Lead-free Implementation and Issues in Electronic Set Makers

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ISMP2004

Lead-free Implementation & Issues in Electronic Set Maker

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Contents

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■ Environmental Regulations

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	Regulations	Region	Timeline	Contents
Hazardous Materials	RoHS	EU	'06.07	• Restrictions on 6 Hazardous Material (Cd, Pb, Hg, Cr6+, PBB, PBDE) ☞ Electrical and electronic equipments
	REACH	EU	Being considered	• New EU regulatory framework for chemicals ☞ More than one ton of a chemical substance per year would be required to register
	Proposition65	US (CA)	'86.11	• Manufactures should provide a "clear and responsible" warning before exposing anyone to a listed chemicals ☞ over 700 chemicals, special regulation for Pb ('03.9, 300ppm)
EPR	WEEE	EU	'05.08	• Producers must recover and reuse/recycle the waste (Recycle/Reuse system set-up: ~ '05.08) • Reuse/Recycling rate Minimum 65~75% ('06.12.31) ☞ Electrical and electronic equipments
	Recycling	Japan	'01.04	• Recycling of 5 Electrical Products (50~60%) ☞ Refrigerator, Washing Machine, Air-conditioner, TV, PC

Life Cycle	Law Material	Component	Product	Use of Product	Waste
Regulations	**RoHS**, REACH, Proposion65			Vermont	**WEEE**, Recycling

✓RoHS : Restriction of Hazardous Substance
✓REACH: Registration, Evaluation and Authorization of Chemicals
✓EPR : Extended Producer Responsibility
✓WEEE : Waste of Electric and Electronic Equipment

✓ Heavy Metals (4): Cd, Pb, Hg, Cr6+
✓ Brome containing (2) : PBB, PBDE
- PBB : Poly Brominated Biphenyl
- PBDE : Poly Brominated Diphenyl Ethers

■ SEC Eco-Product

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■ **Lead-free : Lead-free Mfg. ready for all business unit by Sep. 2004**
■ **Eco-Design : Remove RoHS-restricting materials for all developing sets from Jan. 2005**
■ **Eco-Partner : Supply Chain ready for RoHS restriction by Jun. 2005**

2002	2003	2004	2005	2006	2007
1 GBM, 1 Model Adoption (Dec. '03)			Japan (ready)	EU	
				(China)	

Lead-free Transition Ready (Sep.'04)

• **SEC Lead-free Symbol**

LEAD-FREE	@	©	®
	Sn-Ag series	Sn-Cu series	Sn-Zn series
Component	PCB		

■ Lead-free Qual

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• **Lead-free Transition Phases**

Step	Item	Condition	Status
STEP 1 **Material Selection**	o Standard Lead-free Alloys Selection o Material Properties Evaluation (10 items)	JIS Z3284 spec. (Sony, Dell Spec. B/M)	**Lead-free Alloy Standardization (Sn-Ag-Cu etc.)**
STEP 2 **Process Optimization**	o Soldering Process Optimization DOE - Test Board Level (Flow, Reflow, Repair) o Thermal Shock, Temp./Humidity Test - 1000 cycle	Better or similar joint strength than SnPb solder (ref.)	**Completed**
STEP 3 **Reliability Test**	o PCB Ass'y Level Reliability Test (5 items) - Thermal Shock, Temp./Humidity test 1000 cycle o Set Level Reliability Test	Reliability Tests of each SEC business unit+ Buyer requirements on reliability	**Completed**
STEP 4 **Main Product Application**	o Lead-free Mfg. Evaluation for Main Products o Short Term Market Reliability Check - 6 months	Insure quality and reliability equivalent to or better than SnPb	**Completed**
STEP 5 **Mass Production**	o Outsourcing Company, Overseas Factories o Long Term Market Reliability Check - 24 months	Insure quality and reliability equivalent to or better than SnPb	**5 Product Completed**

■ Solders and M

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o SEC Standard Alloy Selections

