TOSHIBA

User's Guide

Lead(Pb)-free Technology on Memory Products (June 2005)

2005

TOSHIBA

Lead(Pb)-free Technology on Memory Products (June 2005)

TOSHIBA CORPORATION
Semiconductor Company
Memory Division

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Lead(Pb)-free Technology on Memory Products

Contents

1. TOSHIBA Policy and the Necessity to Eliminate Lead(Pb)

1.1 Lead(Pb)-free Regulations and Global Trends

(1) Regulations

The EU directives (OJ L037) on WEEE and RoHS, Waste Electrical and Electronic Equipment and the Restriction of the use of certain Hazardous Substances in electrical and electronic equipment, is enforced.

The use of the substances such as lead (Pb), mercury (Hg), cadmium (Cd), hexavalent chromium (Cr^{6+}) and PBB/PBDE will be banned from July 2006.

(2) Global Trends

Table 1-1 Global Trends of Lead(Pb)-free

EU	Legislated WEEE/RoHS Directives. Usage of lead(Pb) will be banned on July 2006.
US	Lead(Pb)-free trend is accelerated by major customers from the lead(Pb)-free movement in EU.
Japan	Lead(Pb)-free trend has been made further progress since Waste Electronic Law was enforced in 2001.

1.2 Basic Policy of Lead(Pb)-free on TOSHIBA Memory Products

(1) Shift to Lead(Pb)-free Products

TOSHIBA completed lead(Pb)-free implementation for all memory products by the end of December 2003.

(2) Leads Finish Plating Materials

Sn-Ag and Sn-Cu are selected as alternative materials to solder plating for our lead(Pb)-free products.

(3) Lead(Pb)-free Solder Ball Materials

Sn-Ag-Cu is selected as alternative materials to solder ball for our lead(Pb)-free products.

(4) Part Number of Lead(Pb)-free Products

The part number is changed to distinguish the lead(Pb)-free from the lead(Pb) contained products.

Note: The plating and ball materials are subject to change due to the technology improvement.

1.3 Definition of Lead(Pb)-free Components

Definition of lead(Pb)-free components is conducted by “Roadmap 2002 Commercialization of Lead-Free Solder version. 2.1” by JEITA (Japan Electronics and Information Technology Industries Association).

The JEITA definition of lead(Pb)-free components is: (1) to satisfy the description of Phase 1 in the Table below, and (2) the amount of contained lead(Pb) in the prescribed parts, which stated in Phase2 or Phase3, planned for lead(Pb)-free adoption should be less than 0.1 weight percent.

The definition of TOSHIBA memory lead(Pb)-free components is compliant with JEITA.

Table 1-2 Definition of Lead(Pb)-free Components

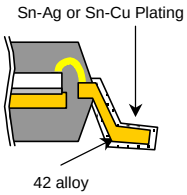
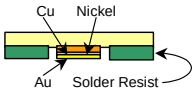
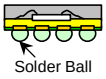
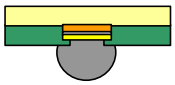
Phase	Category	Description
Phase1	Components with lead-free solder	Heat resistance against soldering in assembly with lead-free solders.
Phase2	Lead-free terminal components	No lead contained plating and electrodes of terminal parts of components assembled to PWB etc. The components may contain leaded composing components and materials.
Phase3	Lead-free components	No lead contained in all the internal bonding and/or composing components and materials.

Quoted from “Roadmap 2002 Commercialization of Lead-free Solder version. 2.1” of JEITA

1.4 Lead(Pb)-free Materials

Lead(Pb)-free materials of main package are shown in Table 1-3.

Table 1-3 Lead(Pb)-free Materials by Package Types

Package			Lead(Pb)-free Material				
Package	Appearance	Structure	Sn-Ag	Sn-Ag-Cu	Sn-Cu	Au	Description
SOP, TSOP			●		●		
LGA						●	
BGA				●			

Note: When materials for lead(Pb)-free terminal are stated more than two, its specification depends on the part type.

1.5 Identifying Lead(Pb)-free Products

(1) Part Number

A letter of “G” is specified in a part number field of lead(Pb)–free packages to distinguish lead(Pb)-free products from the lead(Pb) contained products.

