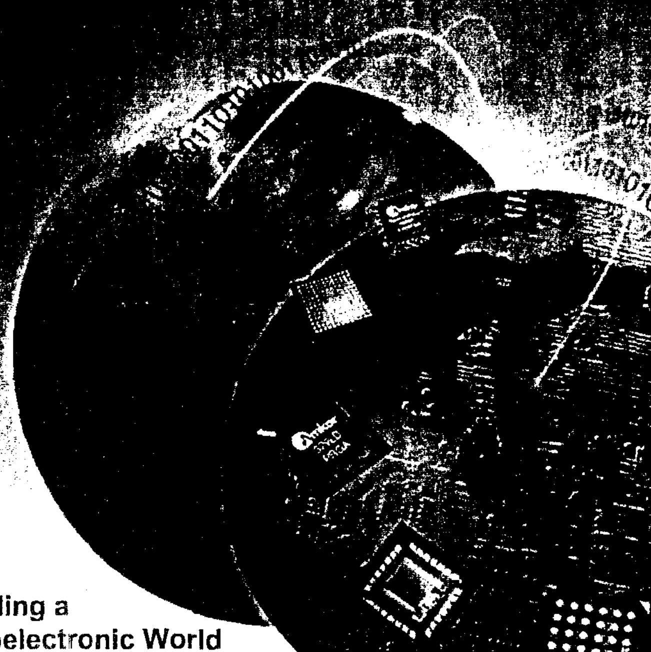
Second Joint Reliability in Packaging

김 진 영
(Amkor Technology Korea Inc. 기술연구소)

2nd Level Reliability in Packaging

Amkor
R&D, ATK1



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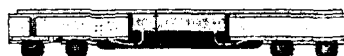
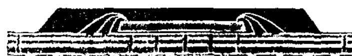
Package Types

2 Lyr PBGA

etCSP

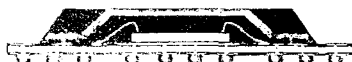


4 Lyr PBGA

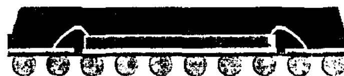


MCM PBGA

TEPBGA - 2

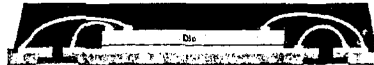


flexBGA

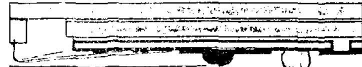


TSBGA

MLF



SBGA



ultraCSP

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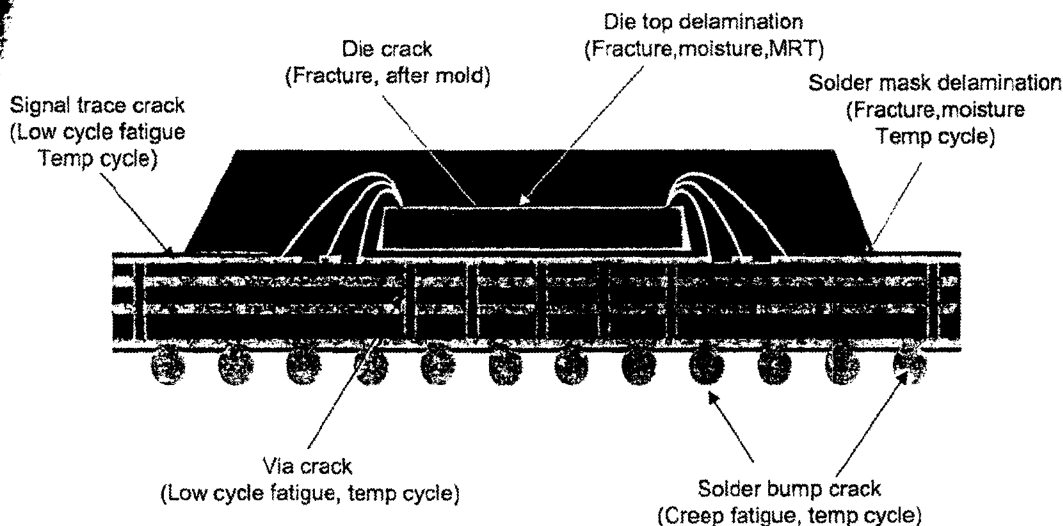
Mechanical Failure in Package



