettability of Sn-10wt%Pb alloy films with 10μm thick from different electroplating baths (Bath 1 and Bath 2) .

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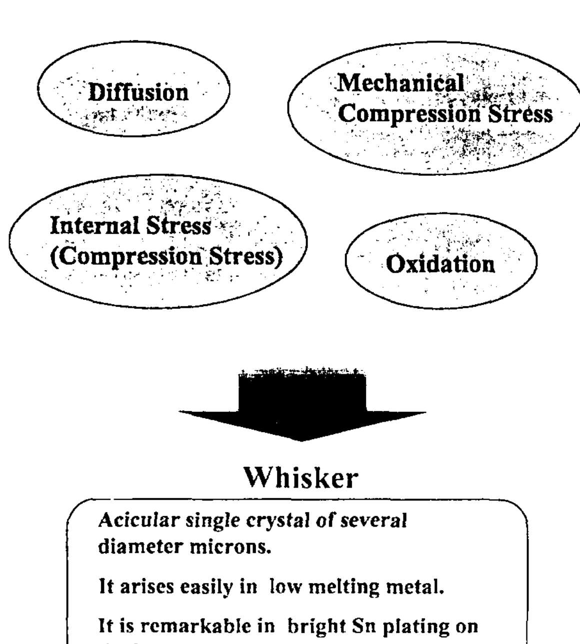
Whisker of Lead-Free Solder Plating



In the use of lead-free solder plating such as Sn, Sn-Cu plating, the problem of whisker is important

Mechanism is not clear !!

Standardization of test method is needed.

Standardization Project (NEDO(JEITA) 2001-2003)

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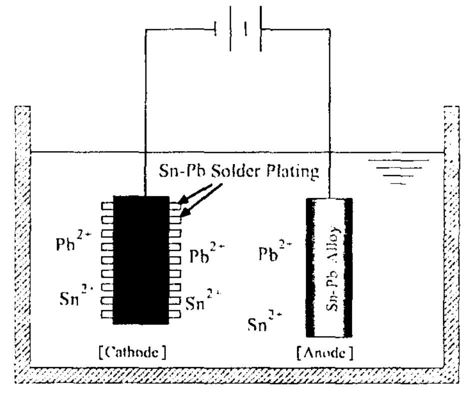
Selection of Anode Electrode for Lead-Free Solder Plating



Sn-Pb alloy is used as a soluble alloy anode for Sn-Pb alloy Solder Plating

What kind of anode is ideal for the lead-free solder plating ?

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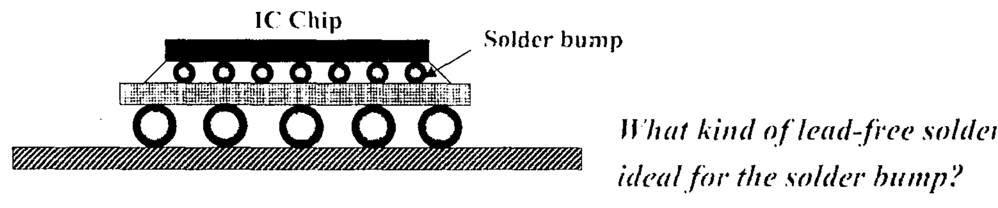
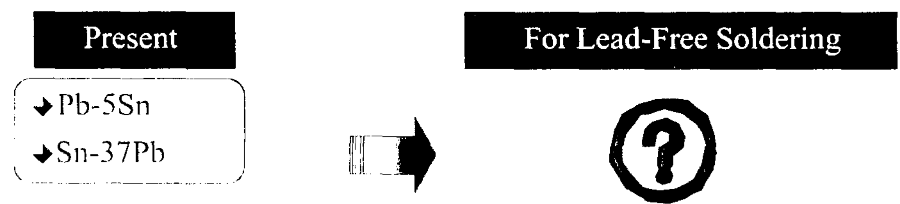
Solder Bumping for Lead-Free Soldering



What kind of lead-free solder is ideal for the solder bump?