(Except for some custom products. Please contact TOSHIBA sales representatives for the details)

Table 1-4 Example of Part Number Comparison of Lead(Pb) contained and Lead(Pb)–free Products

Products	Lead(Pb) contained Part Number	Lead(Pb)-free Part Number
NAND 1Gb TSOP	TC58NVG0S3AFT00	TC58NVG0S3ATG00
NOR Flash 64Mb P-TFBGA	TC58FVM6T2AXB65	TC58FVM6T2AXG65

Note: underlined letters show the package type

(2) Packing Label

Lead(Pb)-free marking is indicated in the outer box label as follows:
Lead(Pb)-free products: “Lead (Pb)-Free”
Lead(Pb)-free finish products: “Lead (Pb)-Free Finish”

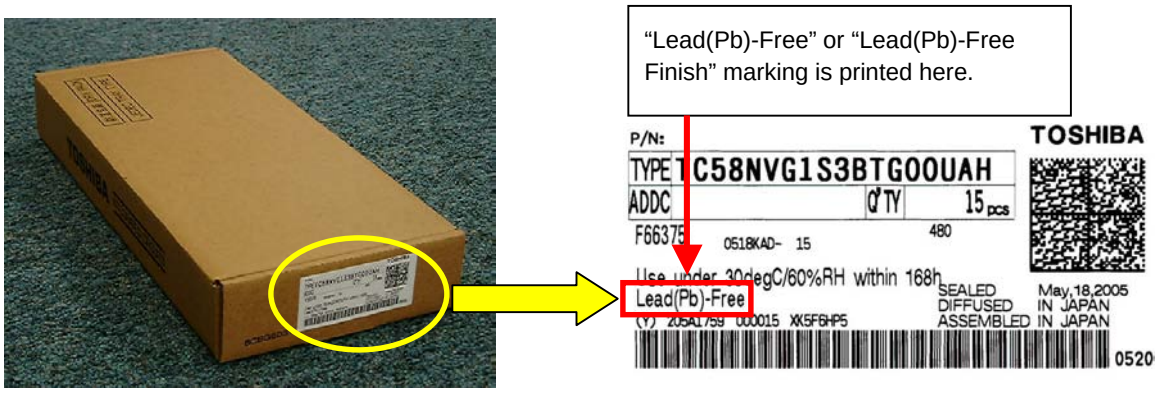


Fig 1-2 Location of Lead(Pb)-free Marking

2. Precautions for Lead(Pb)-free Soldering

(1) Various lead(Pb)-free solder materials are available in the market.
Some examples are described in Fig 2-1.
It will be necessary to select soldering material carefully and confirm reliability and workmanship of lead(Pb)-free soldering before the actual production.

Note: elting Points are determined by representative value, which depends on composition ratio. Please consult solder vendor for details.

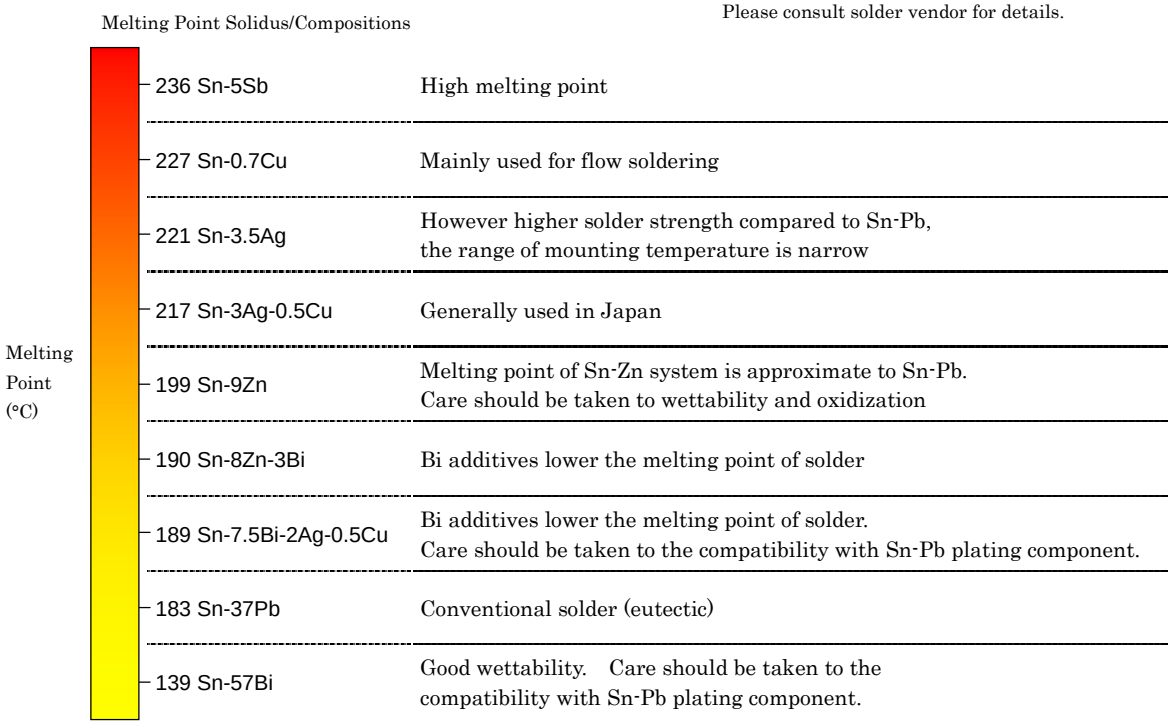


Fig 2-1 Characteristics of General Lead(Pb)-free Solder

(2) Generally, the soldering temperature of lead(Pb)-free solder is higher than that of lead(Pb) contained solder.
Please ensure that the soldering temperature does not exceed maximum temperature of components.
Fig 2-2 shows the example of reflow temperature profile by the use of lead(Pb)-free paste (Sn-3Ag-0.5Cu) for your reference.