- Reflow : ① Sn-3~4Ag-0.5~0.7Cu ② Sn-8Zn-3Bi :for low temp
- Wave : ① Sn-3~4Ag-0.5~0.7Cu ② Sn-0.7Cu
- Repair : ① Sn-3Ag-0.5Cu

o Acceptable Components Materials

- Surface Finish : ① Ni/Au, Ni/Pd, Ni/Pd/Au - OK
  ② Matte Sn, Sn-(0~3wt.%)Bi – Need Whisker Test Data
  - Thickness: minimum 8 ㎛ (10㎛ recommended)
  - Ni 1.5 ㎛ under-layer is needed for Alloy42, Cu-base alloys
- BGA/CSP Ball : ① Sn-Ag-Cu
- Flip Chip Bump : ① Sn-Ag ② Sn-Cu for Electroplated Bump
  ③ Sn-Ag-Cu for Stencil printed Bump

※ Not Acceptable : Pb, In, Bi (over 3%)

o PCB Surface Treatment

- ① OSP ② ENIG ③ Immersion Ag

■ Test Items for Sol

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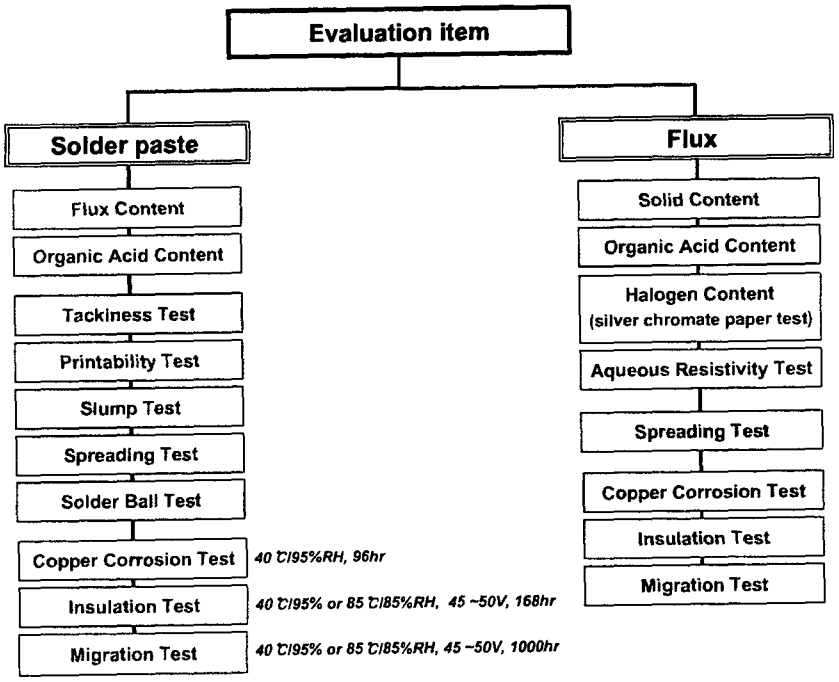

■ Test Items for La

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Comp.	Item	Spec.	Criteria
Non Solid (Passive Comp.)	Heat Resistance	▪ Apply according to usage conditions 1) Reflow: Peak ≥260℃ (≥10sec) ≥ 217℃ (90~120sec) 2) Wave : 260± 5℃ (10± 1sec) 3) Iron : 400± 10℃ (4~5sec)	▪ Electrical function : Satisfied with Spec. ▪ Apparatus function : Satisfied with Spec. ▪ Appearance : Crack, No alteration
Solid State	Moisture Sensitivity	▪ External/Internal inspection after/before test ▪ Baking : 125+5-0℃ Min 24hr ▪ After Temp./Humidity test : Over 30℃60% 192hr ▪ After Temp./Humidity test : Test within 15m~4hr 1) Peak 250℃+0-5℃ (20~40sec) ≥ 217℃ (60~150sec)	▪ De-lamination, Wire Open, No Crack.
All	Soldering for components	▪ Steam Aging : 93± 3℃100%, after 8hr 1)Reflow : 1)Reflow : 150~180℃ (50~70sec) 220℃↑ (20~30sec) 240~245℃ (Peak) 2) Wave : 245℃± 5 (3± 1sec)	▪ Min 95%
Pitch ≤0.5mm (IC, Connector)	Tin Whisker	▪ Conduct test with upward of conditions 1) 60℃,95%RH 1000 hr 2) -55℃/+85℃ 30 min/cycle 1000 cycles	▪ Max 50㎛

