Solder Ball Land Type에 따른 SJR (Solder Joint Reliability)

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Solder Joint Reliability With Variations Of Solder Ball Land Design

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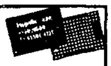
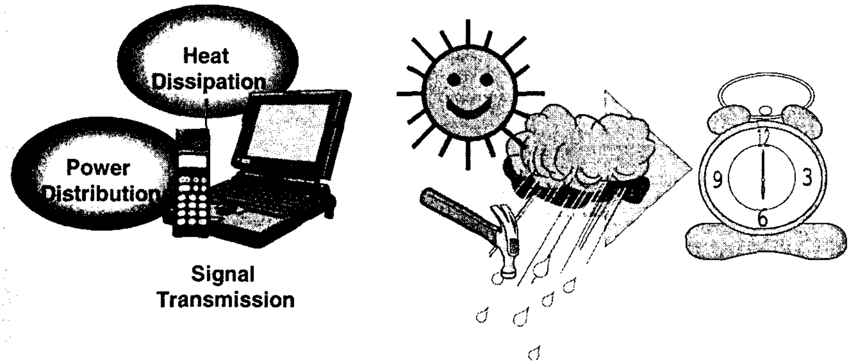


Contents

1. What Is Solder Joint Reliability ?

"The probability of the solder joint performing it's intended function over intended life and under the operating conditions encountered."



Performance **Environment** **Intended Life**

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2. How The Solder Joint Characteristics Can Be Measured & Ensured ?

A. Mechanical strength test 1
: Ball shear strength, Ball pull test, Scrubbing test
(Criteria for the approved mass device & process monitoring)

B. Mechanical strength test 2
: Drop test, Point bending test, 4-Corner Strain Test
(Criteria for the solder joint strength of the mobile product)

C. Life time estimation
: Failure monitoring during T/C
(Criteria for the newly designed structure & material set)

3. Temperature Conditions & Simulations For The SJR

3-1. Temperature Conditions Of Memory Module During The Operation

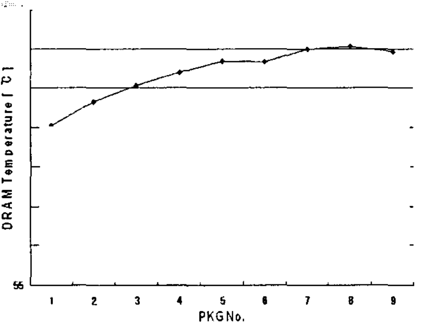
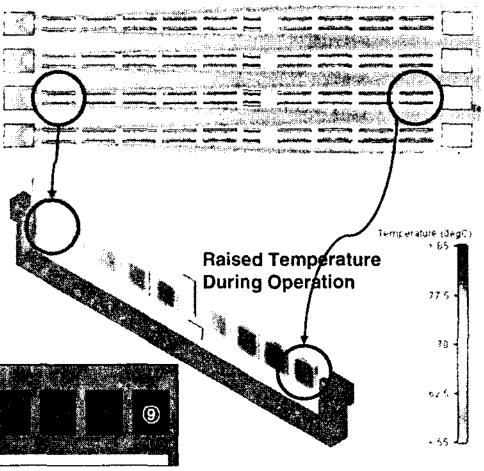


Fig. 3-1 Temperature Gradient Of PKG On The Module1

Fig. 3-2 Temperature Profile Of Mounted Module On The Main Board



Raised Temperature During Operation

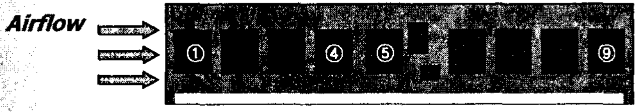


Fig. 3-3 Air Flow Direction By Cooling Fan

3-2. Solder Joint Fracture Mechanism By Temperature Conditions

- Solder Joint Fracture By C.T.E. Mismatch

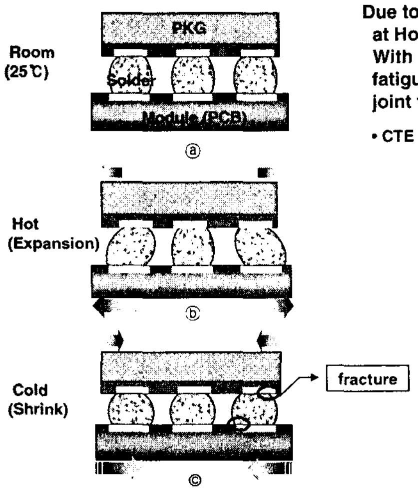
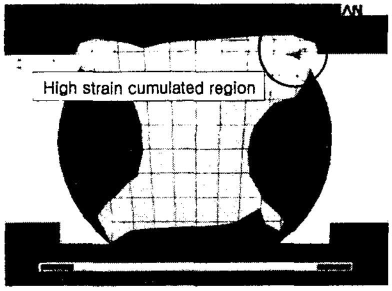


Fig 3-4. Stress on solder ball by C.T.E.