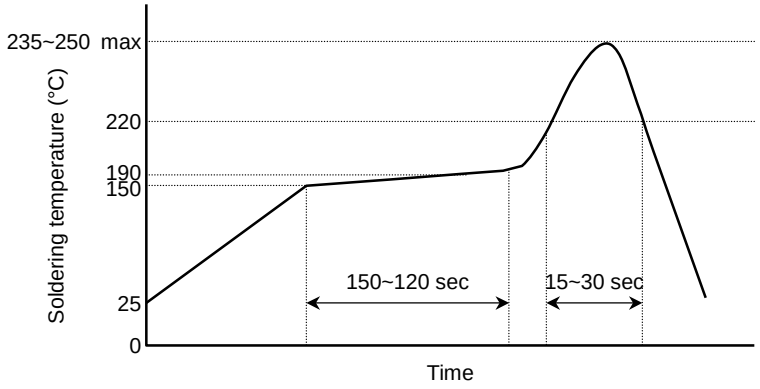


Fig 2-2 Example of Reflow Temperature Profile of Sn-3Ag-0.5Cu

3. Quality and Reliability on Lead(Pb)-free Products

Reliability test result of lead(Pb)-free products and board mounted testing results are provided.

Since the test conditions may vary by each product, please inquire TOSHIBA sales representatives for the details.

3.1 Package Quality and Reliability

3.1.1 Heat Resistance for Reflow Soldering

As the melting point of lead(Pb)-free solder is higher in general, reflow soldering temperature may be higher than Sn-Pb soldering.

The heat resistance test of lead(Pb)-free package is performed with the use of higher temperature reflow than that of the lead contained package.

(1) Reflow Temperature Profile for Heat Resistance Test

Fig 3-1 shows reflow temperature profile for heat resistance test of lead(Pb) contained products and Fig 3-2 shows that of lead(Pb)-free products.

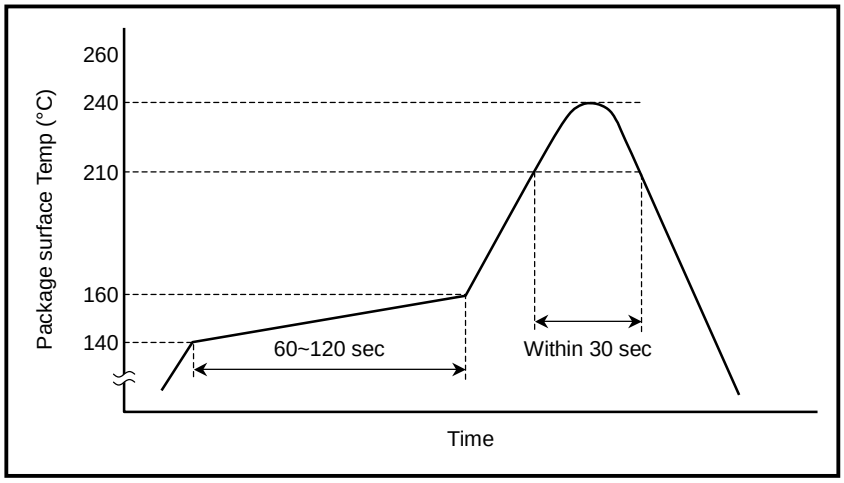


Fig 3-1 Reflow Temperature Profile for Heat Resistance Test of Lead(Pb) contained Products

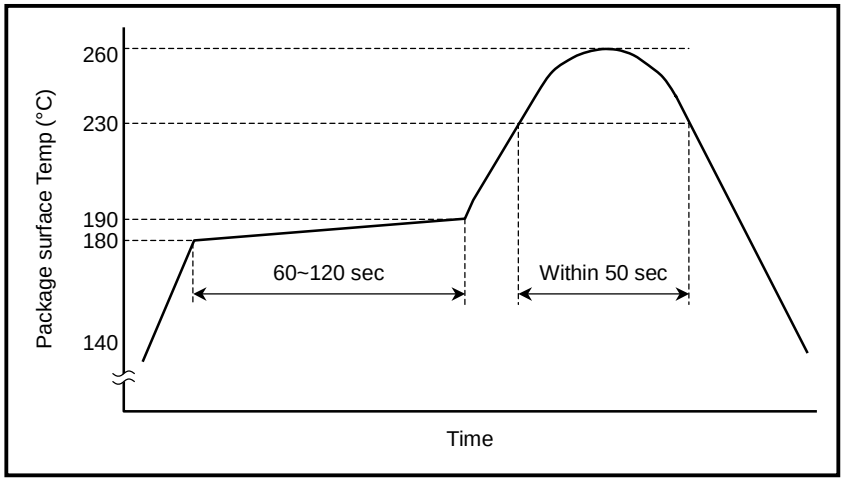


Fig 3-2 Reflow Temperature Profile for Heat Resistance Test of Lead(Pb)-free Products