L/F Reliability

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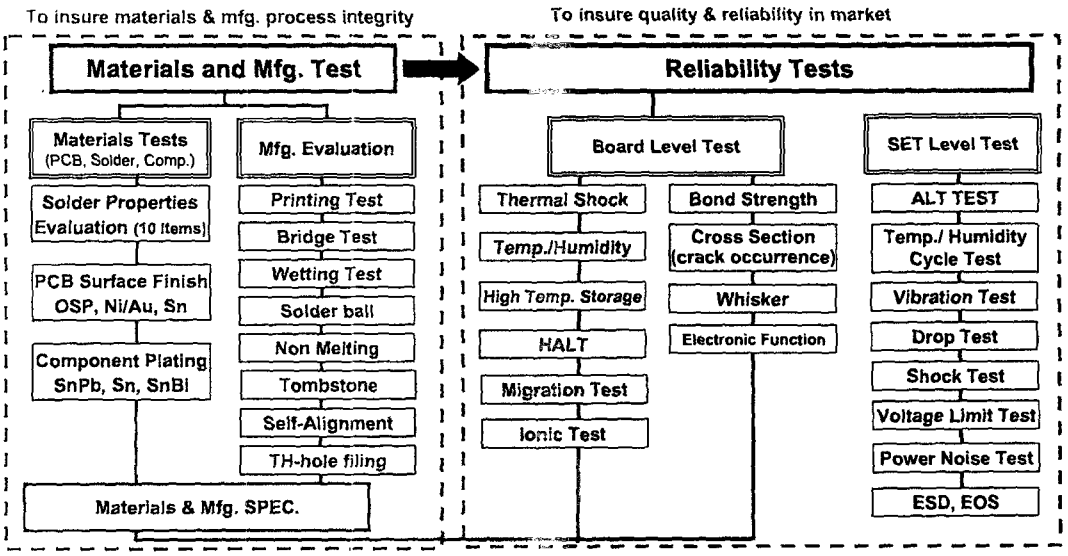

Lead-free Mig

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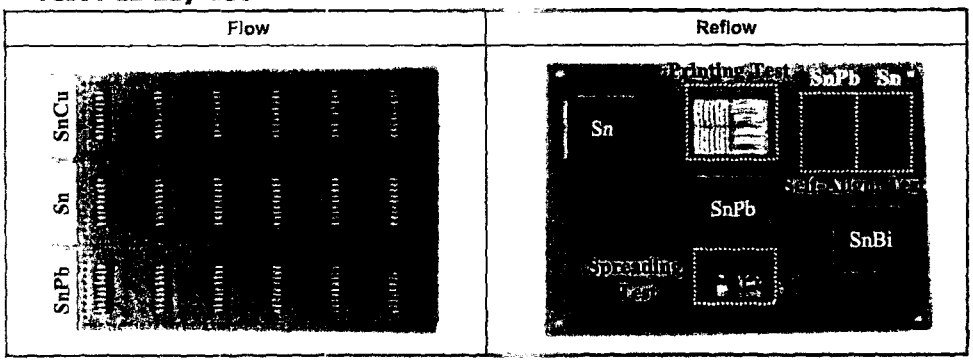
• **Solders and Materials for Process Development**