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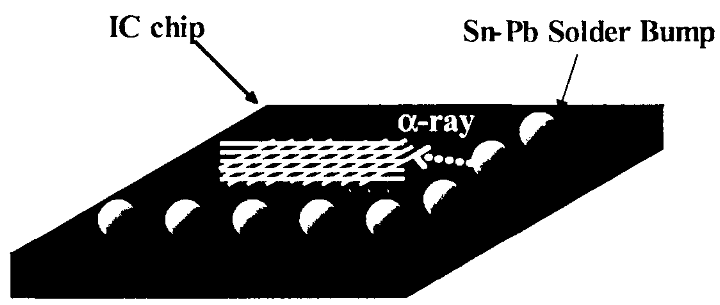
Malfunction of Integrated Circuit by α - ray from Radiochemical Impurities in Lead.



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Formation Methods of Solder Bumps

Method	Note
Evaporation method	The batch processing.
Ball Mounting method.	The contrivance of the mounting jig
Soldering paste screen printing process	Contrivance of mask and paste.
Micro Punching Method	For development and trial manufacture.
Ball Bonding Method	For development and trial manufacture
Solder injection Method	For substrate bump formation
Super Solder Method	Substitution deposition of lead on tin particle.
Super Juffit Process	The special adhesion layer on Cu.
Electroplating Method	Photolithography
Dimple Plate Method	Silicon wafer with anisotropic etching.
Dip Method	Dipping into Melting Solder
Metal Jet Method	Principle of ink jet printing

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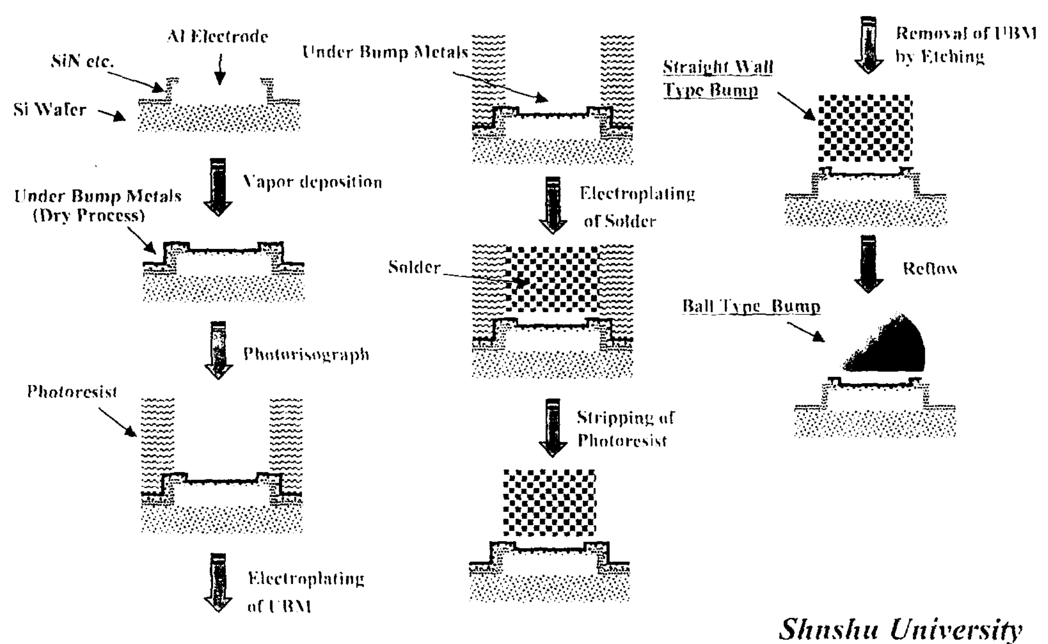
Solder Bump Formation Process using Electroplating Method



