RENESAS Semiconductors

Working Towards Lead-Free Products

Packaging and Test Technology Div.
Renesas Technology Corp.

Contents

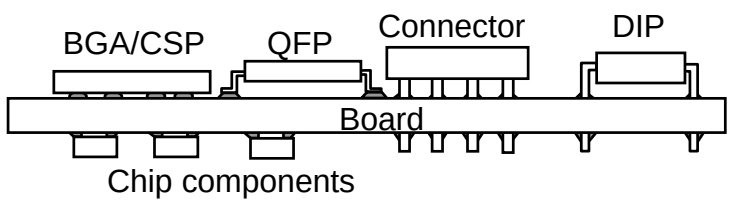
Technology Development for Lead-Free Component Mounting

Board
(Customer)

Selection of solder materials Establishment of mounting conditions

- Investigation of operation efficiency, joint reliability, costs and other factors
- Prevention of poor wetting, bridges, and other defects
- Uniform soldering temperatures for solder with a high melting point

Evaluation of combinations of various lead-free materials



Coordinating work temperatures used by customers with heat resistance of components

Components
(Renesas Technology Corp.)

Making component electrodes lead-free and improving heat resistance

- Balancing mass-production capabilities, reliability, and costs
- Improving materials and constructions
- Standardization

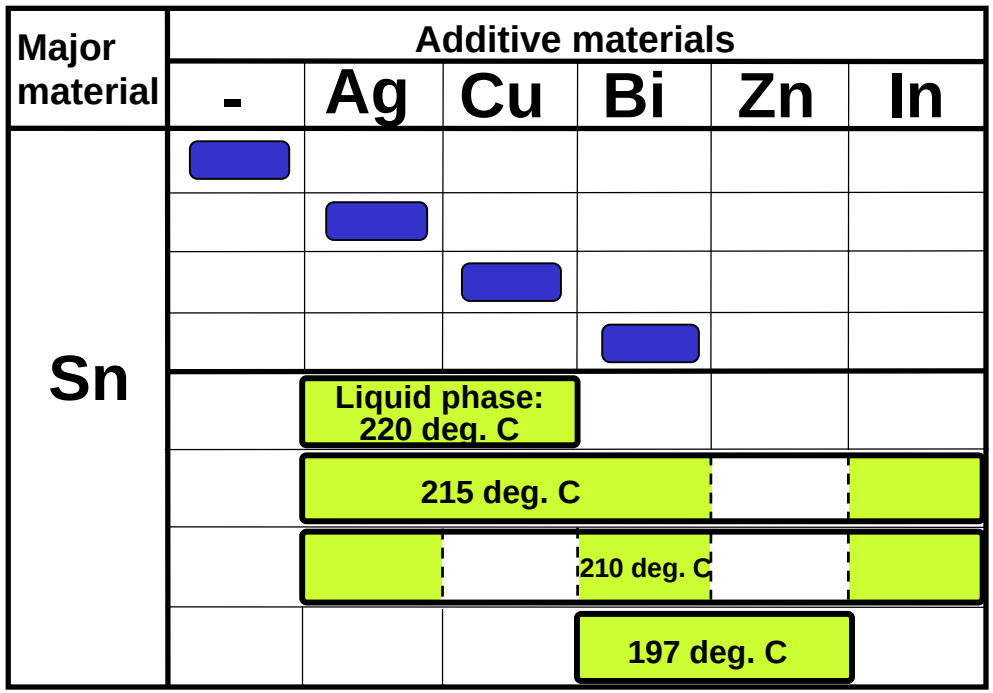
[1] Lead-Free Alternatives

1.1 Lead-Free Materials for Terminals

[Conventional lead specifications for terminals]

Surface treatment method		Plating	Dipping
Material		Sn-10Pb	Sn-37Pb
Melting point	Liquid phase	216 deg. C	183 deg. C
	Solid phase	183 deg. C	

[Major lead-free plating materials]



Lead-free materials for device electrodes: binary alloy

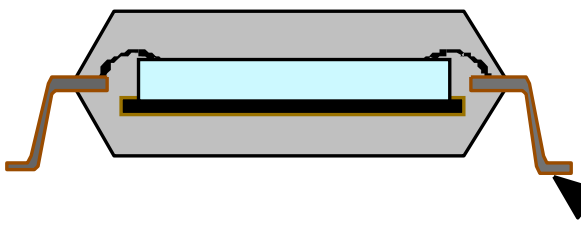
Major lead-free solder materials for mounting: ternary, quaternary, quinary alloys

1.2 The Basic Approach to Achieve Lead-Free Production

- The following were selected as plating materials that allow lead-free production.
  - ➲ Plating materials for terminal surface: Sn-Bi, Sn-Cu, and Ni/Pd/Au
  - ➲ Solder dipping material: Sn-Cu
  - ➲ Material for external balls: Sn-Ag-Cu
- The percentage of lead-free products is being gradually increased between 2002 and 2005, and our goal for overall conversion to lead-free terminals is the End/2005.