Process	Solder Comp.	PCB		Component	
		Surface Finish	Thickness	Type	Surface Finish
Flow	Sn-37Pb	OSP	1.6t (FR-1)	Connector	SnPb
	Sn-0.3Ag-0.7Cu				Sn
	Sn-0.7Cu				SnCu
Reflow	Sn-37Pb	OSP	1.6t (FR-4)	0.5 QFP	SnPb Sn SnBi
		Sn			
	Sn-3.0Ag-0.5Cu	Ni/Au		1608C, R	SnPb Sn

• **Test PCB Lay-out**



■ Wave Soldering

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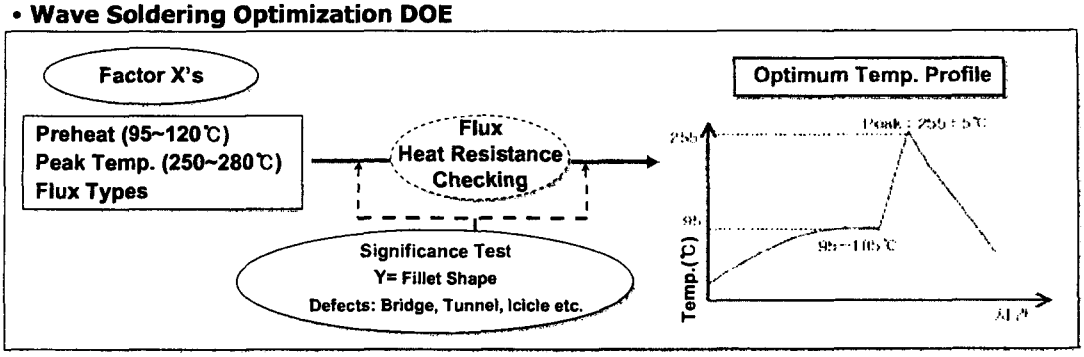
• **Wave Soldering Optimization DOE**



• **Problem & Measures in Wave Soldering**

Profile	Design	Equipment
▪ Preheating temp: 100 ± 5℃ ▪ Peak Temp. : 255±5℃ ▪ Dip time: 3 ~ 5sec ▪ Cooling condition: **rapid cooling** (Peak temp. → solidification temp. : ~ 8℃/sec) ※ Double-sided, Mixed tech.: during Wave soldering → **Top side temp. 150℃↓**	▪ Solder composition - Single-side PCB : Sn-Cu - Double-side PCB: Sn-Ag-Cu **→ good through-hole filling** ▪ Flux - Rosin content ↑ : Improvement of solder wetting - Heat resistance ↑ ▪ Improvement of the PCB design	▪ Cooling system: prevention of solidi -fication defect ; shrinkage crack & Lift-off ▪ Solder pot material: SUS304 → SUS 316L + heat-treatment ▪ Installation of guide line

■ Fillet Shape after

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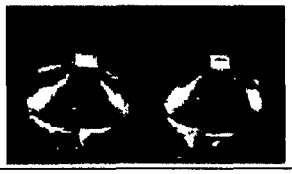
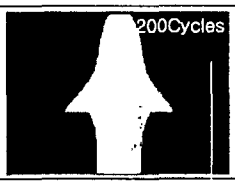
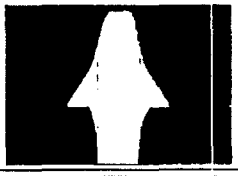
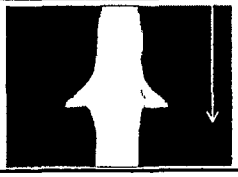
• **Wave Soldering condition: preheating temp → 98℃, peak temp → 255℃**

• **All good fillet shape: lead finish → SnPb, Sn, SnCu**

Finish	Fillet Appearance	Fillet cross-Section
SnPb		
Sn		
SnCu		

Printing Test

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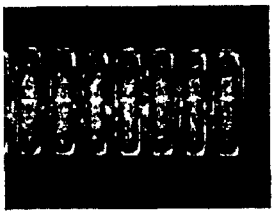
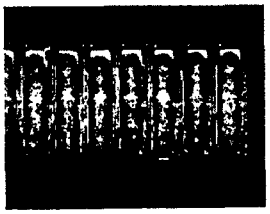
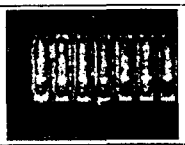
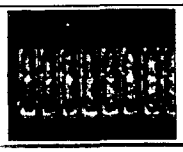
• **Solders and Materials for Process Development**