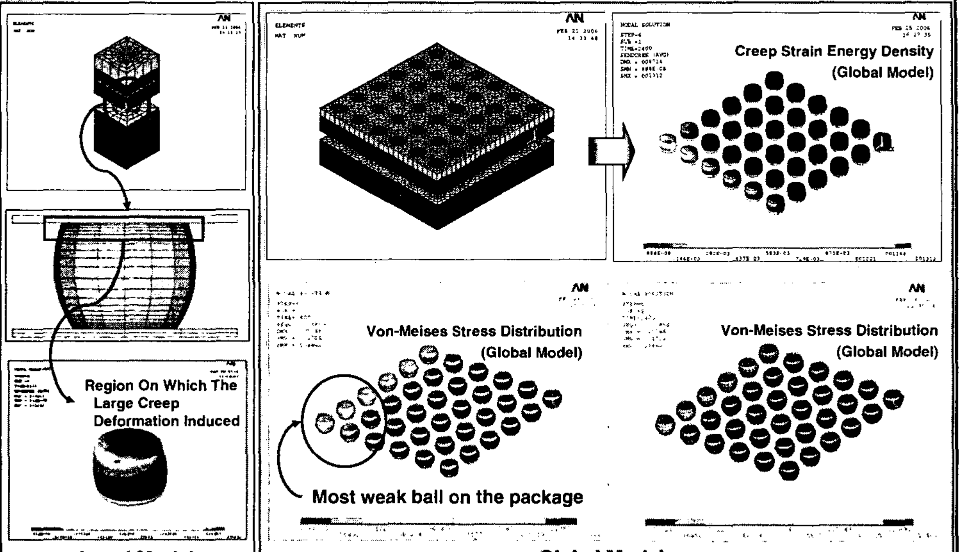
Due to C.T.E mismatch, PCB expands more than PKG at Hot and shrinks more at the cold temp.
With this symptom, solder ball is under periodic fatigue stress during thermal cycle and then solder joint facture can be caused.

- CTE value :
  EMC : 10ppm
  Die : 3ppm
  SUB. : 20ppm

- Strain Distribution At The Solder Ball



3-2. Stress & SJR Simulation During The Temperature Cycle (Quarter Model)



Creep Strain Energy Density (Global Model)

Von-Meises Stress Distribution (Global Model)

Von-Meises Stress Distribution (Global Model)

Region On Which The Large Creep Deformation Induced

Most weak ball on the package

Local Model

Global Model

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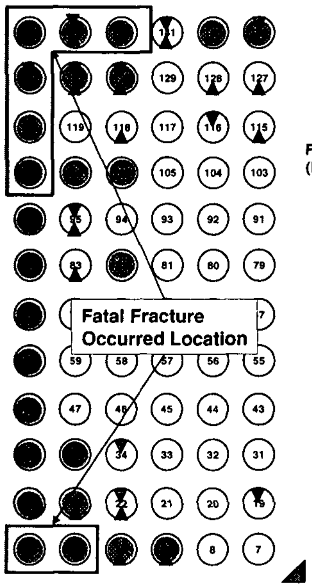
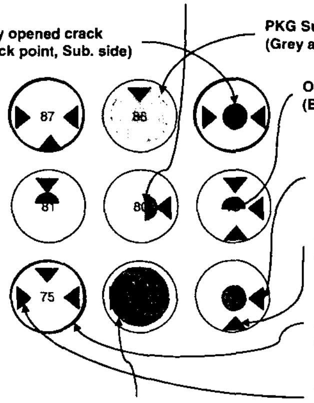
4. Real Fractures Of The Solder Joint Of PKG & PCB Side

4-1. The Half Side View Of Solder Joint Fracture Of 144Ball FBGA Package



Fatal Fracture Occurred Location

Fig. 4-1 Origin of S/B joint fracture generation



Opened crack > 100㎛ (Green half circle , PCB. side)

Fully opened crack (Black point, Sub. side)

PKG Sub Core Crack (Grey area, Sub. side)

Opened crack > 100㎛ (Black half circle , Sub. side)