(2) Reflow Heat Resistance Test

The Test sequence is (1) moisture-proof packing open, (2) soak and (3) reflow (4 times). Visual inspection for the deformation or fracture and electrical characteristics test are performed.

Scanning Acoustic Tomograph (hereinafter referred to as SAT) is used to detect the delamination and cracks.

Table 3-2 shows the result and pictures by SAT of heat resistance test for reflow soldering of the lead type package (TSOP-I 48-P-1220-0.5) and ball type package (P-TFBGA56-0710-0.8).

Table 3-2 Result of Reflow Soldering of Heat Resistance Test

Test	Condition	Package	Result	
			Quantity	Failure
Reflow Heat Resistance (Electrical Characteristics)	30°C/70%RH 192h IR Reflow 260 Max × 4times	TSOP-I 48-P-1220-0.5	500	0
		P-TFBGA56-0710-0.8	500	0
Reflow Heat Resistance (Visual, SAT)	30°C/70%RH 192h IR Reflow 260 Max × 4times	TSOP-I 48-P-1220-0.5	60	0
		P-TFBGA56-0710-0.8	60	0

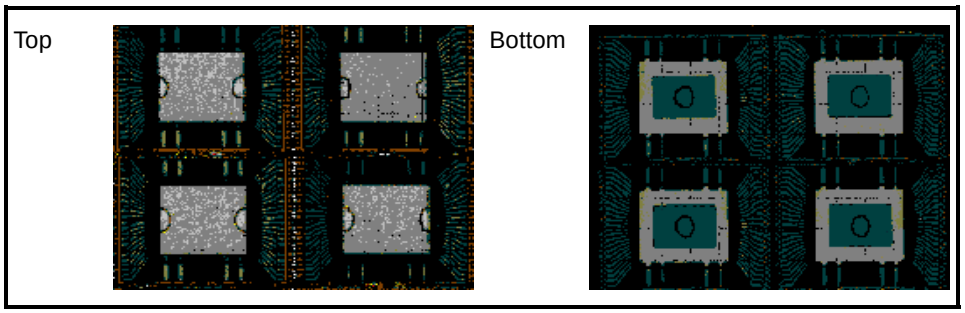


Fig 3-3 Picture of TSOP-I 48-P-1220-0.5 by SAT

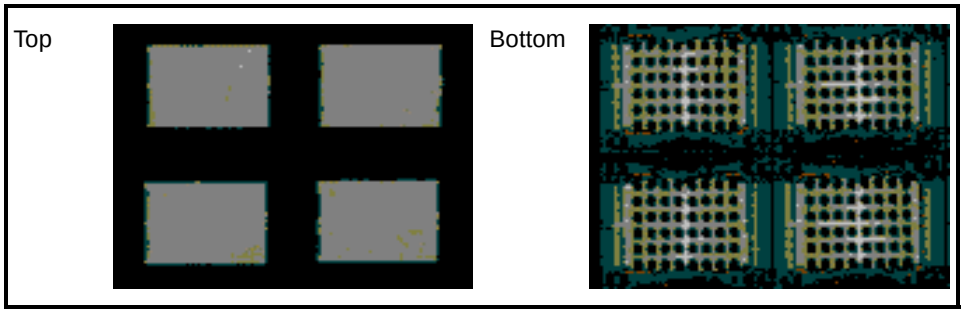


Fig 3-4 Picture of P-TFBGA56-0710-0.8 by SAT

3.1.2 Package Reliability

Table 3-3 shows the reliability test result for the leads type package (TSOP-I 48-P-1220-0.5) and Table 3-4 shows ball type package (P-TFBGA56-0710-0.8).