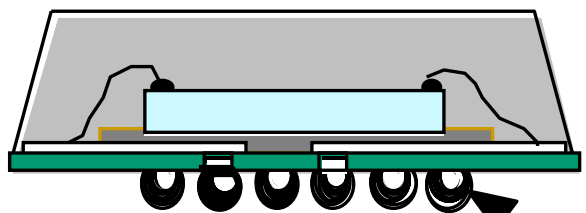
The lead-free products become compliant with the directive on RoHS in Europe because only lead (Pb) is a still applied chemical out of 6 substances.

Outer lead plating



Sn-Pb → lead-free plating
Sn-Bi, Sn-Cu
Ni/Pd/Au

External balls



Sn-Pb → Sn-Ag-Cu

1.3 Lead-Free Materials for Renesas Semiconductors

Applicable packages			Lead-free materials for Renesas products						
			Sn-Bi	Sn-Cu plating	Ni/Pd/Au	Sn-Cu dipping	Sn-Ag-Cu	Sn	Au
Surface mounted type (SMD)	IC and LSI packages	QFP, TQFP, LQFP, HQFP	○	○	◎				
		SOP, TSSOP, TSOP(1), TSOP(2), HSOP	○	○	◎				
		QFJ, SOJ	○	○					
		P-VQFN	○	○	◎				
		BGA, TFBGA, HBGA					○		
		LGA							◎
	Transistor and diode packages	UPAK, SOT-89, DPAK(S), MP-3, LDPAK(S), TO-220S	○	○					
		MPAK, SOT-23mod	○	○					
		URP, UFP	○						
Pin insertion type (THD)	IC and LSI packages	DIP, SDIP	○	○	◎	○			
		G-DIP						◎	
		C-DIP						◎	◎
		ZIP	○	○					
		PGA							◎
	Transistor and diode packages	TO-92, TO-220, TO-3P				○			
		DO-34, DO-35				○			
		DPAK-L, LDPAK-L	○						

H : Formerly manufactured by Hitachi

M : Formerly manufactured by Mitsubishi

H M ▶ Common for (H) and (M)

◎ : Same specifications as earlier products

[2] Plan for Achieving Lead-Free Production and Improving Heat Resistance

2.1 Plans for Lead-Free Microcomputers, SoCs, and Memories

(1) Lead-Free Materials

<table>
<tr><th></th><th>Applicable packages</th><th>Current terminal specifications</th><th colspan="2">Lead-free terminal specifications</th></tr>
<tr><th></th><th></th><th></th><th>H</th><th>M</th></tr>
<tr><td rowspan="5">Surface mounted type</td><td>QFP, SOP, TQFP, TSOP(I), LQFP, QFJ, TSOP(II), SOJ</td><td rowspan="3">Sn-Pb plating</td><td>Sn-Bi plating</td><td rowspan="3">Sn-Cu plating</td></tr>
<tr><td>SOP, TSOP(II)</td><td>Sn-Cu plating</td></tr>
<tr><td>SOP8, TSOP8</td><td>Ni/Pd/Au</td></tr>
<tr><td>BGA
TFBGA, HBGA</td><td>Sn-Pb solder balls</td><td colspan="2">Sn-Ag-Cu solder balls</td></tr>
<tr><td>LGA</td><td colspan="3">Au plating</td></tr>
<tr><td>Pin insertion type</td><td>DIP
SDIP</td><td>Sn-Pb plating</td><td>Sn-Bi plating</td><td>Sn-Cu plating</td></tr>
</table>

(2) Plan for Providing Lead-free Terminals for Microcomputers, SoCs and Memories

Technology development	**The selection of materials for both lead plating and balls has been completed as well as the development of mass-production technology.**
Supported samples	**Engineering samples and commercial samples are supported (except for some products not to be provided with lead-free terminals)**
Mass production support	**Requests for lead-free solutions are supported.** **Some portion of products is already in mass production and the remainder will be introduced in response to customer demand.**

Note: Conversion for some products has been already implemented. Please address your sales contact person for more details on lead-free schedule.

(3) Plan for Improving Heat Resistance (Microcomputers, SoCs, and Memories)

- **Improvement in heat resistance: Our goal is to achieve sufficient quality under reflow condition of 260 deg. C at solder joint**

Currently, almost all packages reach the above goal except for some products* for which countermeasures are being taken. Also, there are some packages that have a heat resistance of lower than 260 deg. C because of their construction.