Fully opened crack (Green point, PCB. side)

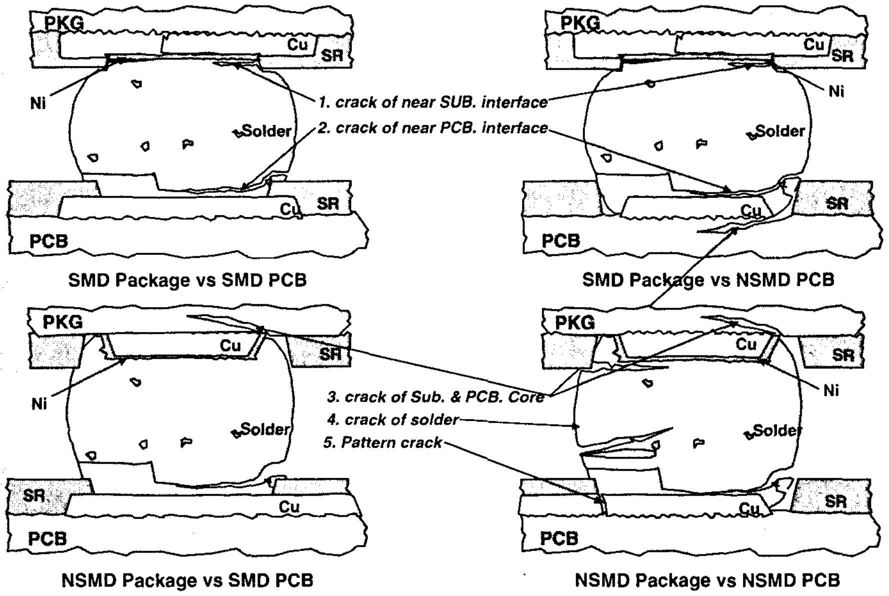
Origin of crack generation (Black arrow, Sub. side)

PCB ball land which has broad area than isolated one (Red circle, PCB pattern shape)

Origin of crack generation (Green arrow, PCB. side)

PCB Core Crack (Blue area, PCB. side)

4-2. Solder Joint Fracture Mode With Variations Of Land Design



SMD Package vs SMD PCB

SMD Package vs NSMD PCB

NSMD Package vs SMD PCB

NSMD Package vs NSMD PCB

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5. How The Solder Joint Life Time Can Be Estimated ?

5-1. Acceleration Factor For Temperature Cycle (AF)

▶ Modified Coffin-Manson (Norris-Landzberg) Equation

$$AF=\left[\frac{\Delta T_l}{\Delta T_f}\right]^{1.7}\left(\frac{f_f}{f_l}\right)^{1/3}\exp\left(1414\left\{\frac{1}{T_{\max f}}-\frac{1}{T_{\max l}}\right\}\right)=15.2$$

5-2. Life Time For Solder Joint

TFop = $AF_{T/C}$ x TF_{st} = 15,200cycles

AF : Acceleration Factor
ΔT_l : TCTlow~TCThigh
ΔT_f : Ton-Toff
f_f : Frequency of on/off cycles for the product (cycles/day)
f_l : Frequency of cycles during the test (48hrs)
$T_{\max f}$: Maximum temperature in the field (30℃+273℃=303K)
$T_{\max l}$: Maximum temperature in the lab (125℃+273℃=303K)
1414 : Ea/k (Ea :0.122, k:8.62E-5)

Product	On/Off Cycle (A)	AF@ T/C (B)	Test Cycles (C)	Cycles (D=BxC)	Equivalent Lifetime (D/A)
ES	2/month	15.2	1000	15,200	633 Yrs
HES	3.5/weeks	15.2	1000	15,200	82 Yrs
PC	1/day	15.2	1000	15,200	42 Yrs
CE	2/day	15.2	1000	15,200	21 Yrs

6. Solder Joint Fracture With Variations Of The Land Design

6-1. SJR Test Results Of The Single Side Mounted F144 Package

6-1-1. Purpose

- To evaluate the T/C SJR of single side mounted PKG on the PCB designs (SMD vs NSMD).
- To evaluate the 2L & 4L package substrate for T/C SJR characteristics.

