Pb-free Status and Strategy of Semiconductor Business in Samsung Electronics

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Eco-Product Status and Strategy of Semiconductor Business in Samsung Electronics

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Semiconductor Business
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Worldwide Eco-product Trends

- No pending legislation following defeat of Reid Bill (1991)
- International restrictions WILL affect U.S. exports
- Draft WEEE (Waste from Electrical and Electronic Equipment) Directive/RoHs: proposes lead ban in Europe by 2006. 7.
- Individual EU members (Denmark and Sweden) are imposing separate restrictions on industrial lead usage
- Joint EU and other independent projects studying changeover to lead-free solders
- NCMS/CALCE Lead-Free Solders Project (LFSP) examined over 70 lead-free candidate alloys (1997)
- NEMI Lead-Free Assembly Project (LFSP) suggests Sn3.8Ag0.7Cu for reflow, Sn0.7Cu, Sn3.5Ag for wave soldering (2000)
- Most major Asian manufacturers (e.g. Samsung, Fujitsu, Hitachi, Matsushita, Mitsubishi, Toshiba) plan for lead-free product lines by 2001-2005
- Significant landfill restrictions enacted in Japan by 2001
- Green products linked to quality and improved bottom line

* WEEE :waste from electrical and electronic equipment
* RoHS :restricting the use of hazardous substances

Original Data from B. Han of CALCE

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Green Development History

From 1998	Began a basic research for developing the green semiconductor.
Feb. 2000	Set up the Lead-free Product TFT team responsible for removing lead from packages and modules and strengthened the development effort.
Oct. 2000	Set up the Green Product TFT team charged with eliminating lead and halogenated compounds.
May 2001	Developed the 1st Samsung green semiconductor.
From May 2001	A TFT team has been overseeing a device solution network(DSN) for mass-producing eco-products or expanding product lines. In addition, Samsing Electronics has been improving production techniques.
From 2003	Lead-free production system is adopted for all products
From 2004	RoHS compliant product development system is adopted for all products

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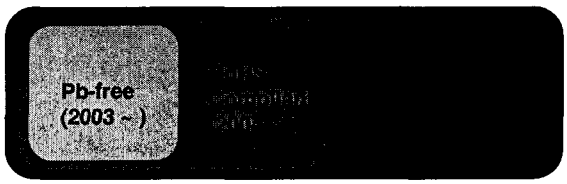
Eco-product



(Based on EU RoHS Directive and Customer Requirements)

RoHS compliant (Available)	
	Upper Limit(%)
Cr+6	**0.01**
Cd	**0.0005**
Hg	**0.01**
PBBs	**0.01**
PBDEs	**0.01**
Pb	**0.1(in solder)** **0.01(except solder)**

Halogen-free (Developing)	
	Upper Limit(%)
Cr	**0.09**
Br	**0.09**
Sb	**0.09**

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Eco-product Strategy

1. GPS(Green Procurement System) : Employed for raw material acquisition/ processing. (Environmentally friendly supply network)

2. Production procedures : Improved through "clean technologies" to minimize the use of raw materials.

3. Product Design : Refined to strengthen the energy-saving capability of products.

4. Study on Disposal : Focused on Recyclability/Reusability.

5. Database : Based on product-related environmental information
(Disclosed in the future.)

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Green Procurement

1. Definition: The act of procuring eco-products and services
2. Objective:
   - Achieve compliance with European Parliament's Directive on Restriction of the Use of Certain Hazardous Substances (RoHS) by 2006
   - Six toxic substances (Pb, Cd, Cr+6, Hg, PBBs, PBDEs)
3. Roadmap: Step 1 (~'03): design the green procurement system
   Step 2 (~'04): set green procurement methods and ban hazardous substances
   Step 3 ('05~): raise competency through green supply networks
4. Green procurement audit procedure
   - Target of audit : On-Site Audit(containing banned material),
     Documentary Audit(not containing banned material).
   - Audit appraisal : 3parts (System: Eco-administration system, Operation: Hazardous material management system, Process: Material/product management)
   - Additional points are given to suppliers with ISO14001 certification