*** Some QFP and SOP packages formerly manufactured by Mitsubishi**

The heat resistance was confirmed and improvement measures taken:

- **For package surface temperature of 260 deg. C reflow: Small and thin packages**

  QFP (less than 28 mm□), LQFP, TQFP, SOP, TSOP, BGA, TFBGA, etc.

- **For package surface temperature of 245 deg. C reflow: Large and thick packages**

  QFP (28 mm□ or more), QFJ

The above packages can reach 260 deg. C or higher at the point of the solder joint.

For large and thick HQFP packages with built-in heat sinks, the maximum reflow and peak temperature is 240 deg. C (solder joint: 250 deg. C or higher).

Technical improvement solutions have been established, and we are working to expand our range of applicable products, considering factors such as customer needs and the manufacturing timing for individual products.

Note: The actual heat resistance temperature differs depending on the type of product package. Please consult Renesas sales agency for the relevant product.

2.2 Plans for Lead-Free Terminals for Linear/Logic IC, TRS, and Diode Packages

(1) Lead-Free Materials

	Applicable packages		Current terminal processing	Lead-free terminal specifications	
				H	M
Surface mounted type	IC	SOP, P-VQFN TSSOP, TVSOP	Sn-Pb plating	Ni/Pd/Au plating	Sn-Cu plating
		LQFP, SSOP		Sn-Bi plating	
	TRS	UPAK DPAK-S, LDPAK-S		Sn-Bi plating	
		TSSOP, SOP, LFPAK		Ni/Pd/Au plating	
	Di	MPAK, URP UFP, SFP, etc.	Sn-Pb plating (Lead material: Cu-based)	Sn-Bi plating	
Pin insertion type	IC	DIP	Sn-Pb dipping or Sn-Pb plating	Ni/Pd/Au plating	Sn-Cu plating
		SIP		Sn-Cu dipping	
	TRS	TO-xx		Sn-Bi plating	
		DPAK-L, LDPAK-L			
		TO-220		Sn-Cu dipping (Sn-Bi plating)	
		TO-92			
	Di	MHD (DO-34) DHD (DO-35)	Sn-Pb dipping (Lead material: Fe covered with Cu)	Sn-Cu dipping	

(2) Plans for Lead-Free Terminals for Linear/Logic IC, TRS and Diode Packages

Technology development	**The selection of materials for both lead plating has been completed as well as the development of mass-production technology.**
Supported samples	**Engineering samples and commercial samples are supported (except for some products not to be provided with lead-free terminals).**
Mass production support	**Requests for lead-free solutions are supported.** **Some portion of products is already in mass production and the remainder will be introduced in response to customer demand.**

Packages for which mass production support is behind schedule:

- **Digital, Linear IC: DIP**
- **Diode: LLD**
- **General-purpose linear device: TSSOP8, JEDEC SOP14 (soon open)**
- **MSIG: SOP, QFP, DIP**

Note: Conversion for some products has been already implemented.
Please address your sales contact person for more details on lead-free schedule.

(3) Plans for Improving Heat Resistance in Linear/Logic IC, TRS, and Diode Principle Packages

● **Improvement in heat resistance: Our goal is to achieve sufficient quality under reflow condition of 260 deg. C at solder joint**

Currently, almost all packages reach the above goal except for some that are under way.

Reflow heat resistance of surface mounted products:

- **For package surface temperature of 260 deg. C: LQFP, SOP, TSSOP, UPAK, LFPAK, MPAK, URP, UFP, SFP, etc.**
- **For package surface temperature of 250 deg. C: DPAK-S, LDPAK-S**

Technical improvement solutions have been established, and we are working to expand our range of applicable products, considering factors such as customer needs and the manufacturing timing for individual products.

● **For soldering by hand for glass diodes : A distance of 1 to 1.5 mm should be maintained between the solder and the glass body.**