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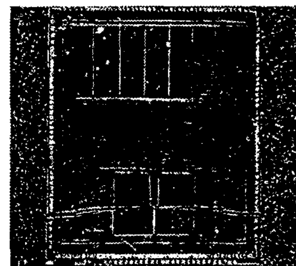
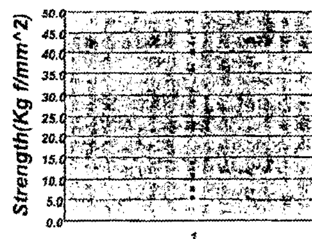
Mechanical Failure in Package

- **Elastic failure**
  - ✓ Usually brittle materials
    - Si, GaAs, Glass, EMC
  - ✓ Cleavage failure
  - ✓ Stress is the major concern of failure
    - stress-based life prediction
  - ✓ Low fracture toughness
    - low crack resistance,crack
    - crack initiation ~ fracture strength
  - ✓ Instant fracture
    - After mold, bending test





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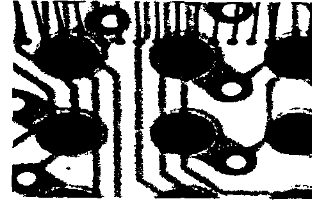
Mechanical Failure in Package

- **Plastic failure**
  - ✓ Ductile materials
    - Copper, Solder
  - ✓ Ductile dimple failure
  - ✓ Plastic strain is the major concern of failure
    - strain-based life prediction
  - ✓ Fracture strength (shows large elongation)
  - ✓ High fracture toughness
    - High crack resistance
    - fatigue design (life > crack initiation time)
  - ✓ Low cycle fatigue life
    - less than 10000 cycles



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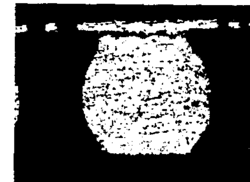
Mechanical Failure in Package

- **Creep-fatigue failure**
  - ✓ T > 0.3 Tm (melting temperature)
    - eutectic solder : T_m=183 °C
  - ✓ material degradation
    - micro crack (Pb rich/Sn rich phase), coarsening
  - ✓ Time dependent failure
    - ramp rate, hold time
  - ✓ Accumulated creep strain is the main concern of failure
    - strain-based life prediction
  - ✓ Material structure is important
    - eutectic/lead free solder
  - ✓ Low cycle fatigue life (little than 10000 cycles)



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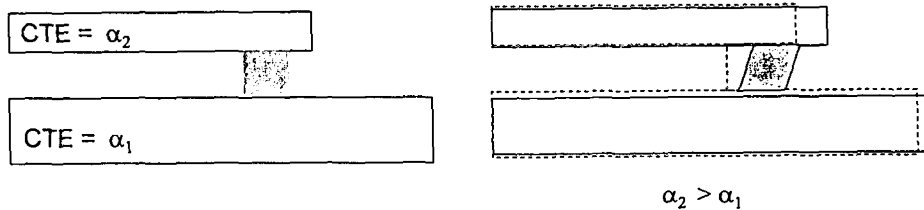
2nd Level Reliability in packaging

- Solder Joint Fatigue Failure -

◆ Failure Mechanism

- Displacement due to mismatch of the CTE
- Thermally induced displacement results in a high peel and shear stress near the bonded edges of joint
- Fatigue crack initiates at the bonded edges
- Crack propagates along the interface leading to failure of the bump



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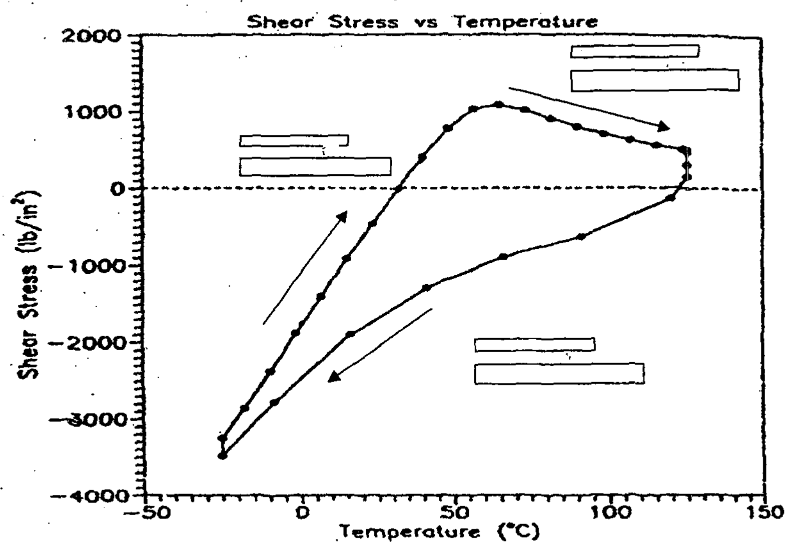
Solder Joint Fatigue Failure