Table 3-3 Reliability Test Result of TSOP-I 48-P-1220-0.5

Test	Condition	Solder Plating	Result	
			Quantity	Failure
HAST (Highly Accelerated Stress Test)	130°C/85%RH/3.6V 100h	Sn-Cu	100	0
		Sn-Ag	100	0
THB (Temperature-Humidity and Bias test)	85°C/85%RH/3.6V 1,000h	Sn-Cu	200	0
		Sn-Ag	200	0
TCT (Temperature Cycle Test)	–65°C/150oC 500cyc	Sn-Cu	200	0
		Sn-Ag	200	0

Pre-conditions: 30°C/70%RH 192h IR Reflow (260°C Max × 4times)

Table 3-4 Reliability Test Result of P-TFBGA56-0710-0.8

Test	Condition	Solder Ball	Result	
			Quantity	Failure
HAST (Highly Accelerated Stress Test)	110°C/85°C RH/3.6V 100h	Sn-Ag-Cu	100	0
THB (Temperature-Humidity and Bias test)	85°C/85°C RH/3.6V 1,000h		200	0
TCT (Temperature Cycle Test)	–55°C/125 500cyc		200	0

Pre-conditions: 30°C/70%RH 192h IR Reflow (260°C Max × 4times)

3.1.3 Solderability

(1) Solderability Test

The leads are soaked in soldering bath to evaluate solderability. Table 3-5 shows solderability test result.

Table 3-5 Solderability Test Result

Test	Test Condition		Solder	Solder Plating	Result	
	Solder Temp	Soak Time			Quantity	Failure
Solder-ability	215°C	3sec	Sn-Pb	Sn-Pb	30	0
	230°C		Sn-Pb	Sn-Cu	30	0
				Sn-Ag	30	0
	245°C		Sn-Ag-Cu	Sn-Cu	30	0
				Sn-Ag	30	0

Pre-conditions: 85°C/85%RH 16h Criteria: Solder wetting area should be more than 95%

(2) Meniscograph (Rapid Heating Method)

Measuring the time to become zero buoyant level (zero-cross time: wetting time) of wetting force – time graph plotted by meniscograph method.

When zero-cross time is shorter, wettability is better.

Fig 3-5 shows zero-cross time of Sn-Pb solder paste and Fig 3-6 shows that of Sn-Ag-Cu solder paste.

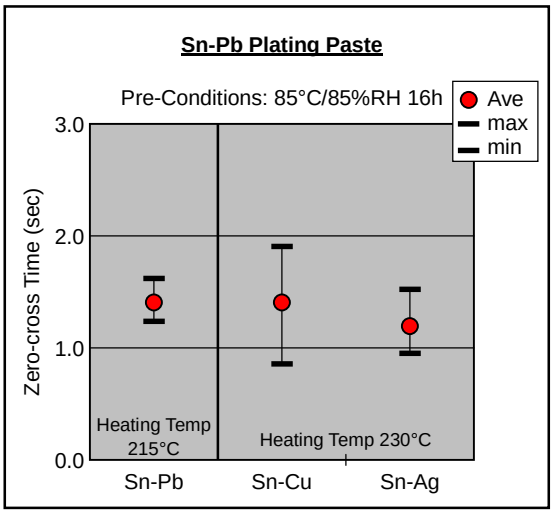


Fig 3-5 Zero-cross Time of Sn-Pb Paste

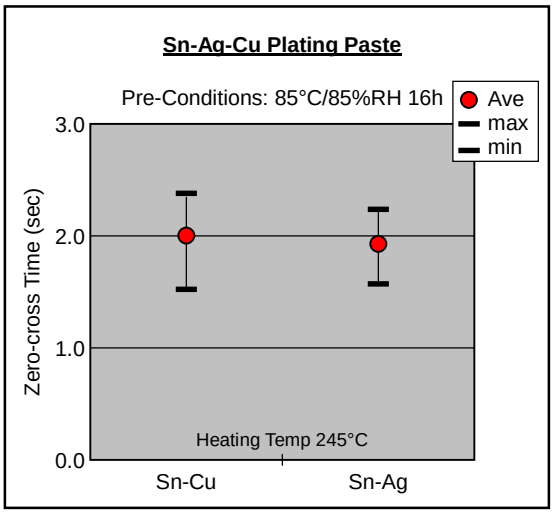


Fig 3-6 Zero-cross Time of Sn-Ag-Cu Paste

Criteria: Zero-cross time should be less than 3sec.

3.1.4 Whisker Evaluation

The whisker evaluation test was performed for 1,000 hrs and the test results are in Table 3-6.

Table 3-6 Whisker Evaluation and Result of Sn-Cu and Sn-Ag Plating of TSOP-I 48-P-1220-0.5

Test	Test Condition	Solder Plating	Result	
			Quantity	Failure
Whisker	60oC/90%RH/1,000h	Sn-Pb	240	0
		Sn-Cu	240	0
		Sn-Ag	240	0

Criteria: Inspected by Stereo Microscope (×50 magnified), and whisker length should be less than 50 micrometers.

3.2 On Board Reliability

As for leads type package, the test results for the combinations of lead(Pb) contained and lead(Pb)-free paste vs. lead(Pb) contained and lead (Pb) -free packages are provided.

Since soldering reliability depends on the soldering conditions such as solder paste type, reflow temperature profile and board, we recommend to verify its solderability and reliability at customer's condition prior to the implementation.