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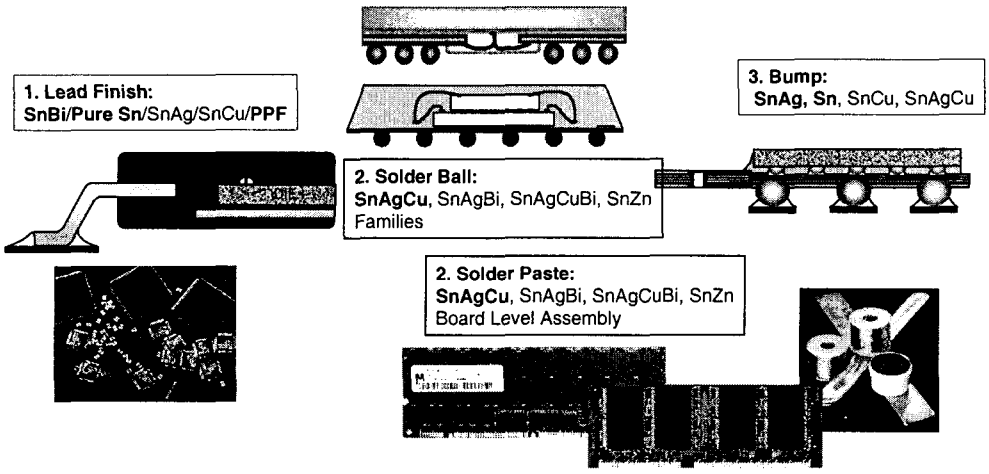
The Parts which must be changed to the Lead-free

Lead frame Package | **BGA Type Package** | **Flip Chip Package**



1. Lead Finish:
SnBi/Pure Sn/SnAg/SnCu/PPF

2. Solder Ball:
SnAgCu, SnAgBi, SnAgCuBi, SnZn Families

3. Bump:
SnAg, Sn, SnCu, SnAgCu

2. Solder Paste:
SnAgCu, SnAgBi, SnAgCuBi, SnZn
Board Level Assembly

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Preferential Pb-free Lead Finish

	Sn	SnBI	SnAg	SnCu	Pd
ASIA	SEC (Developing)	SONY, Fujitsu, Matsushita NEC, TOSHIBA, Renesas SANYO, **SEC(Mass Prod.)**	TOSHIBA	TOSHIBA Renesas Rohm	SONY, Matsushita TOSHIBA, Renesas, SEC (Developed)
US	MOTOROLA, TI, Intel National Semiconductor ON Semiconductor AMD, Fairchild	MOTOROLA (for Japan customers)			MOTOROLA, TI, Fairchild On Semiconductor
EU	Infineon, Phillips ST Microelectronics				Philips Cypress

	Asia	US	EU	Total
Pure Sn	1	6	3	10
Sn-Bi	9	2		11
Sn-Cu	2	1		3
Sn-Ag	1	1		2
NiPdAu	5	3	2	10

*20 Companies : Samsung, Intel, Renesas, TI, Toshiba, ST Micronics, Infineon, Philips, NEC, TSMC, Motorola, IBM, Matsushita, Fujitsu, AMD, SONY, Sharp, Seiko-Epson, HP, Amkor

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RoHS Compliant Product Qualification and Production Status (Memory)

Memory Components

Product Families	Qualified Product	Comment
Component (Plastic Package, Substrate Package)	TSOP	Under mass production
	SOJ, SOP, DIP	Under mass production
	WSOP, QDP	Under mass production
	TQFP, LQFP	Under mass production
	WBGA	Under mass production
	FBGA, PBGA	Under mass production

Memory Module Components

Product Families	Qualified Product	Comment
Module	SODIMM(Sync/DDR Unbuffer)	Under mass production
	RIMM	Under mass production
	Sync DIMM (Buffered/Unbuffered)	Under mass production
	DDR DIMM (Buffered/Unbuffered)	Under mass production
	Card(Memory Stick)	Under mass production
Card	xD card, RSMMC, MMC COB	Under mass production