Factor X's	SnPb	SnAgCu	Test Method
Snap off Speed	0.5 mm/sec	**1.0 mm/sec**	DOE (2- Sample T) Y= Print height, Height Dev., Print Shape, Print Defects
Print Speed	50 mm/sec	**50 mm/sec**	
Print Pressure	1.5 Kgf/cm²	**2.0 Kgf/cm²**	
0.4mm pitch print shape			

• **Continuous Printability Evaluation: No bridge untill 50th Print**

1st	20th	40th	50th
			

Mounting Test

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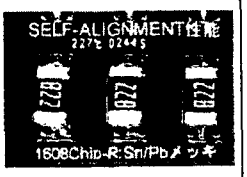
• **Self-Alignment Test Results (1/2 X Shift)**

→ Mounting accuracy should be increased to within1/3 of pad size for Sn plated passive in SnAgCu reflow.

Finish	After Mounting	During Reflow	After Reflow	Comment
SnPb Plating				100% Self-Alignment
Sn Plating				80~85% Self-Alignment

■ Reflow Soldering

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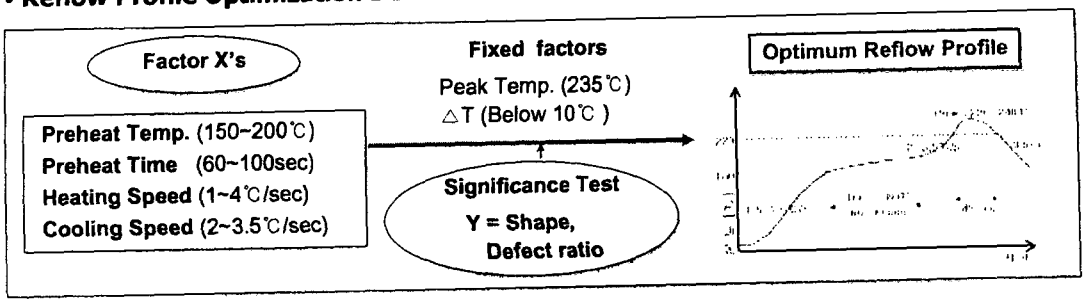
• Reflow Profile Optimization DOE



• Problem & Measures in Reflow Soldering

Profile	Design	Equipment
▪ Preheat Temp. : 160~180℃ ▪ Preheat Time : 60~90sec ▪ Time above 220℃ : 45sec ▪ Peak Temp. ≥ 235±5℃ ▪ Temperature Deviation, △T ≤ 5℃	▪ PCB finish : HASL not allowed (OSP, Sn, ImAg, EMIG) ▪ PCB Tg : Middle Tg ↑ ▪ Pad to Mask Opening Size = 1 : 1 (Due to low spreadability of Lead-free Solder) ▪ Comp. Heat Resistance: 260℃,10sec (IC, LED Electrode, connector, housing materials)	▪ Mounter Accuracy Control (Low self- alignment characteristic) ▪ Reflow Oven - Heater Capacity : Lead-free Temp. Profile (Zone #, Length, Max. Temp. etc) - N_2 Reflow

■ Reliability Test

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• PBA Level Reliability Test

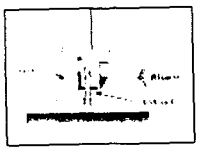
Thermal Shock Test: -40℃/ +85℃, to 1000 cycles.

Temp./Humidity Test: +85℃/85%RH, to 1000 hrs.

- Bond Strength and Microstructure Analysis at every 200cycle and 100hr.