- Failure mechanism -



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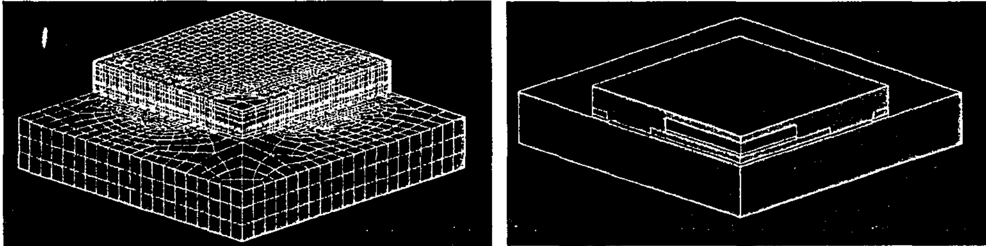
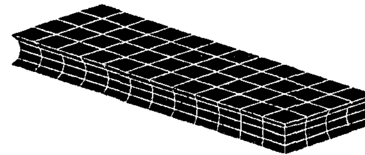
Solder Joint Fatigue Life Prediction

- Case 1 : MLF package -

- **Global Model (1/4th Symmetric) - Elastic Analysis**



- **Local Model (Corner Joint) - Visco-plastic analysis**
  - Detailed Model of Joint of Interest
  - Creep and Temperature Dependent Properties for Solder



$$\dot{\varepsilon}_{s,s,cr.} = \dot{\varepsilon}_{GBS} + \dot{\varepsilon}_{MC}$$

$$\dot{\varepsilon}_{s,s,cr} = 1.7x10^{12} D\left(\frac{\sigma}{E(T)}\right)^3 + 8.9x10^{24} D\left(\frac{\sigma}{E(T)}\right)^7$$

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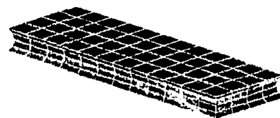
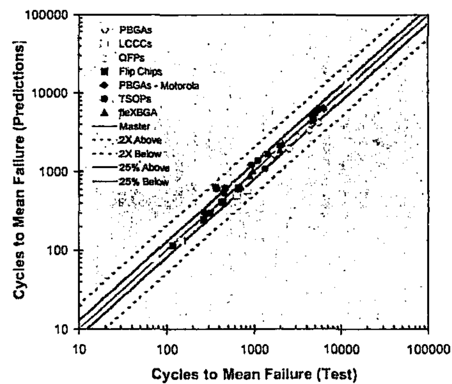
Solder Joint Fatigue Life Prediction

- Case 1 : MLF package -

- **Life Prediction Model**
  - Partitioned Accumulated Creep Strains (ε_{GBS} & ε_{MC}) Calculated from FEA.





$$N_f = (0.02E_{GBS} + 0.063E_{MC})^{-1}$$

Where,

ε_{GBS} & ε_{MC} = Accumulated Creep Strains
N_f = Cycles to Mean Failure (N50)

- Life Prediction Equation used to determine the Mean Life

- First Failure is Estimated from Mean Life as

$$0.6N_f \leq First\ Failure \leq 0.7N_f$$

Prediction Accuracy : ± 25%

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Solder Joint Fatigue Life Prediction

- Case 1 : MLF package -

Case	CTE	Modulus	Mean Life	Estimated First Failure	Estimated First Failure	Rank for 2nd Level Rel
				-40/85 C Cycle	-40/125 C Cycle	
	ppm / C	Kg/mm²	cycles	cycles	cycles	
EMC7	[illegible]	1500	8340	8000	4500	[illegible]
EMC5	14	980	6100	3660	2100	2
EMC9	14	1400	[illegible]	2680	1525	3
EMC6	14	1670	3880	2340	1340	4
EMC10	13	1150	Same as EMC2		1000	5
EMC2	13	1200	3000	1800	1000	5
EMC3	13	1450	2530	1525	870	6
EMC4	13	1680	2260	1356	775	7
EMC8	11	2100	950	570	325	8
EMC11	11	2300	Slightly worse than EMC8			9
EMC12	10	2100	Slightly better than EMC1			9
EMC1	10	2400	700	420	250	10