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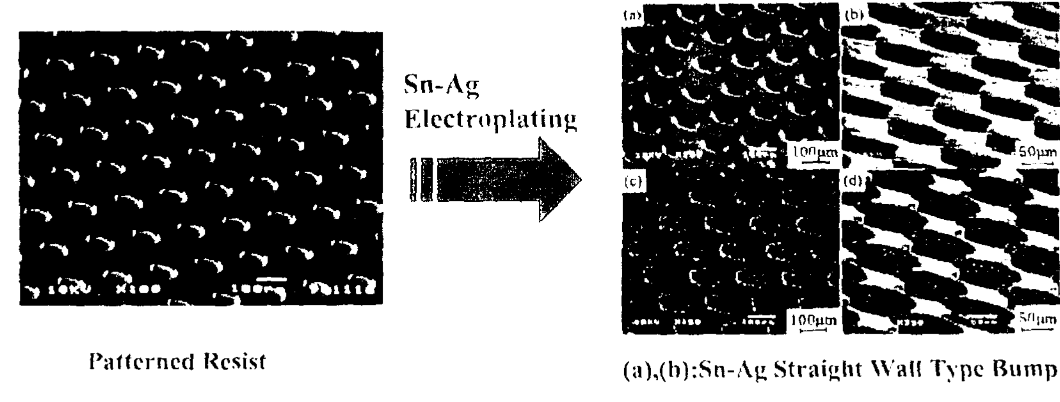
Sn-Ag Solder Bump Formation using Electroplating Method



Patterned Resist

(a),(b):Sn-Ag Straight Wall Type Bump

(c),(d):Sn-Ag Mushroom Type Bump

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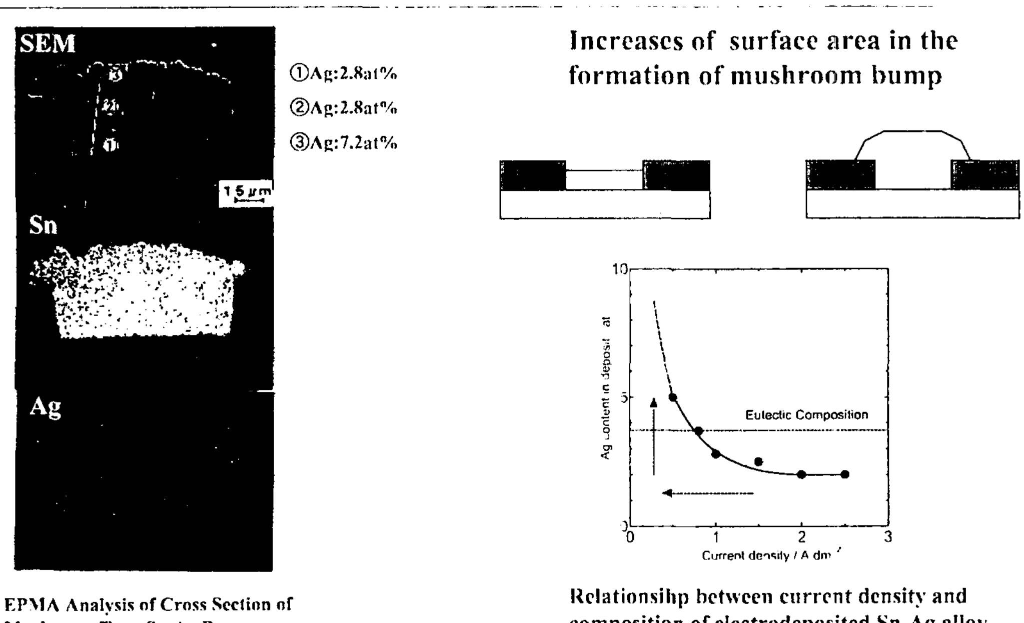
Cross Sectional Analysis of Mushroom Type Sn-Ag Solder Bump



EPMA Analysis of Cross Section of Mushroom Type Sn-Ag Bump

Relationsihp between current density and composition of electrodeposited Sn-Ag alloy.