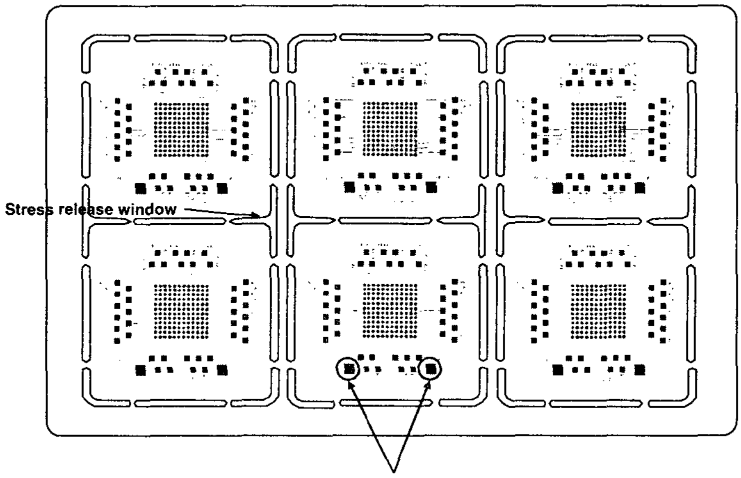
6-1-2. Descriptions

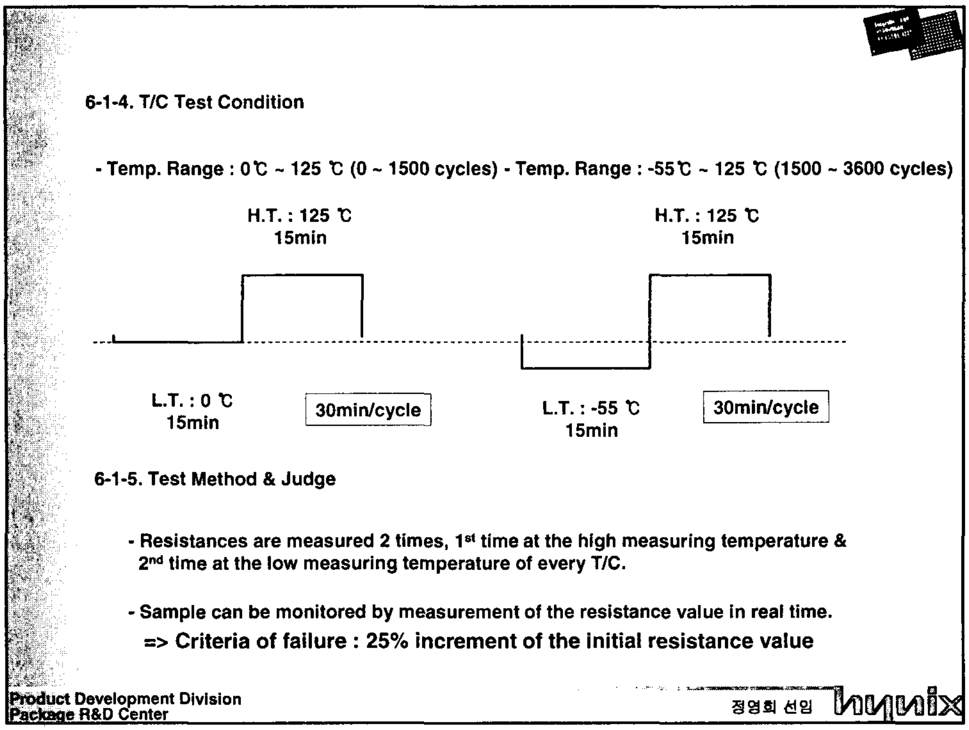
	PKG Substrate	Daisy PCB
Matrix	Ball Land Type	Ball Land Type
# 1	SMD 400㎛ (4 Layer)	SMD 400㎛
# 2		NSMD 350㎛
# 3	NSMD 400㎛ (4 Layer)	SMD 400㎛
# 4		NSMD 350㎛
# 5	SMD 400㎛ (2 Layer)	SMD 400㎛
# 6		NSMD 350㎛
# 7	NSMD 400㎛ (2 Layer)	SMD 400㎛
# 8		NSMD 350㎛

Table 6-1. Table of test matrix

6-1-3. T/C Test Daisy Chain PCB Module

PCB Daisy (Thickness 1mm, 4Layer)





6-1-4. T/C Test Condition

- Temp. Range : 0℃ ~ 125 ℃ (0 ~ 1500 cycles) - Temp. Range : -55℃ ~ 125 ℃ (1500 ~ 3600 cycles)

6-1-5. Test Method & Judge

- Resistances are measured 2 times, 1st time at the high measuring temperature & 2nd time at the low measuring temperature of every T/C.
- Sample can be monitored by measurement of the resistance value in real time.