- Automotive Applications
- All Other Applications
- Portable Applications
- Unacceptable for All Applications

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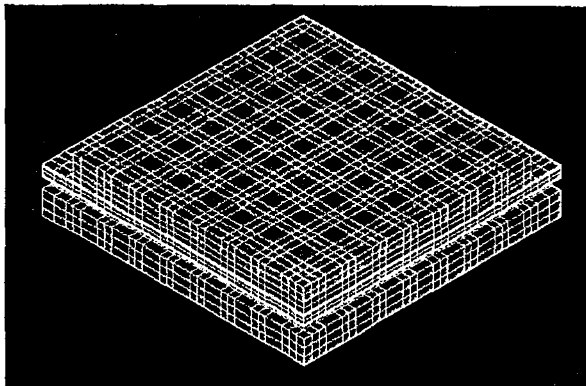
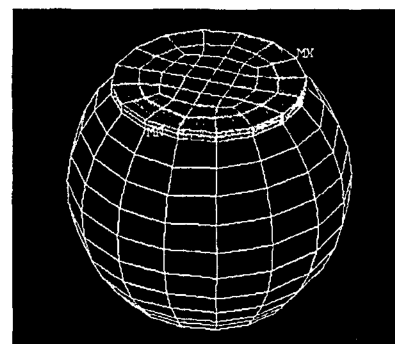
Solder Joint Fatigue Life Prediction

- Case 2: PBGA package -

- **Global Package Model**





Local Solder Joint Model

Solder Volume =
Solder Ball Vol. + 50% Paste Volume

Paste = 5 mil Thick, Aperture = 0.45 mm

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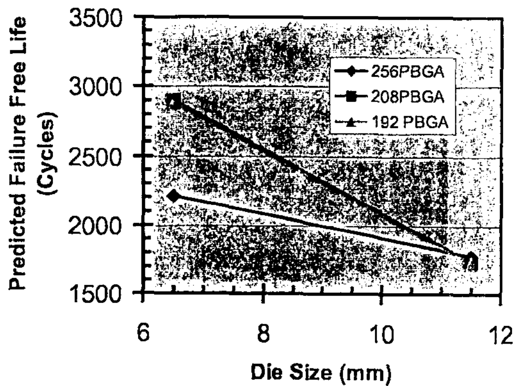
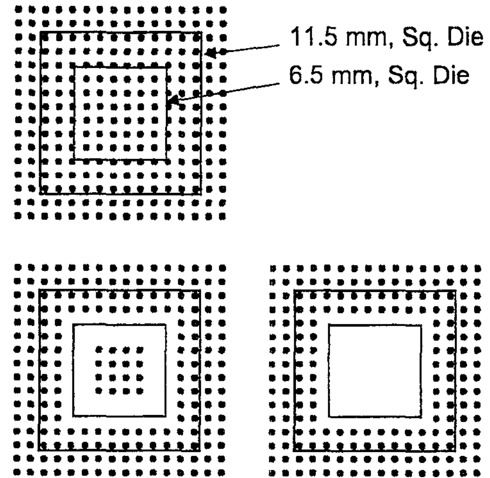
Solder Joint Fatigue Life Prediction
- Case 2: PBGA, Die size effect -

- **256/208/192, 17 x 17 mm, 1.0 mm Pitch PBGAs**
  - Substrate : 0.36 mm Thick, 2 Layer
  - PCB : 31 mils Thick
  - Solder Ball Size = 20 mils





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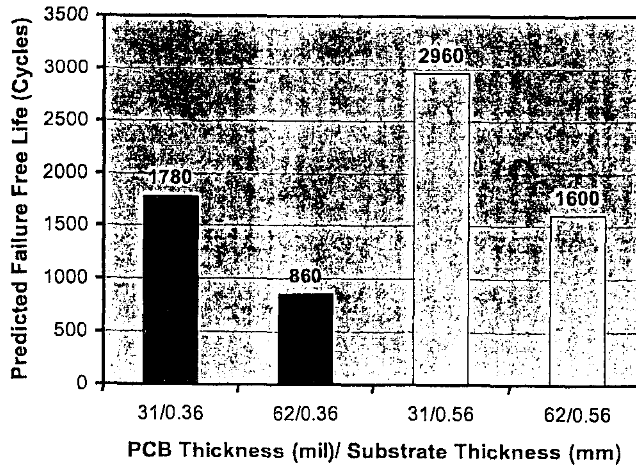
Solder Joint Fatigue Life Prediction
- Case 2: PBGA, PCB/Substrate thickness effect -