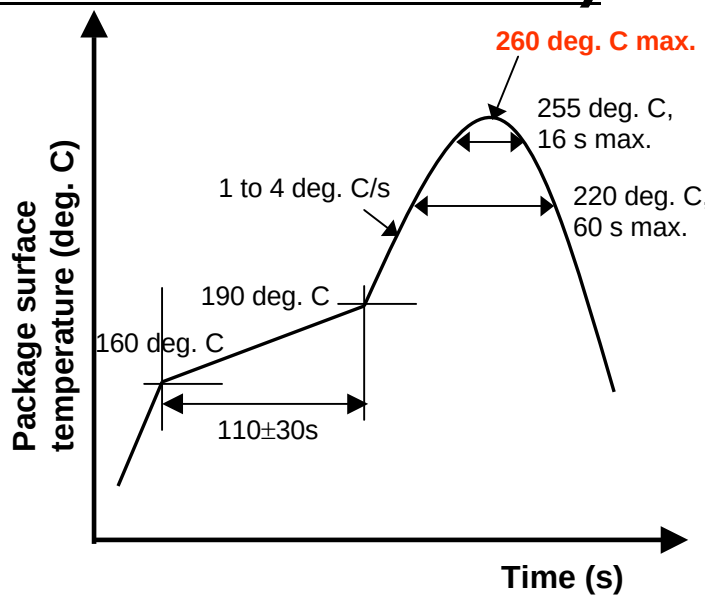
● **SFPs cannot be soldered by hand.**

Note: The actual heat resistance temperature differs depending on the type of product package. Please consult Renesas sales agency for the relevant product.

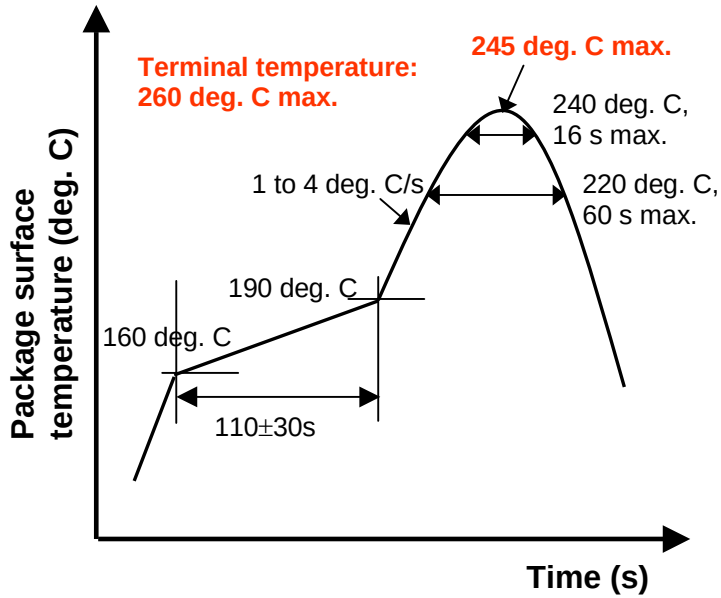
[3] Soldering Heat Resistance that Supports Lead-Free Solder

3.1 Reflow Heat Resistance Conditions (Inflared/Hot Air Reflow)

Temperature measurement location:
Top surface of package



(a) Small, thin packages



(b) Large, thick packages
(QFPs (28 mm□ or larger), QFJs)

● The reflow condition for large and thick HQFP packages (28 mm□ or larger) formerly manufactured by Hitachi is 240 deg. C max. at the peak. (Peak: 240 deg. C, main heating: 220 deg. C or higher, 30 to 50 seconds, pre-heating: 150 to 180 deg. C, 90±30 seconds)

Note: Please consult Renesas sales agency concerning individual products.

3.2 Heat Resistance Conditions for Flow

Temperature measurement location: Melted solder

Surface-mounted packages

- The flow solder mounting conditions for surface-mounted packages are the same as those for lead solder.

Item		Recommended conditions	Upper limit value	Condition regulations
Pre-heating	Temp.	80 to 150 deg. C	–	Board surface
	Time	1 to 3 min.		
Solder dipping	Temp.	230 to 250 deg. C	260 deg. C*	Solder bath temperature
	Time	2 to 4 sec	7 sec*	Time immersed in solder bath

***: Products such as thin package TQFPs and TSOPs should be mounted at a solder bath temperature of 235 deg. C max. and should be left in the solder bath for 5 seconds max.**

- **No recommendations are provided for flow conditions for surface-mounted packages formerly manufactured by Mitsubishi.**

Pin insertion packages

The soldering conditions for DIPs and other pin insertion packages are the same as those for lead solder.
: 260 deg. C max., 10 s max.

For dipping of the following packages, a distance of 1.0 to 1.5 mm should be maintained between the package and the solder.

DO type, MHD, TO type, SP type, DPAK, and LDPAK

3.3 Heat Resistance Conditions for Soldering by Hand

H

- **350 deg. C, 3 s max.**
  If conditions exceed these values, soldering should be done within 3 seconds at a lead temperature of 260 deg. C

M

- **370 deg. C, 5 s max.**

Note: Please consult Renesas sales agency concerning individual products.

[4] Samples for Mounting Evaluation

Samples are provided for evaluation of lead-free mounting.

- **For products with lead-free type number registered:**

  It is possible to place a purchase order in line with a standard procedure.

- **For lead-free products not registered yet:**

  Please contact and place a request to our sales person.

Remark points;

#1. In tape & real packing, minimum quantity of samples is 1 packing unit.