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RoHS Compliant Product Qualification and Production Status (System LSI)

System LSI Components

Product Families	Qualified Product	Comment
QFP/LQFP	100, 128, 240/64, 144,160,208,256	
TQFP	80,100	Under mass production
Others	64WQFP, 84ELP	
BGA/HBGA/FBGA	272_2L/4L,304,492/480/64,144,256,272	
BGA	272/484BGA,176CABGA,144/160/208TBGA	Under mass production
Others	83TALGA	
QFN	24	Under mass production
FBGA	144FBGA	Under mass production
SOP	20/28/32SOP, 20SSOP	Under mass production
QFP	48QFP, 48LQFP	
L/F	8SOP, 8DIP	Under mass production

All types of Pb-free memory/S-LSI products were qualified.

♣ Halogen-free Product

♦The halogen-free packages and modules will go into mass production in 2005

♦SEC will convert all our products to halogen-free ones by 2006

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Pb-free Lead Finish Development Roadmap

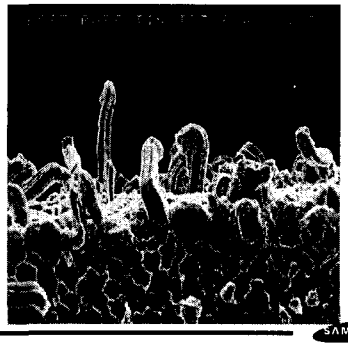
Lead frame Package

Lead Finish:
SnBi, Matte Sn, PPF(Sn, Pd)

■ Pb-free Lead finish Development Roadmap

		'03	'04	'05
Plating	Sn-Bi	Qual	Mass Prod.	
	Pure Sn		Qual	
Pd PPF		Qual	Risky Prod.	

	Advantages/Disadvantages
SnBi	-. Popular in Japanese manufacturers -. Difficult to control alloy composition -. Bi is by-product of Pb-mining
Pure Sn	-. Low cost solution -. Popular in US, EU -. Whisker issue
Pd PPF	-. Whisker-free -. A42 : Corrosion -. Incompatibility(Test) -. High Cost



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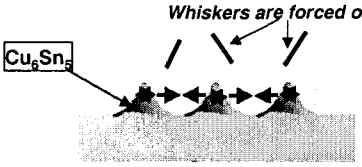
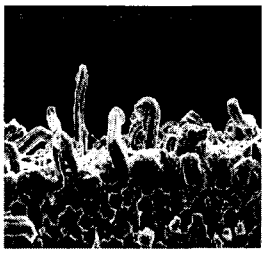
Whisker Mechanism

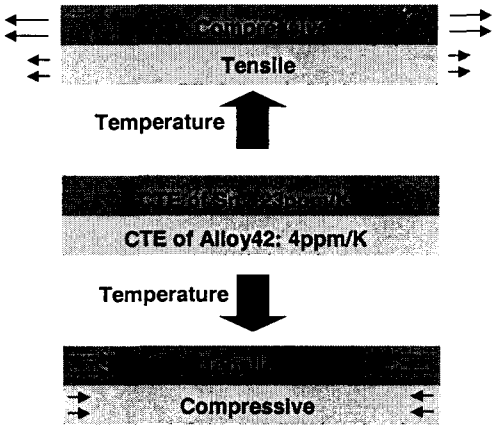
** Compressive Stress Caused By IMC Growth(Cu L/F)*



Adapted from Lee B.Z, and Lee D.N., Acta Metallurgica(1998)