- **256 PBGA, 17 x 17 mm, 1.0 mm Pitch**
  - Die Size = 11.5 mm
  - Solder Ball Size = 20 mils



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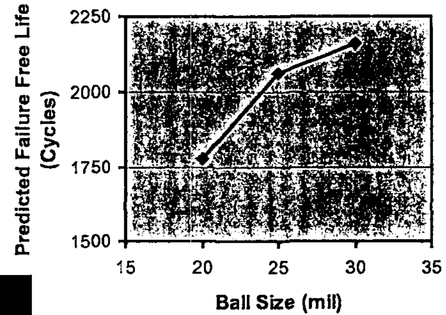
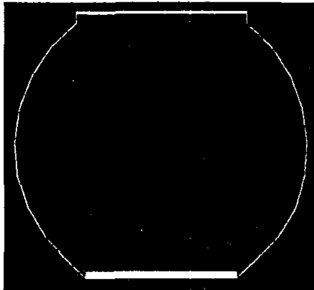
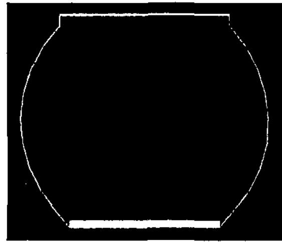
Solder Joint Fatigue Life Prediction
- Case 2: PBGA, Solder ball size effect -

- **256 PBGA, 17 x 17 mm, 1.0 mm Pitch**
  - Die Size = 11.5 mm
  - Substrate : 0.36 mm Thick, 2 Layer
  - PCB : 31 Mils Thick

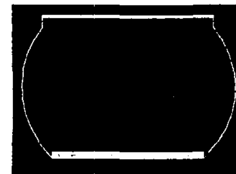




30 Mils Ball
Diameter = 0.78 mm
Height = 0.70 mm



25 Mils Ball
Diameter = 0.66 mm
Height = 0.56 mm



20 Mils Ball
Diameter = 0.56 mm
Height = 0.375

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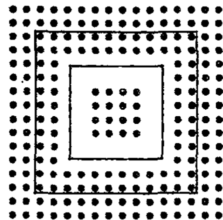
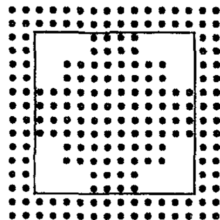
Solder Joint Fatigue Life Prediction
- Case 2: PBGA, Ball array effect -

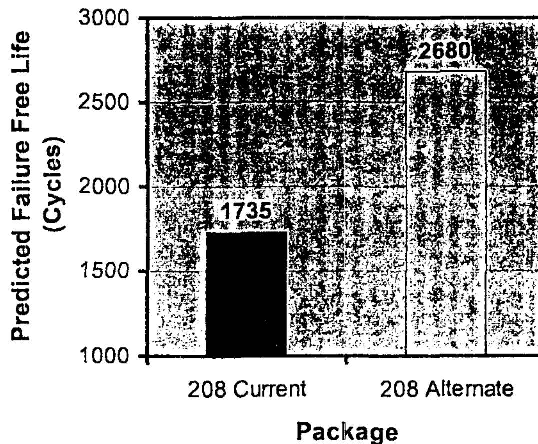
- **Die : 11.5 mm**
- **PCB : 31 Mil Thick**
- **Substrate : 0.36 mm**



For Die Size
< = 7 mm Sq.
Life > 2900 Cycles



For Die Size
> 7 mm Sq.