#2. In this case, small quantity can be provided by WS code (particularly standard logic ICs or transistors)

Note: Please consult Renesas sales agency for detailed information.

[5] Distinguishing between Lead-Free and Conventional Products

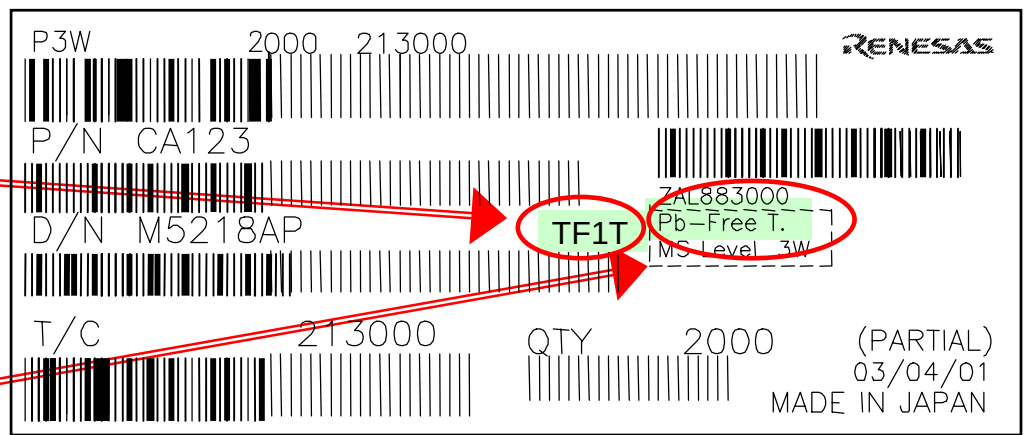
How products are distinguished

Product classification	H	M
Microcomputer (MCU) Microcomputer (MPU), SoC	Product type and P/N: As a rule, current, with V added at end Mark: as a rule, V display is added Internal control code [D/N]: Current, with V added at end	Product type: Same as current Internal control code [D/N]: A special character is used for the first two digits of the four-digit code following the product type, to distinguish the product (Ex) Product type #### Microcomputer M38869MCA-aaaHP U### SoC M65511AFP #F## Memory M5M5V408BFP ST##
Memory	Product type and P/N: Same as current Internal control code [D/N]: Current, with E added at end	
(AND flash)	Internal control code: With E added as 11th digit of product type	
Diode, transistor	Product type: Same as current P/N: Not stamped Internal control code [D/N]: Current, with -E added at end	
Standard logic, standard linear, module IC, etc.	Product type and P/N: Same as current Internal control code [D/N]: Current, with -E added at end	Same as above
Application specific linear device		

- '-E' is added to the product types of diodes, transistors, and application specific linear devices described in the delivery specifications.

Display based on inner box label

Internal control code



"Pb-Free T." indicates that the terminals of the product are lead-free

Possible discrimination

1) on order paper
   - D/N + appropriate suffix
2) on inner box label - Pb-Free T.
3) on inner box label - D/N with appropriate suffix
4) on package itself - only micro-computer and SoC of former Hitachi

[6] Evaluating Lead-Free Solder Characteristics

6.1 Solder Wettability (1)

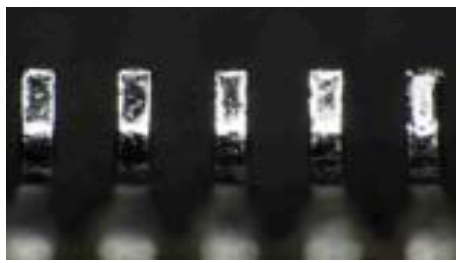
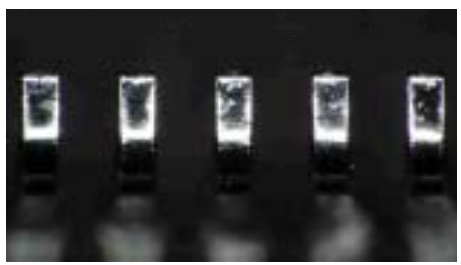
- **Solder balancing method**

  Pre-processing conditions: A: Stored at 105 deg. C 100%, 4h, B: Stored at 100 deg. C 100%, 4h