** Compressive Stress Caused By CTE mismatch(Alloy42 L/F)*



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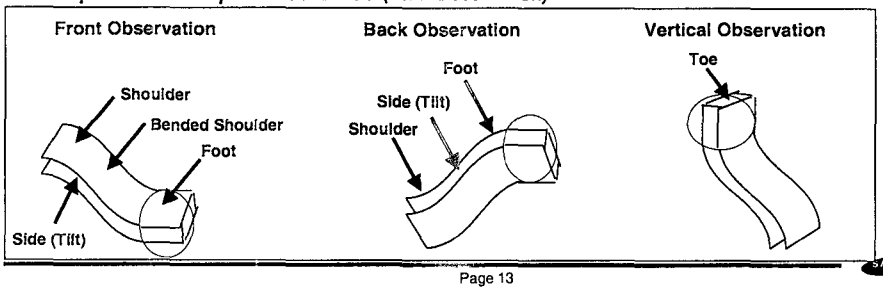
Whisker Spec. and Inspection Method

■ *SEC's Whisker Spec*

● Standardized by NEMI(2003) (10 chips for each condition)

Test Item	Conditions	Maximum Whisker Length
Temperature Cycles	-55 ℃ ~ 85 ℃, 500 cyc., 3cyc/1hr	Below 50 ㎛ (Pass)
Temperature/Humidity	60 ℃/93 %, 1000 hr	Below 50 ㎛ (Pass)
Ambient	Room Temperature, 6 month	Below 50 ㎛ (Pass)

■ *3 Step Whisker Inspection Method (SEM Observation)*



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Comparison of Whisker Test Methods

Tests	NEMI	JEDEC	SEC(Semicon.)
Aging Test (Hightemp/humidity)	60'C / 93+2-,3%RH	60'C / 93 +2-,3%RH	60'C / 93%RH
TC Test (Temperature Cycling)	-55+0,-10'C ~ 85+10,-0'C (soak 10min., 3cycle/hour)	-55+0,-10'C ~ 85+10,-0'C (soak 10min., 3cycle/hour) R/O: every 500cycles	-55'C ~ 85'C
Storage Test (Ambient)	20~25'C, 30~80%RH	30+/-2'C, 60+/-3%RH R/O: every 1500hrs	Air conditioned facility
Bias Test	Storage test with +5Volts bias	-	-

Tests	NEMI(2004.5.~)	JEDEC(2004.6.~)	SEC(Semicon.)
Aging Test (Hightemp/humidity)	Minimum 4000hrs	Appropriate duration	1000hrs
TC Test (Temperature Cycling)	Minimum 1000cyc	Appropriate cycle	500cycle
Storage Test (Ambient)	Minimum 4000hrs	Appropriate duration	6months

* SEC's unified whisker test spec. will be determined based on NEMI's.(~ 2004. 3Q)

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NEMI Proposal (2004.5. ~)

Maximum Whisker Length			
Device Considerations (Package type, lead pitch or operating frequency)	**Class 1**	**Class 2**	**Class 3**
Discrete Device (2 pins)	67 µm [1]	40 µm	Pure tin and high tin content alloys not acceptable.
Multi-lead packages	(Minimum gap between leads - .05mm)/3 or 67 µm, whichever is smaller[1][2][3]		
Operating Frequency > 6GHz (RF)[4] or t_{rise} < 59 psec (digital)	50 µm		

Table 1: Whisker Length Limits

18.4.1. Class 1

Consumer Products, Typically with relatively short product lifetimes (5 years *maximum is typical). No major concerns by the user that the tin whiskers might* break off and cause problems elsewhere in the product.

18.4.2. Class 2

High Reliability Business Applications such as Telecom Infrastructure equipment, High-end Servers, etc. which require long product lifetimes and minimal downtime. Products such as disc drives typically fall into this category. Breaking off of a tin-whisker is a concern.

18.4.3. Class 3

Mission/Life Critical High Reliability Applications such as military, space and medical applications. Pure tin and high tin content alloys not acceptable.