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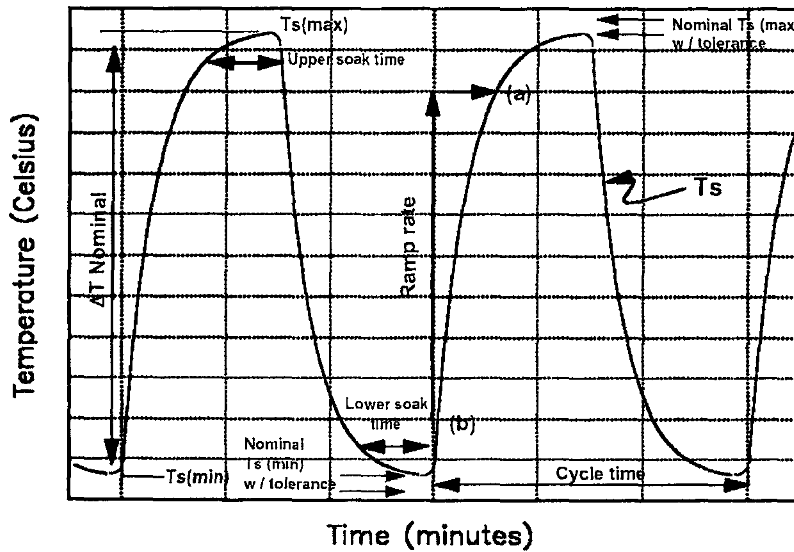
Solder Joint Reliability Test

Temperature Profile

- JEDEC Standard No. 22-A104-B-



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Temperature Profile

- JEDEC Standard No. 22-A104-B-

Table 1 — Temperature cycling test conditions

Test Condition*	Nominal Ts(min)(°C) with Tolerances	Nominal Ts(max)(°C) with Tolerances
A	-55(+0, -10)	+85(+10, -0)
B	-55(+0, -10)	+125(+15, -0)
C	-65(+0, -10)	+150(+15, -0)
G	-40(+0, -10)	+125(+15, -0)
H	-55(+0, -10)	+150(+15, -0)
I	-40(+0, -10)	+115(+15, -0)
J	-0(+0, -10)	+100(+15, -0)
K	-0(+0, -10)	+125(+15, -0)
L	-55(+0, -10)	+110(+15, -0)
M	-40(+0, -10)	+150(+15, -0)

Table 3 — Typical frequency and soak mode for test conditions

Condition	Typical Cycles/Hr	Typical Soak Mode
A	2 – 3	1 & 2
B	2 – 3	1 & 2
C	2	1 & 2
G	< 1 – 2	1, 2, 3 & 4
H	2	1 & 2
I	1 – 2	1, 2, 3 & 4
J	1 – 3	1, 2, 3 & 4
K	1 – 3	1, 2, 3 & 4
L	1 – 3	1, 2, 3 & 4
M	1 – 3	1, 2, 3 & 4

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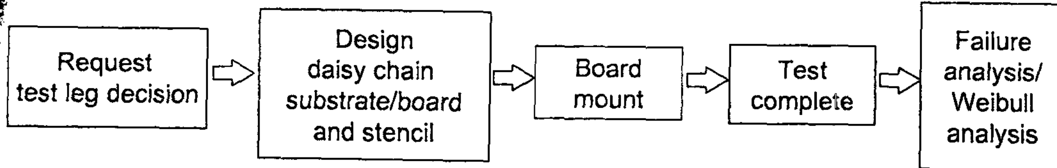
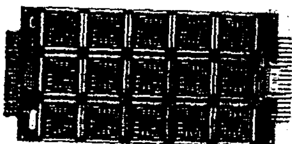
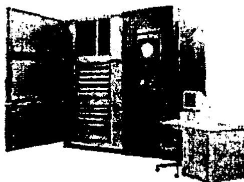
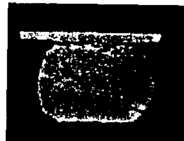
Solder Joint Reliability Test

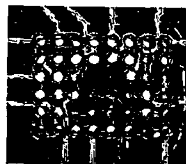
- Test procedure-

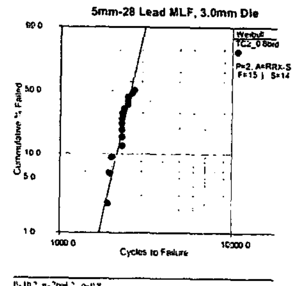












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Solder Joint Reliability Test

- Test specification-

- **Package Attributes**

Body Size Length (mm)	7
Body Size Width (mm)	7
I/O	48
Pitch (mm)	0.5
Die X (mm)	2.3
Die Y (mm)	2.8
Die Z (mil)	10
Leadframe Thickness (um)	250
Land Width (um)	230
Land Length (um)	400
Emc	7351UL
DA	A3