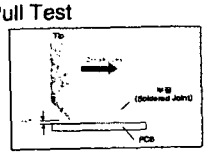
• Bond Strength Test

Shear Test



- Tip Height : 500㎛
- Test Speed : 200㎛/s

Pull Test



- Tip Height : 10㎛
- Test Speed : 200㎛/s

- Test Speed : 200㎛/s

• Thermal Shock Test Result

Wave Soldering (OSP PCB finish, 500cycles)

Comp. \ Solder	SnPb	SnAgCu	SnCu
SnPb	Min. 6.9kgf	Min. 3.6kgf	Min. 5.2kgf
SnCu	Min. 5.1kgf	Min. 4.6kgf	Min. 5.2kgf
Sn	Min. 5.1kgf	Min. 4.9kgf	Min. 4.9kgf

Reflow Soldering (OSP PCB finish, 1000cycles)

Comp. \ Solder	SnPb	SnAgCu	SEC Spec
1608R (SnPb)	Min. 3.8kgf	Min. 4.1kgf	> 2.0kgf
1608R (Sn)	Min. 3.0kgf	Min. 4.0kgf	
0.5 QFP (SnPb)	Min. 1.0kgf	Min. 1.0kgf	> 1.0kgf
0.5 QFP (SnBi)	Min. 1.4kgf	Min. 1.1kgf	
0.5 QFP (Sn)	Min 1.5kgf	Min 1.2kgf	

Reliability of Lead-free solder joint is equivalent to or better than that of Sn-Pb.

■ Fillet Shape after

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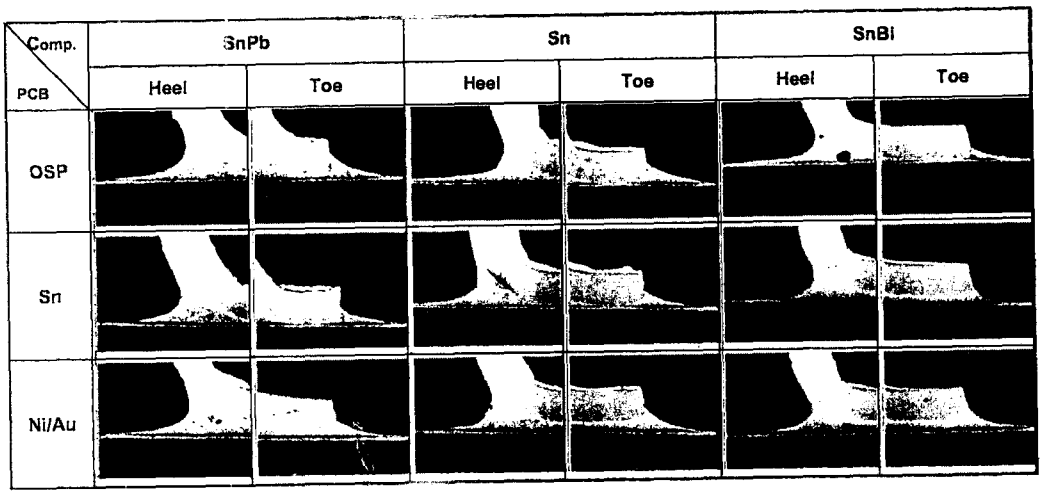
- **After thermal shock 1000 cycles**

There was no crack in solder joint for all **Component & PCB surface finish.**



■ PCB Design Change

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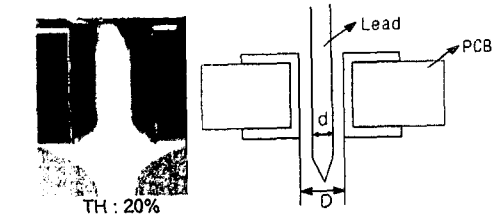
- **Lead-free Wave Soldering**

  - Issue: Not enough TH-filling
  - Cause: Lower solderability of lead-free solder
  - solution: Land hole size increase (diameter)