=> **Criteria of failure : 25% increment of the initial resistance value**

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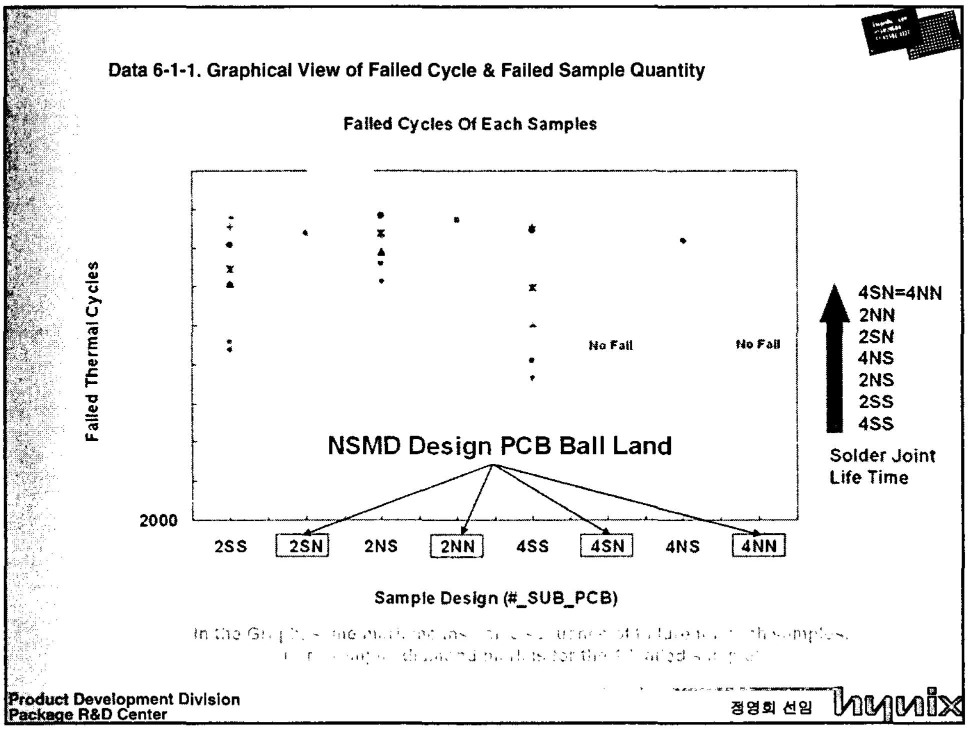

Data 6-1-1. Graphical View of Failed Cycle & Failed Sample Quantity

In the Graph, [illegible] samples.
[illegible]

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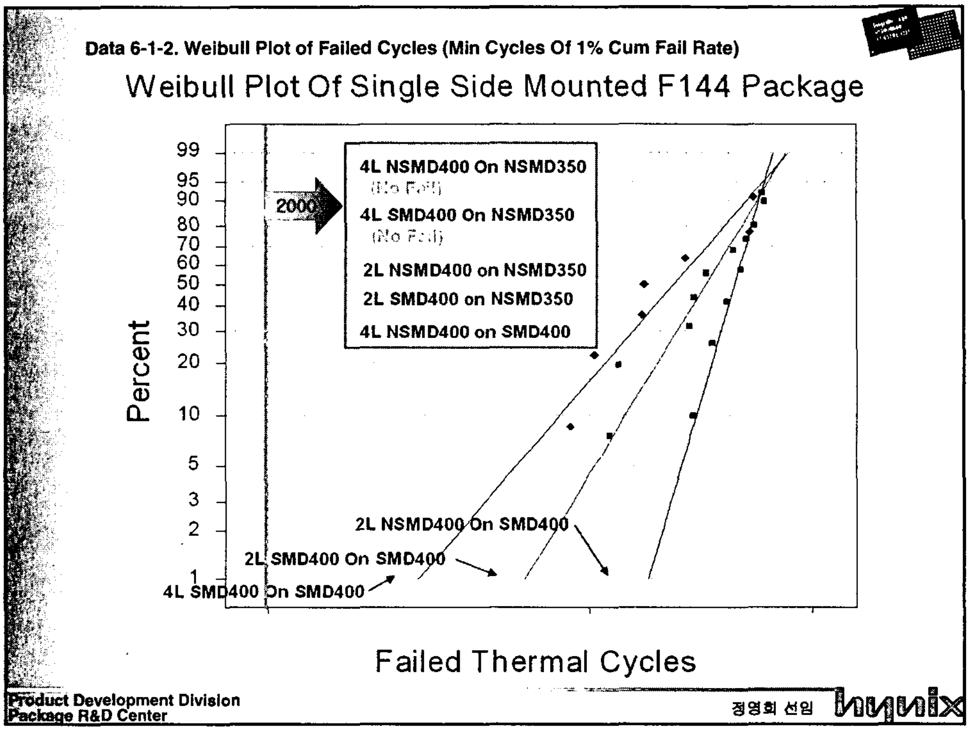