The test board is described below;

Board specification of Leads Type Package (TSOP-I 48P-1220-0.5)

Board (A): FR-4 (6 layers)/120 × 200 × t 1.2 (mm)/Au-Ni plating
Board (B): FR-4 (6 layers)/ 40 × 160 × t 1.2 (mm)/Au-Ni plating
Metal Mask: t 120 μm (apertureϕ0.25 × 1.475 mm)
Package: 48pins TSOP/20 × 12 × t 1.2 (mm)/Lead 42 Alloy

* Board (A) is applied to temperature cycle test and lead joint strength test, and Board (B) is applied to repetitive bending test.

Board specification of Ball Type Package (P-TFBGA107-0912-0.8)

Board: FR-4 (4 layers)/40 × 108 × t 0.8 mm/Soluble Flux
Metal Mask: t 150 μm (apertureϕ0.45 mm)
Package: 107pinsBGA /9 × 12 × t 1.4 (mm)/Ballϕ0.4 mm

* The board is applied to the each test of temperature cycle, repetitive bending strength, drop and package pull/shear strength.

3.2.1 On Board Temperature Cycle Test

Table 3-7 shows on board temperature cycle test of the leads type package (TSOP-I 48-P-1220-0.5) and Table 3-8 shows that of the ball type package (P-TFBGA107-0910-0.8).

Table 3-7 On Board Temperature Cycle Test Result of TSOP-I 48-P-1220-0.5

Test	Test Condition	Solder Paste	Solder Plating	Result	
				Quantity	Failure
TCT (Temperature Cycle Test)	–25°C/125°C 500cyc	Sn-Pb	Sn-Pb	30	0
			Sn-Cu	30	0
			Sn-Ag	30	0
		Sn-Ag-Cu	Sn-Cu	30	0
			Sn-Ag	30	0

Table 3-8 On Board Temperature Cycle Test Result of P-TFBGA107-0912-0.8

Test	Test Condition	Solder Paste	Solder Ball	Result	
				Quantity	Failure
TCT (Temperature Cycle Test)	–25°C/125°C 500cyc	Sn-Pb	Sn-Pb	30	0
		Sn-Ag-Cu	Sn-Ag-Cu	30	0

Criteria: Electric resistance on solder joint should be less than twice of initial values

3.2.2 Solder Joint Strength Test

Solder joint strength of lead(Pb)-free package is similar to lead(Pb) contained package.

Fig 3-7 shows the method of lead joint strength test, and Fig 3-8 shows lead joint strength in various combination with solder plating and solder paste for TSOP-I 48-P-1220-0.5.