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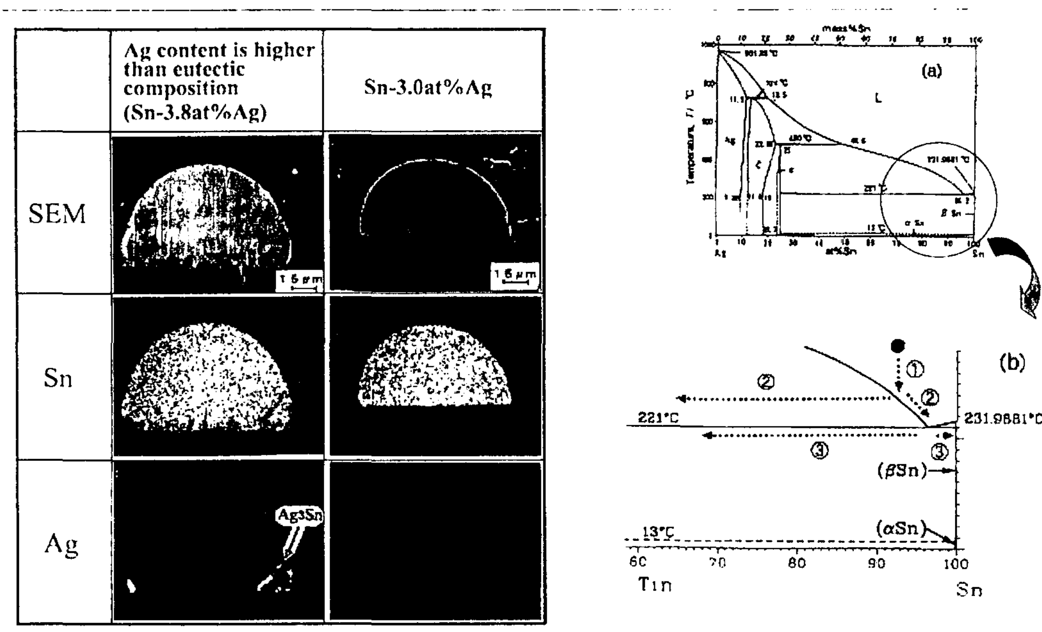
Cross Sectional Analysis of Ball Type Sn-Ag Solder Bump



EPMA analysis of ball type Sn-Ag Solder bump

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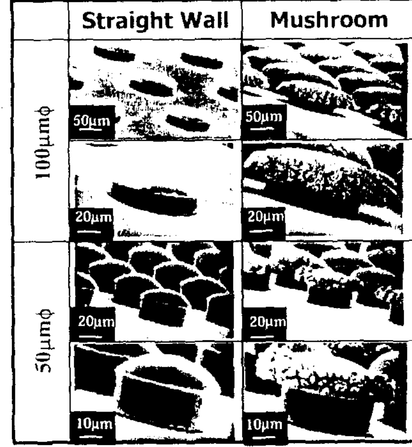
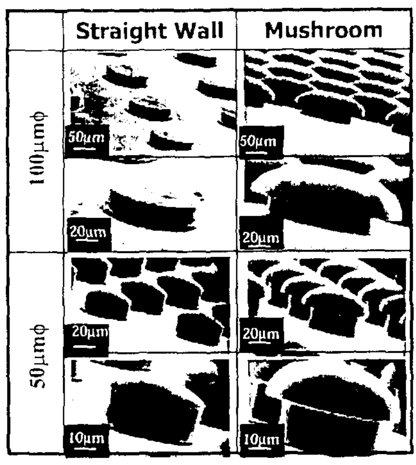
Electroplating Sn-Ag Solder Bump Formation under Galvanostatic Mode and Potentiostatic Mode



Galvanostatic Mode



Potentiostaic Mode

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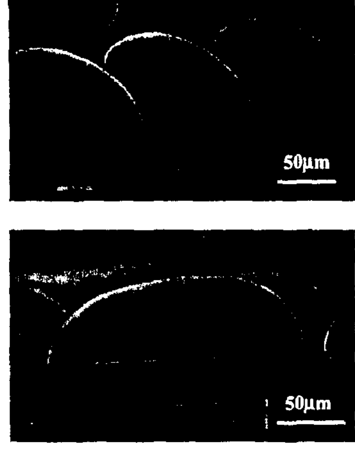
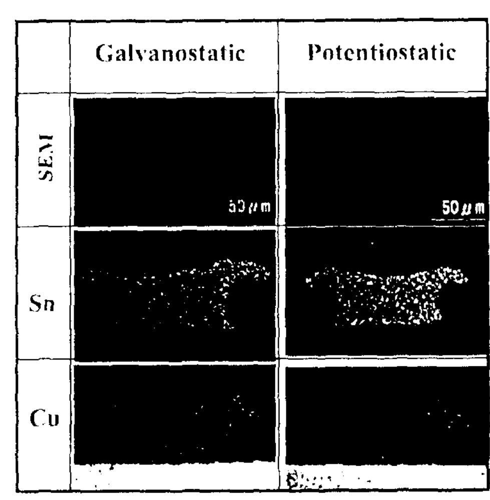
Sn-Cu Solder Bump Formation using Electroplating Method