Sample	Plating	Solder paste	Pre-processing condition	Solder balancing			Soldering method (wetted surface area)
				Max.	Min.	Ave.	
QFP1420-100-Fe	**Sn-Cu**	**Sn-Ag-Cu (245 deg. C)**	A	**0.4 s**	**0.3 s**	**0.36 s**	**95% or more**
LQFP1414-100-Cu	**Sn-Cu**	**Sn-Ag-Cu (245 deg. C)**		**0.8**	**0.4**	**0.56**	**95% or more**
QFP1420-100-Fe	**Sn-Cu**	**Sn-Pb (230 deg. C)**		**0.4**	**0.2**	**0.30**	**95% or more**
LQFP1414-100-Cu	**Sn-Cu**	**Sn-Pb (230 deg. C)**		**0.8**	**0.4**	**0.50**	**95% or more**
LQFP0707-48-Cu	**Sn-Bi**	**Sn-Ag-Cu (245 deg. C)**	B	**0.45**	**0.34**	**0.39**	**95% or more**
LQFP0707-48-Cu	**Sn-Bi**	**Sn-Pb (230 deg. C)**		**0.53**	**0.38**	**0.48**	**95% or more**
TSSOP-14-Cu	**Ni/Pd/Au**	**Sn-Ag-Cu (245 deg. C)**		**0.44**	**0.40**	**0.43**	**95% or more**
TSSOP-14-Cu	**Ni/Pd/Au**	**Sn-Pb (230 deg. C)**		**0.49**	**0.45**	**0.47**	**95% or more**
LQFP0707-48-Cu	**Sn-Pb**	**Sn-Pb (230 deg. C)**	**B**	**0.61**	**0.33**	**0.44**	**95% or more**
		Judgment		Equivalent to conventional specifications			Equivalent to conventional specifications

6.1 Solder Wettability (2)

- Pre-processing condition: 150 deg. C, 168h
- Evaluating conditions: dipping in weak active flux for 5 sec → dipping in solder bath for 5 sec
- Criterion: solder wetted surface area ≥ 95%

	Sn - 1%Bi	**Sn - 2%Bi**	Sn - 4%Bi
Sn-3Ag-0.5Cu solder (230 deg. C)			
Sn-37Pb solder (210 deg. C)			

6.2 Whisker Evaluation (1)

- Testing condition: Long-term storage at room temperature
- Criterion: Whisker length ≥ 50 μm

Plating	Lead frame material	Storage time (h)	Result (Number of whiskers /Number of leads)
Sn-Bi	**Cu**	**13000**	**0/3504**
	Fe-Ni	**13000**	**0/1680**
Sn-Cu	**Cu**	**4000**	**0/1000**
		14500	**0/1080**
		15900	**0/500**
	Fe-Ni	**8800**	**0/500**

6.2 Whisker Evaluation (2)

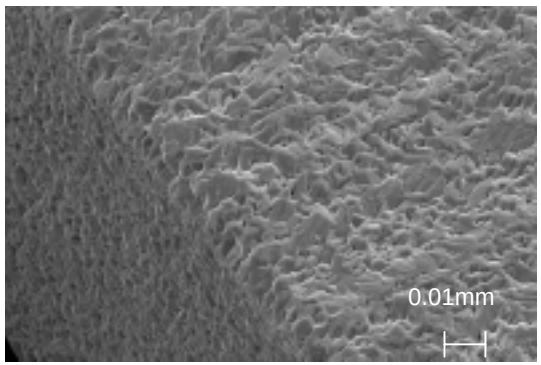
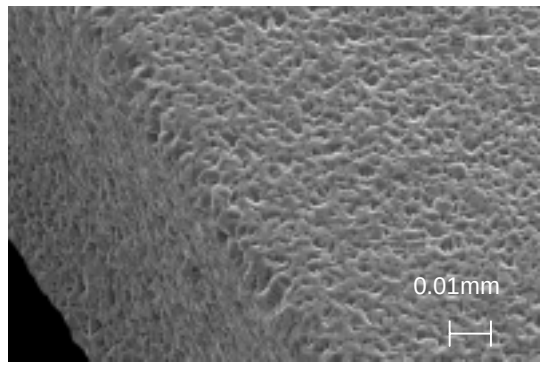
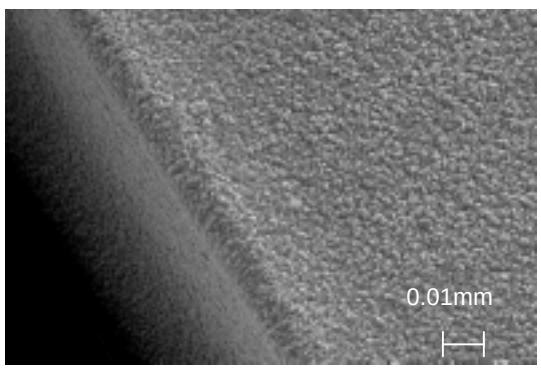
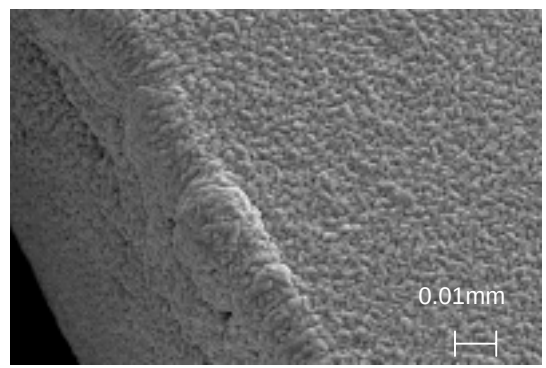
- Evaluation of Sn-Cu plating
- Pre-processing: No soldering, no heating
- Examination: **stereoscopic microscope magnified by 40 (close examination: SEM magnified by 1000)**
- Criterion: Whisker length ≥ 50 μm