- **Motherboard & Assembly**
  - 4 layer FR-4, OSP Finish
  - 1.6 *and 0.8mm thick*
  - 0.28x0.50mm pad
  - SS, Laser, E-Polish stencil
    - 0.125mm Thick, 1:1 Aperture
  - UP78-M-90-3-M13 (Alpha) Paste
- **Temp Cycle Condition**
  - TC1: -40<>125C, 1 cycle/hour
  - TC2: -55<>125C, 2 cycles/hour
  - TC3: 0<>100C, 2 cycles/hour
- **Sample Size**
  - 15 to 30 each
- **Failure Definition**
  - Continuous scanning of daisy chain nets (every 2 minutes)
  - Threshold resistance: 300 ohms
  - OPEN: An event with resistance of net greater than threshold resistance
  - FAIL: A net OPEN for at least 10% of the time during one cycle
  - 15 FAILURES logged for each net
- **BLR exceeds requirements for all applications**
- **Data Summary**

Tracking Number	MLF2-10032000-1	MLF2-10032000-2	MLF2-10032000-3	MLF2-10032000-4	MLF2-10032000-5	MLF2-10032000-6
Board Thickness (mm)	0.8	0.8	0.8	1.6	1.6	1.6
Test Type	TC2	TC3	TC3	TC3	TC2	TC1
Cycles Completed	6595	12158	12158	12158	6595	6114
1st Failure	NA	5883	NA	5927	6276	4182'
# of Failures	0	1	0	1	1	2
# Parts on Test	21	15	15	30	20	13
Report Number						

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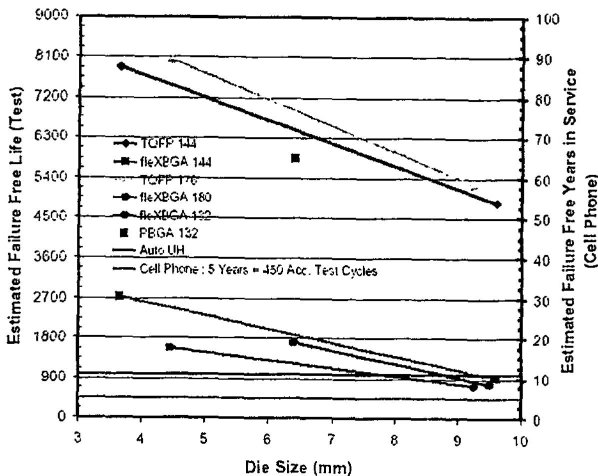
2nd Level Reliability Test

Test Condition vs. Field Condition

Accelerated Test
-40 to 125°C
15 minutes Ramps
15 minutes Dwells
1 Hour Cycle

Field Condition
Sales Person ,
Alaska/Arizona
6 mths (+20 to -20°C)
6 mths (+20 to +55°C)
6 Cycles/day ;
2000 Cycles/Year



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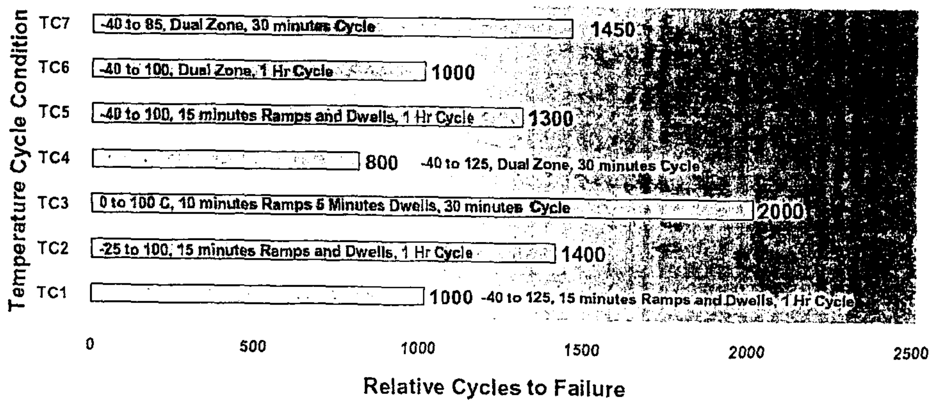
2nd Level Reliability Test

Test Condition Comparison



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