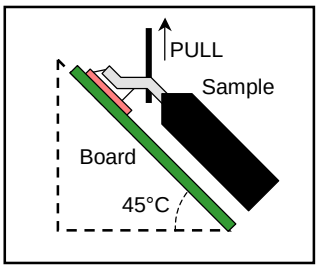


Fig 3-7 Method of Solder Joint Strength Test

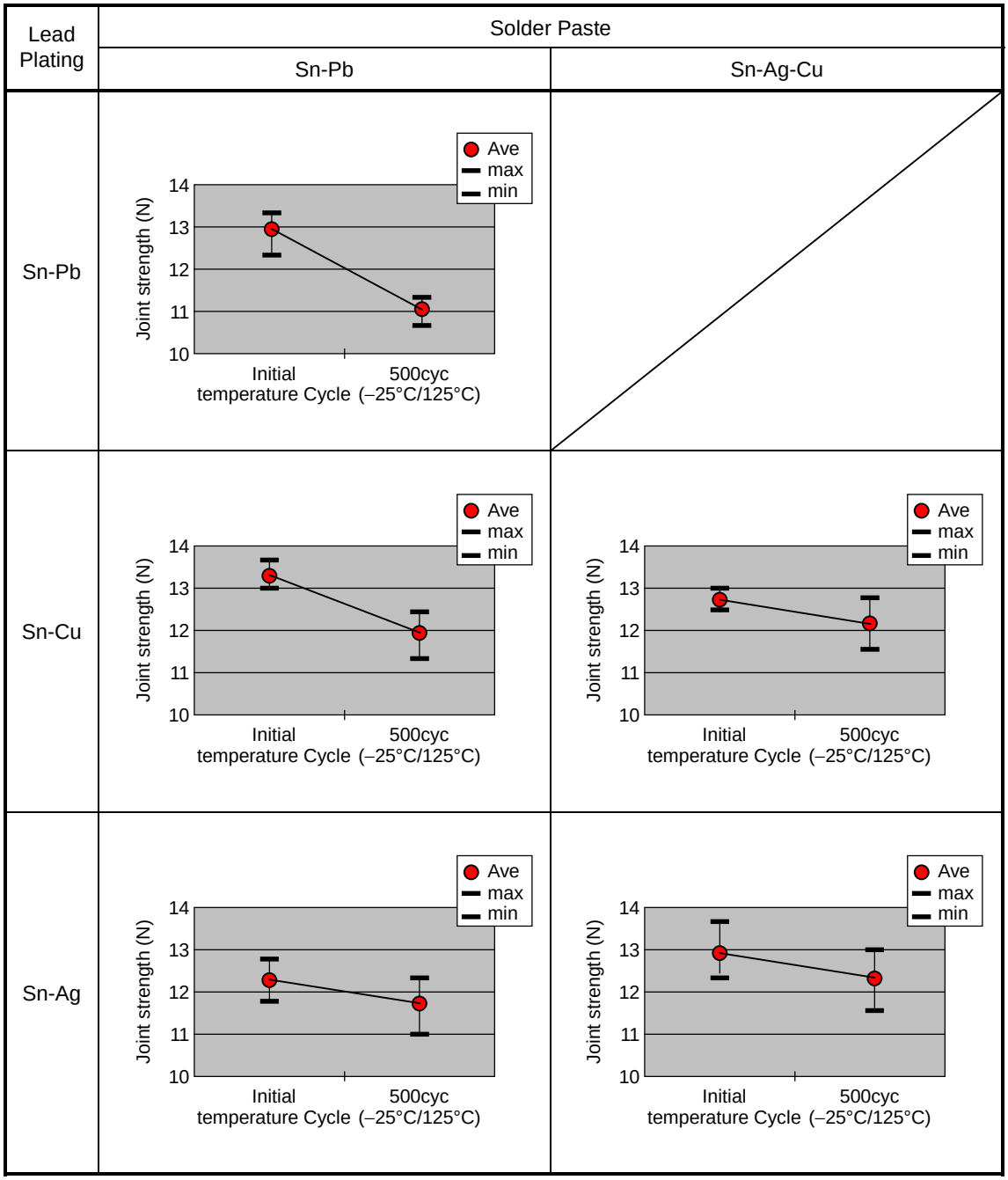


Fig 3-8 Solder joint strength in various combined with solder plating and solder paste

3.2.3 Repetitive Bending Test

Fig 3-9 shows the method of the repetitive bending test, Table 3-9 shows the repetitive bending test result of the lead type package (TSOP-I 48-P-1220-0.5) and Table 3-10 shows that of the ball type package (P-TFBGA107-0912-0.8).

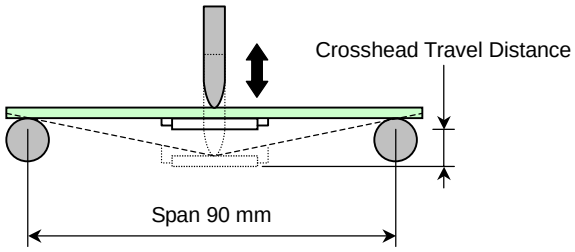


Fig 3-9 Method of Repetitive Bending Test

Table 3-9 Repetitive Bending Test Results of TSOP-I 48-P-1220-0.5 Package

Test	Test Condition		Solder Paste	Solder Plating	Result	
	CTD	Bend Freq.			Quantity	Failure
Repetitive Bending	3.0mm	500times	Sn-Pb	Sn-Pb	5	0
				Sn-Cu	5	0
				Sn-Ag	5	0
			Sn-Ag-Cu	Sn-Cu	5	0
				Sn-Ag	5	0

Table 3-10 Repetitive Bending Test Results of P-FBGA107-0912-0.8 Package

Test	Test		Solder Paste	Solder Ball	Result	
	CTD	Bend Freq.			Quantity	Failure
Repetitive Bending	3.0mm	500times	Sn-Pb	Sn-Pb	5	0
			Sn-Ag-Cu	Sn-Ag-Cu	5	0

Criteria: Electric resistance on solder joint should be less than twice of initial values

3.2.4 Package Pull/Shear Strength Test

The purpose of this test is to compare the soldering strength of the ball type package on the board and the strength of lead(Pb)-free package is similar to lead(Pb) contained package.

Fig 3-10 shows the test method, Fig 3-11 shows the major fracture modes and Table 3-11 shows a package pull/shear strength test result.