Testing condition	Frame material	500h	1000h	2000h	3000h	4000h	Total storage time
Left at room temperature	42 Alloy	○	○	○	○	○	8800h
	Cu frame	○	○	○	○	○	15900h
Stored at 85 deg. C 85%	42 Alloy	○	○				
	Cu frame	○	○				
Stored at 85 deg. C 65%	42 Alloy	○	○	○	○	○	
	Cu frame	○	○	○	○	○	
Stored at 150 deg. C	42 Alloy	○	○				
	Cu frame	○	○				

○: No whiskers
×: Whisker detected

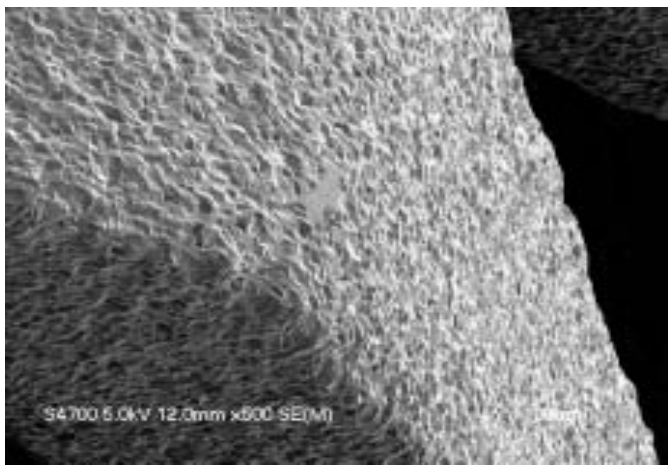
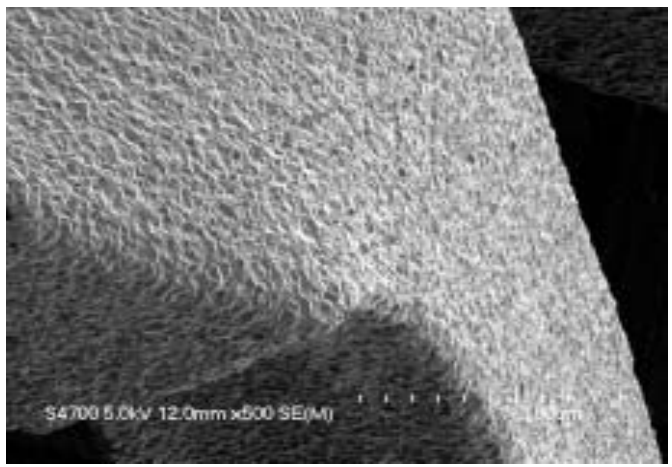
6.2 Whisker Evaluation (3)

- Testing condition: Long-term storage at room temperature
- Criterion: Whisker length ≥ 50 μm

	Lead frame material: Cu	Lead frame material: 42 alloy
Sn-Bi	 Storage time 13000h	 Storage time 13000h
Sn-Cu	 Storage time 15900h	 Storage time 4000h

6.2 Whisker Evaluation (4)

- Pre-processing condition: **85 deg. C/85%RH, 500h**
- Criterion: Whisker length ≥ 50 μm

Appearance		
Lead frame material	42 alloy	Cu
Plating condition	Sn - 0.5%Bi	Sn - 0.5%Bi

6.2 Whisker Evaluation (5)

- Pre-processing conditions: **T cycle [-55 deg. C (10 min.)/125 deg. C (10min.), 500 cycles]**
- Criterion: Whisker length ≥ 50 μm