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Whisker Evaluation Result

■ ***Whisker Evaluation Status (by SEC Spec., SnBi on Alloy42, Mass Production)***

● **SEM Inspection for 20 chips (Package type: 66 TSOP) → ※ Total 1320 Leads Inspected**

Test Items	Test Condition	Max Whisker Length	
Temperature Cycles	-55 ℃ ~ 85 ℃, 3cyc/1hr	4.4 ㎛	21.7 ㎛
Temperature/Humidity	60 ℃/93 % RH	6.5 ㎛	11.2 ㎛
Ambient	Room Temperature, (20~25℃)	5.8 ㎛	8.9 ㎛

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Matte Sn Finish Development Status

1) Component Level Reliability: Passed

Lot ID	Front	Back	Finish	DC	Final
A solution (In 360 ea)	360	360	360	360	360
Yield	100.00	100.00	100.00	100.00	
B solution (In 360 ea)	360.00	360.00	360	360	360
Yield	100.00	100.00	100.00	100.00	
A solution/Ni (In 216 ea)	216	216	216	216	216
Yield	100.00	100.00	100.00	100.00	
B solution/Ni (In 144 ea)	144	144	144	144	144
Yield	100.00	100.00	100.00	100.00	
A solution/X (In 360 ea)	360.00	360.00	360.00	360.00	360
Yield	100.00	100.00	100.00	100.00	

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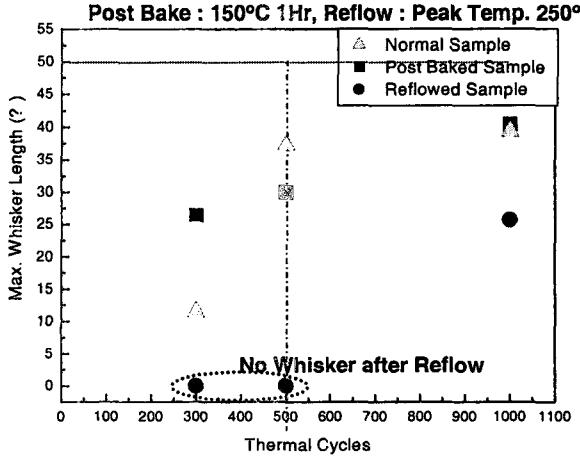
Matte Sn Finish Development Status

2) Whisker Reliability: Qual. Criteria <50um.

Post Bake : 150°C 1Hr, Reflow : Peak Temp. 250°C



3) Board Level Reliability: Solderability - Passed.

Functional Test (Memory Module) – Under Development

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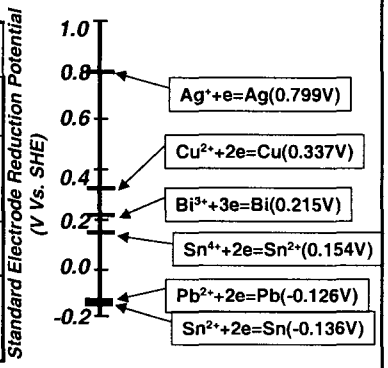
Pb-free Solder for Bumping : Electroplating

◈Candidates, Advantages and Disadvantages

	Advantages	Disadvantages
SnAg	High reliability Commonly used	Large red. potential difference
Sn	Low cost **No whisker issues in solder bump (reflow, underfill)*	High M.P.(232°C)
SnCu	High reliability	High M.P.(227°C)
SnBi	Reflow temp. same as SnPb Low temp. Pb-free sol'n	Bi substitution on plating bath Poor Compatibility Bi: By-product of Pb-mining



Reduction Potential Difference

- ❖ SnAg Electrolyte : 0.935V
- ❖ SnBi Electrolyte : 0.351V
- ❖ SnCu Electrolyte : 0.473V
- ❖ SnPb Electrolyte : 0.010V

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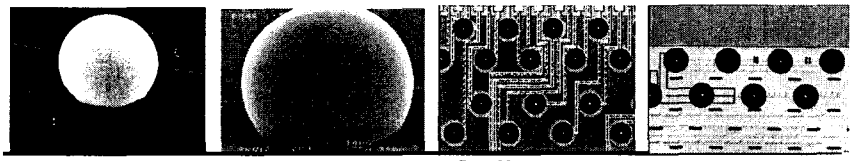
Pb-free Bumping Dev. Schedule