Data 6-1-2. Weibull Plot of Failed Cycles (Min Cycles Of 1% Cum Fail Rate)

Weibull Plot Of Single Side Mounted F144 Package

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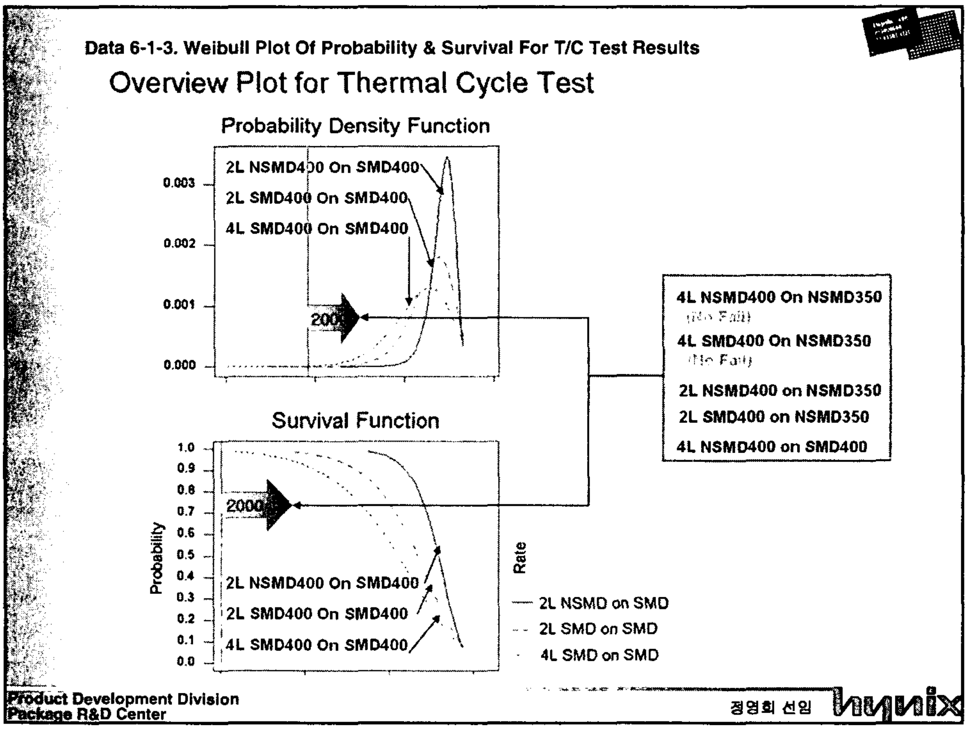

Data 6-1-3. Weibull Plot Of Probability & Survival For T/C Test Results

Overview Plot for Thermal Cycle Test

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6-1-6. Summary Of SJR Test For The Single Mounted Package

-. What's the life time of tested samples?

For the temperature range 0℃~125℃, both of NSMD & SMD 400㎛ design can guarantee the T/C life cycles more than 2000cycles.
This means that more than 42years for the mobile consumer product & 82 years for the PC product can be guaranteed for it's life time.
Regardless of package sub. Design, NSMD type PCB design shows best T/C life life time characteristics.

-. What pair of design can be the best set?