SEM photographs of mushroom type Sn-Cu bumps



EPMA analysis of mushroom type Sn-Cu bump

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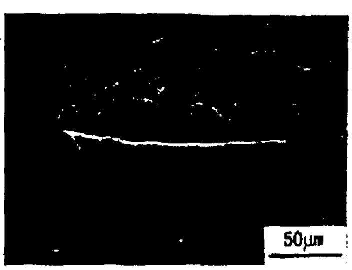
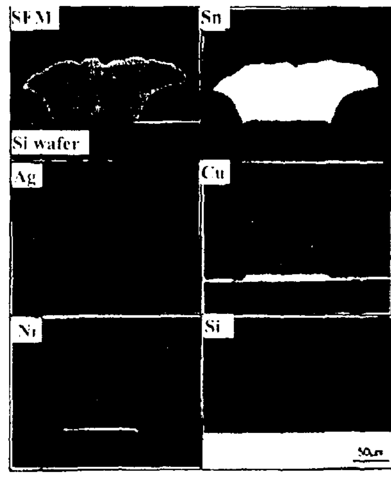
Sn-Ag-Cu Solder Bump Formation using Electroplating Method



SEM photographs of mushroom type Sn-Ag-Cu Solder Bumps



EPMA analysis of a mushroom type Sn-Ag-Cu Solder bump

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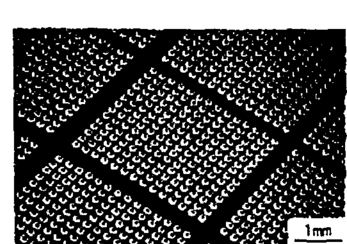
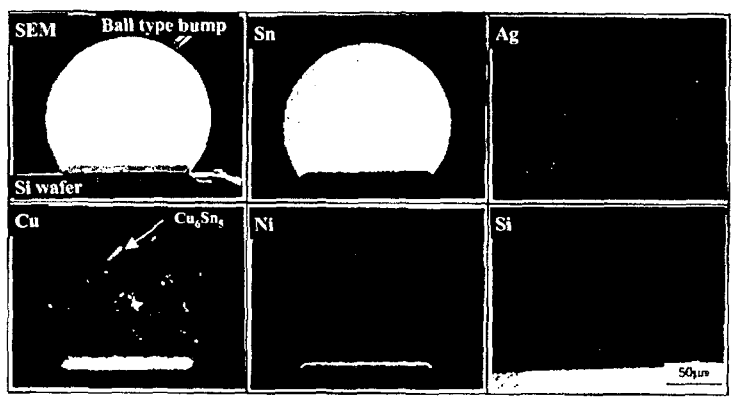
Cross Sectional Analysis of Ball Type Sn-Ag-Cu Solder Bump



SEM photograph of Ball type Sn-Ag-Cu bumps



EPMA analysis of a ball type Sn-Ag-Cu Solder bump

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Conclusion

- In Japan, the lead-free soldering technology has been powerfully advanced, and the surface treatment technology of parts for lead-free soldering has come to a stage of the practical application.
- Sn-Bi plating, Sn-Ag plating, Sn-Cu plating are examined as surface treatment of semiconductor parts (outer lead) at present.
- As a surface treatment of chip parts, Sn plating is regarded as promising.
- As surface treatments of substrate, the followings are examined : Pre-flux processing, electroless Ni/Au plating, electroless Ag plating, etc..
- Lead-free solder bump formation technology using electroplating method has been developed.
- I hope that the lead-free solder plating technology opens up a new global market.

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