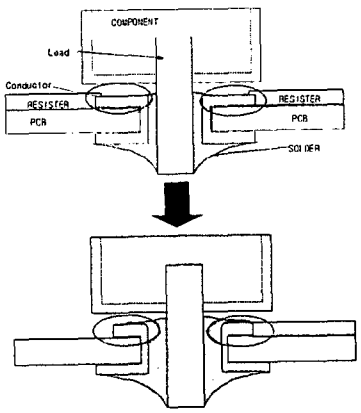
TH : 20%

- D = d + 0.4 ~ 0.6mm

- D' = D × 1.1

TH : 100%

  - Issue: Land finish layer of the component side is exposed (Double-sided PCB)
  - Cause: Lower wettability of lead-free solder
  - Solution: reduction of conductor size



- Conductor size: 10% reduction compared to conventional design

■ PCB Design Guide

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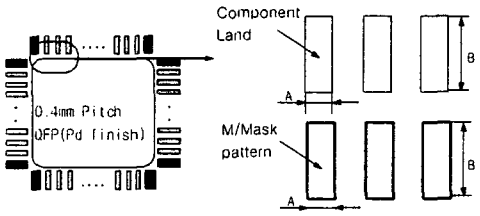
• Lead-free Reflow Soldering

- Issue: Bridge in 0.4mm pitch Pd finish QFP lead
- Solution: Pad size change (width↓, length↑)
  Mask pattern size change



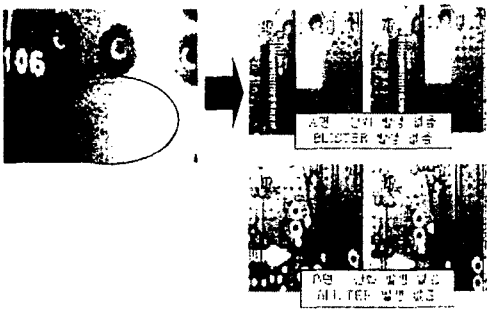
unit: mm

	A	B	M/M Thickness
PAD	0.22	0.9	
M/Mask	0.191	1.1	1.2

unit: mm

	A	B	M/M thickness
PAD	0.2	1.3	
M/Mask	0.19	1.5	1.3

- Issue: As reflow peak temp. increases, blister occurred on the Phenol PCB
- Solution: Make holes in PCB for gas venting



- solder: Sn3Ag0.5Cu
- PCB: FR-1(Phenol)
- Reflow peak temp.: 240℃
- Trouble: PCB Blister
  → vent gas on PCB (hole size: 0.5Ø, Pitch 5.0mm)

■ Lead-free Rework

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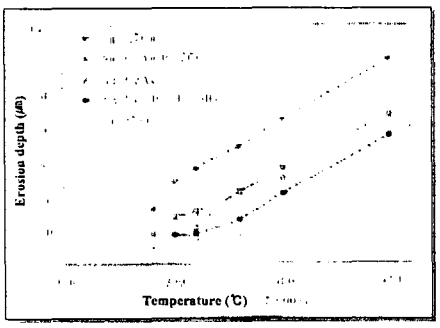
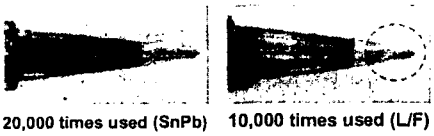
• Issues

Lead-free Solder Rework : Erosion of soldering iron increase due to higher working temperature
→ Iron tip life time decrease to 1/2 ~ 2/3 of Sn-Pb.

• Erosion of Soldering Iron





20,000 times used (SnPb) 10,000 times used (L/F)

• Working Condition

- **Tip Temp. : 360 ~ 390℃**
  (SnPb: 280~320℃)
- **Tip life time : decrease to 1/2 ~ 2/3 of Sn-Pb.**

• Rework Defect Examples

Non-wetted region due to low spreadability of L/F solder

Earing, whitening due to overheat

Insufficient heat due to iron tip deterioration