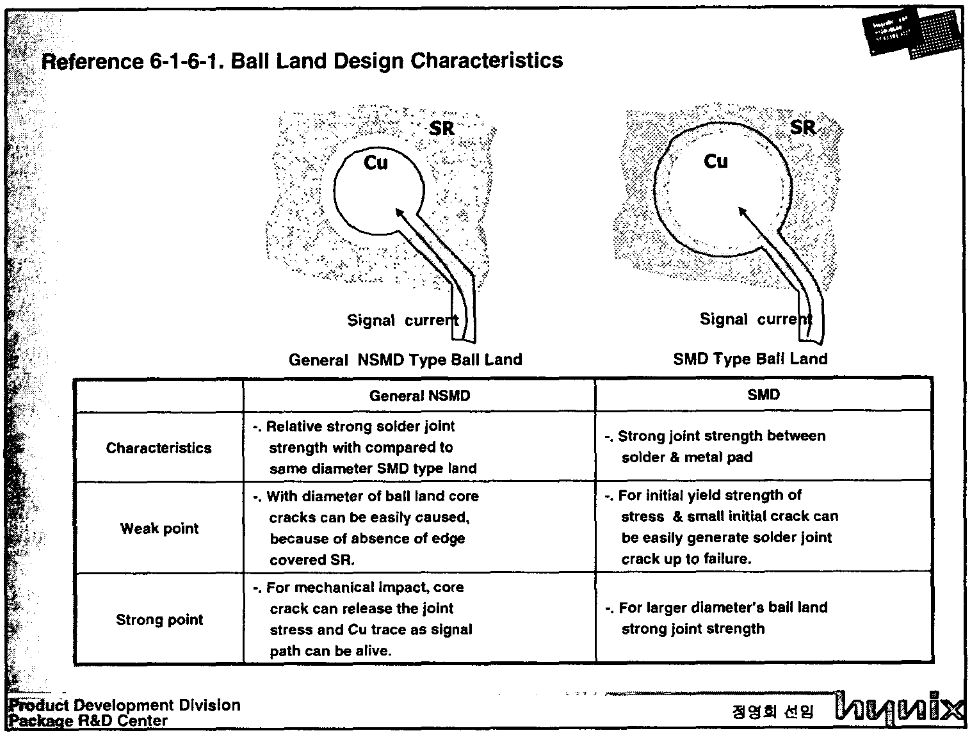
For the best pair of substrate & PCB land design, NSMD Package on the NSMD PCB shows the best results for the T/C life time.

-. Why the thicker(4L) substrate shows the better result than (2L) for T/C?

For the substrate thickness, more thicker substrate(4L) shows better results with compared to the thinner substrate(2L) used package.
This results can be caused from the higher expansion than thinner substrate.
More thicker substrate applied package shrunk more than thinner substrate applied package during the low T/C & expand more during the high T/C.
This means that more thicker substrate used package can easily follow the displacement of module PCB during the T/C, because of it's higher portion of substrate volume with compared to EMC volume in the same height package.

-. Why the thicker(4L) SMD type package on the SMD type PCB shows worst T/C life cycle than other cases?

In case of thicker(4L) substrate applied package, warpage can be more larger than thinner(2L) substrate applied package, and this could be caused from the portion of the EMC & substrate in the same total height.
This larger warpage, also can induce the more stress on the package edge balls.
If one part or both part of substrate & PCB, be NSMD type ball land design, more portion of stress from the warpage difference from the thicker & thinner substrate can be released form the fracture of the core beneath the NSMD ball lands.
So, in case of both sides design's of substrate & PCB are SMD type, the T/C life cycles might be shorter than another cases.



Reference 6-1-6-1. Ball Land Design Characteristics

General NSMD Type Ball Land

SMD Type Ball Land

	General NSMD	SMD
Characteristics	-. Relative strong solder joint strength with compared to same diameter SMD type land	-. Strong joint strength between solder & metal pad
Weak point	-. With diameter of ball land core cracks can be easily caused, because of absence of edge covered SR.	-. For initial yield strength of stress & small initial crack can be easily generate solder joint crack up to failure.
Strong point	-. For mechanical impact, core crack can release the joint stress and Cu trace as signal path can be alive.	-. For larger diameter's ball land strong joint strength