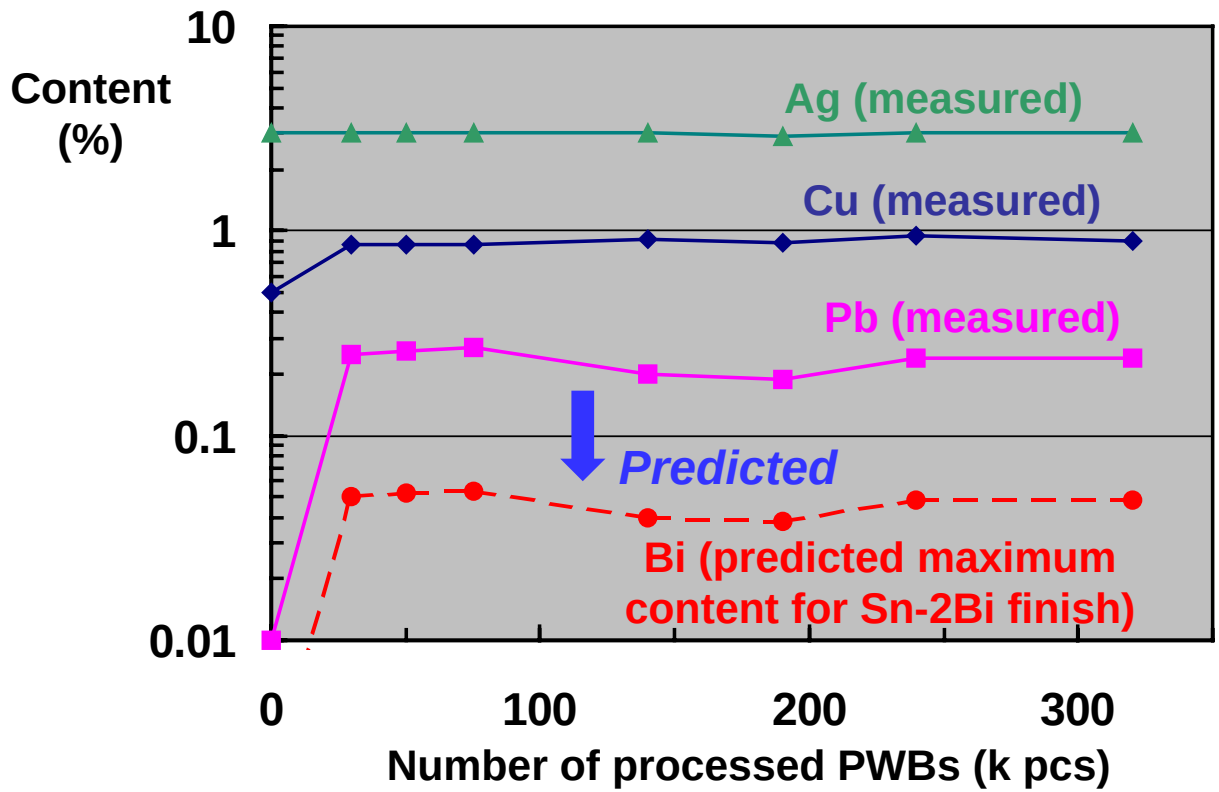
Lead frame material	42 alloy	Cu
Plating composition	Sn - 0.5%Bi	Sn - 0.5%Bi
Result (Number of whiskers /Number of leads) (appearance magnified by 40)	0/500	0/500

6.3 Control of Lead-Free Plating

Current terminal processing		Lead-free terminal processing			Remarks
Composition (wt%)	Thickness (μm)	Composition (wt%)	Target/Concentration control range (wt%)	Thickness (μm)	
Sn-10Pb	7 Typ.	Sn-2Bi	2/ 1 to 3, diodes	7 Typ.	Plating (*1) Because of a purchased pre-coated lead-frame, the plating thickness cannot be indicated.
	10 Typ. (10±5)		2/ 1 to 4, others	10 Typ. (10±5)	
	5 or thicker	Sn-1.5Cu	1.5/ 0.75 to 3	5 or thicker	
		Ni/Pd/Au	100, respectively	— (*1)	
Sn-xPb x = 25, 37, 40	—	Sn-0.7Cu	0.7/ 0.5 to 3, diodes 0.7/ 0.5 to 1.4, transistors	—	Dipping/coating
Sn-37Pb	—	Sn-3Ag-0.5Cu	—	—	Solder ball

6.4 Impurity Content in Flow Solder Bath (Bi predicted content)

- Solder composition: Sn-3Ag-0.5Cu
- Solder bath capacity: 350 kg
- Solder supplement: 3 to 5 kg/day
- Board size: 158 × 250 mm
- Major component plating: **Sn-(10 to 40)Pb plating**
- **Evaluation term: 28 months**



6.5 Evaluation of Other Lead-Free Plated Products

For information on the results of joint strength measurements of lead-free plated products and the results of joint strength measurements of lead-free solder ball products, please refer to the 'Renesas Semiconductor Lead-free Packages' catalog.

The results are judged to be equivalent to those of conventional products.

This catalog is also available on the Internet.

URL: http://www.renesas.com/jpn/catalog/index.html#lead