	Year 2004				Year 2005	
	1Q	2Q	3Q	4Q	1,2Q	3,4Q
Process Set-up						
Bump Process Qual.						
Product Qual.						
Mass Production						

** Pb-free flip chip mass production depends on customer's requirements.*
(Ex. Server, louter : Pb-free exempted by 2010, GDDR)



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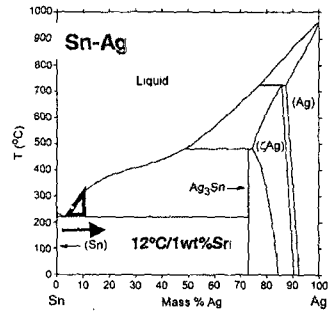
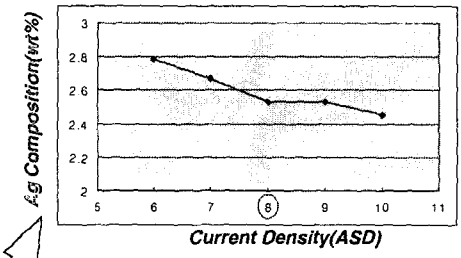
Composition and Bump Height Uniformity

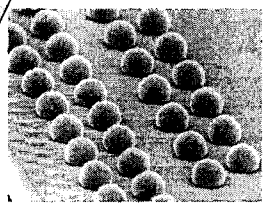
1) Composition



Sn-Ag: Steep Change of Melting Point
(Eutectic: 227°C)
Ag Composition Spec.: 2.5 ± 0.5wt%
Measured Data(1st) : 2.52wt% at 8ASD



2) Bump Height Uniformity (Spec.: Avg. ± 15%)



Spec.: 72.25 ~ 97.75um
(Avg. ± 15%)
Measured Data(1st) : 79.5 ~ 88.5um
(Avg. ± 6%)

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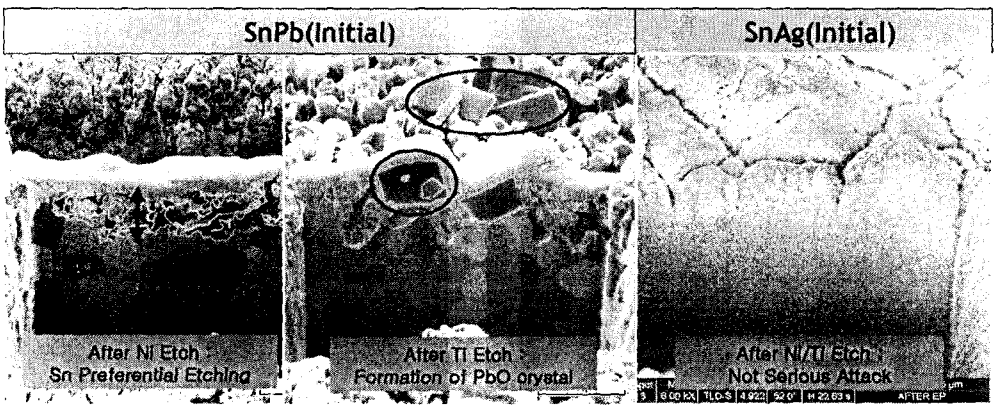
Solder Attack After UBM Etch(FIB)

Ni Etchant : HNO_3, H_2SO_4 Based
Ti Etchant : HF Based



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Summary

- RoHS compliant products are now being mass-produced.
- Eco-product(Pb-free + RoHS compliant + Halogen-free) will be possible from 2005.
- Pb-free flip chip will be qualified by 2004. 4Q.
- Lead Finish: SnBi – Under mass production
  Pd PPF – Under small production
  Matte Sn – will be internally qualified by 2004. 4Q
- Development of Pb-free Solder Ball: Stable Supply, Cost Down