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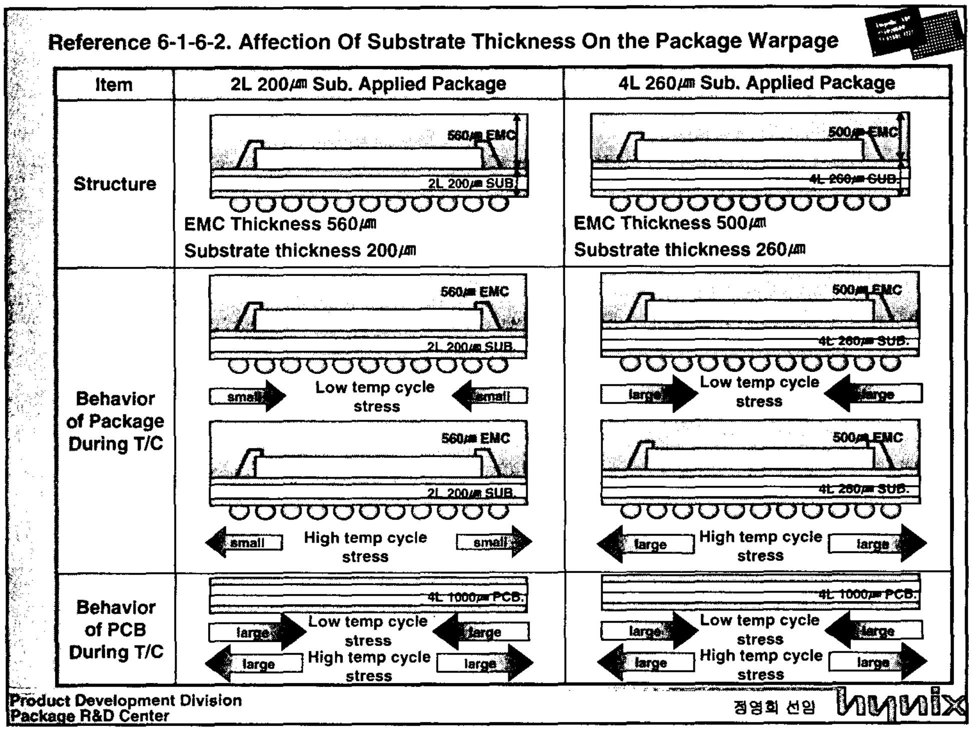

Reference 6-1-6-2. Affection Of Substrate Thickness On the Package Warpage

Item	2L 200㎛ Sub. Applied Package	4L 260㎛ Sub. Applied Package
Structure	EMC Thickness 560㎛ Substrate thickness 200㎛	EMC Thickness 500㎛ Substrate thickness 260㎛
Behavior of Package During T/C	small → Low temp cycle stress ← small ← small High temp cycle stress small →	large → Low temp cycle stress ← large ← large High temp cycle stress large →
Behavior of PCB During T/C	large → Low temp cycle stress ← large ← large High temp cycle stress large →	large → Low temp cycle stress ← large ← large High temp cycle stress large →

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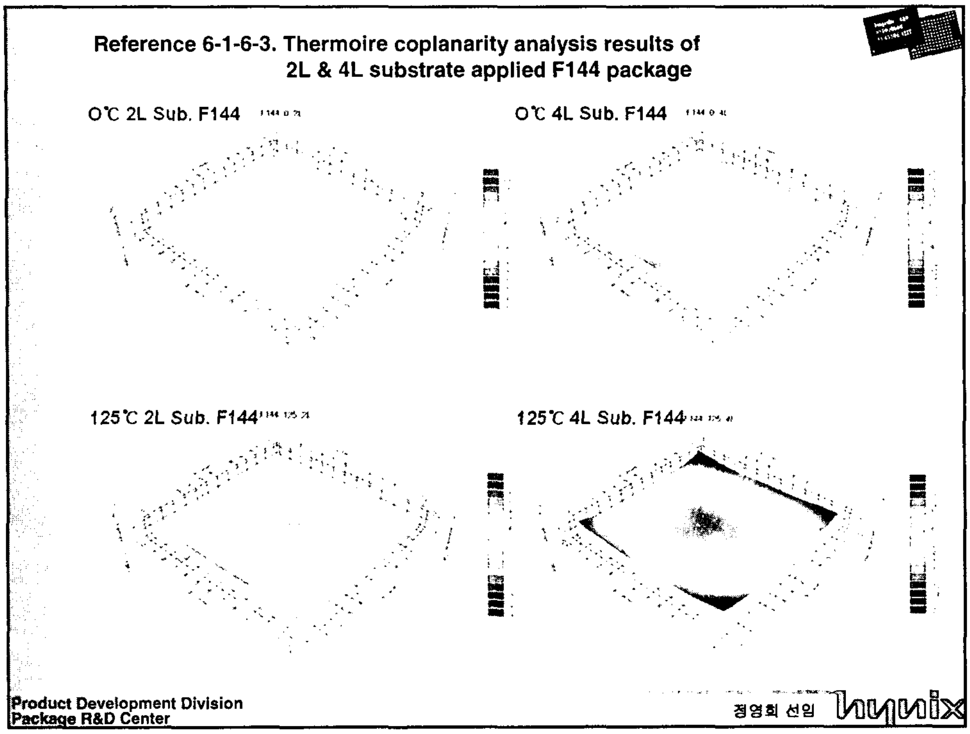

Reference 6-1-6-3. Thermoire coplanarity analysis results of 2L & 4L substrate applied F144 package

O℃ 2L Sub. F144

O℃ 4L Sub. F144

125℃ 2L Sub. F144

125℃ 4L Sub. F144

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