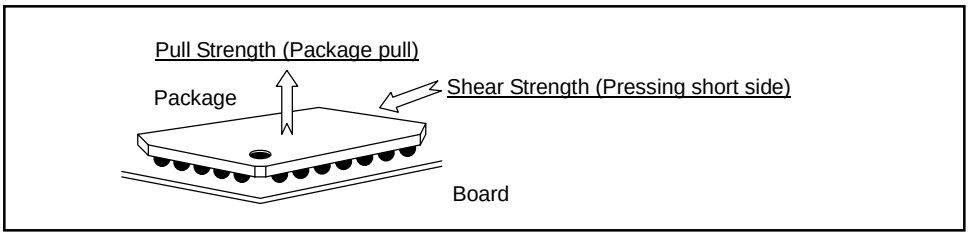


Fig 3-10 Method of Package Pull/Shear Strength Test

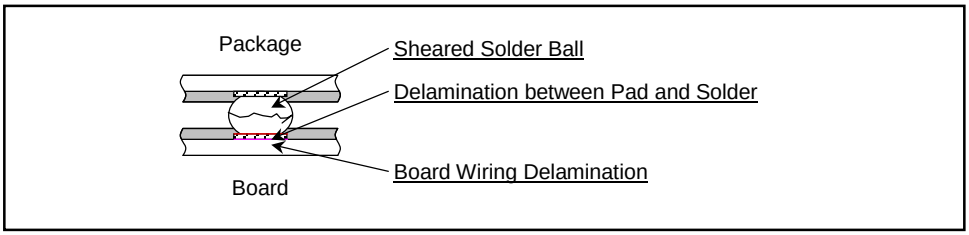


Fig 3-11 Examples of Fracture Mode of Package Pull/Shear Strength Test

Table 3-11 Package Pull/Shear Strength Test Result of P-FBGA107-0912-0.8

Test	Solder Paste	Solder Ball	Result		
			Quantity	Strength (N)	Main Failure Mode
Package Pull	Sn-Pb	Sn-Pb	5	253<215-298>	Board Wiring Delamination
	Sn-Ag-Cu	Sn-Ag-Cu	5	233<205-244>	
Package Shear	Sn-Pb	Sn-Pb	5	573<536-611>	Sheared Solder Ball
	Sn-Ag-Cu	Sn-Ag-Cu	5	624<579-646>	

3.2.5 Drop Test

The drop test is to simulate the drop endurance on mobile equipment such as mobile phone.

Following are the test conditions and the results.

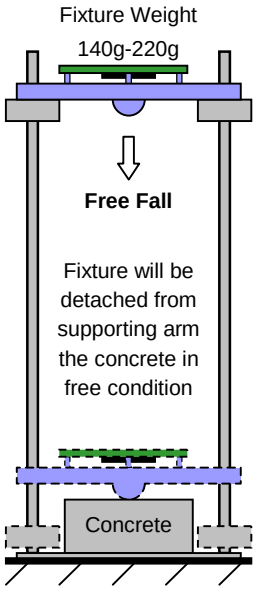


Fig 3-14 Drop Tester

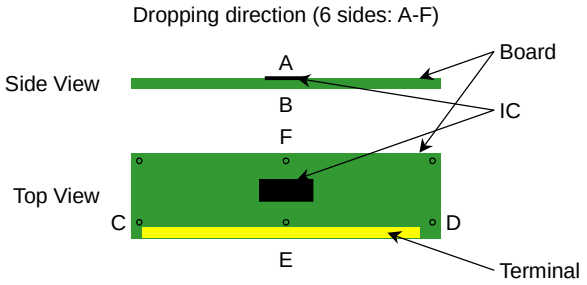


Fig 3-12 Drop Direction of Test Board

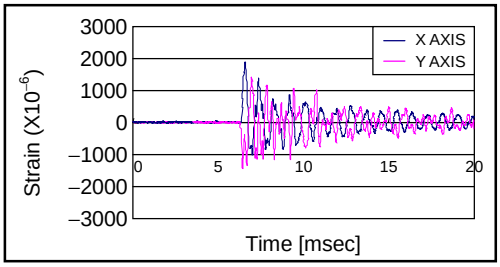


Fig 3-13 Graph Plotted Strain Value on Board

Test Method

After attaching package mounted board on the fixture, drop it to the concrete surface as per 6 directions in 1 cycle.

Fixture attached to every drop faces, screwed on mounting board with 6 directions.

Board strain on package edge is 1800×10^{-6} with face A (equivalent to dropping mobile phone from the 1.5m height)

Table 3-12 Drop Test Result of P-FBGA107-0912-0.8 Package

Test	Test Condition (Drop Freq.)	Solder Paste	Solder Ball	Result	
				Quantity	Failure
Drop	6 Directions 3cyc	Sn-Pb	Sn-Pb	5	0
		Sn-Ag-Cu	Sn-Ag-Cu	5	0

Criteria: Electric resistance on solder joint should be less than twice of initial values

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- Sogo, S. Hara, S. Natori, T. Kobayashi, “Estimation of fall impact strength for BGA solder joints” The 12th Computational Mechanics conference, no.99-5, pp.549-550, November 1999 (in Japanese)
- Sogo, S, Hara, “Investigation on fall impact strength for BGA solder joints” The 13th Computational Mechanics conference, No.00-17, pp.647-648, November 2000. (in Japanese)
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