Failure Analysis (FA) Introduction

(III - Reliability Failure Mode)
## Reliability Stress

<table>
<thead>
<tr>
<th>Reliability</th>
<th>General Condition</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precondition</td>
<td>Baking/L3/Reflowing</td>
<td></td>
</tr>
<tr>
<td>Reflowing (SMT)</td>
<td>JEDEC 240°C/3X</td>
<td></td>
</tr>
<tr>
<td>TCT</td>
<td>-65°C/+150°C/15min</td>
<td>Shock</td>
</tr>
<tr>
<td>TST</td>
<td>-65°C/+150°C/15min</td>
<td>Shock</td>
</tr>
<tr>
<td>PCT</td>
<td>+121°C/100%RH/2ATM</td>
<td></td>
</tr>
<tr>
<td>HL-SLT</td>
<td>+150°C</td>
<td>Time</td>
</tr>
<tr>
<td>LT-SLT</td>
<td>-65°C</td>
<td>Time</td>
</tr>
<tr>
<td>TH Storage</td>
<td>85°C/85%RH</td>
<td>Time</td>
</tr>
<tr>
<td>THB</td>
<td>85°C/85%RH/Vcc</td>
<td></td>
</tr>
<tr>
<td>HAST</td>
<td>+130°C/85%RH/Vcc</td>
<td>Accelerated</td>
</tr>
</tbody>
</table>
Typical Preconditioning Defect Mode

- Moisture distribution
- Weak point

Die surface Delamination

Die crack

Package crack
Failure Mode

Preconditioning

Failure found
- Precondition L3 found 1\textsuperscript{st} open fail
- FS/SS = 11/135 (8%)
- LQFP 100L 18M SSDRAM

Root cause confirm
- Modify die-attached epoxy
- Modify die-pad structure

Advanced EFA
- Open failed on some corner pins
- Die-surface corner delamination

Advanced PFA
1\textsuperscript{st} bonding lifted by preconditioning stress

(Scanning Electrical Microscope)
**Failure Mode**

- **Failure found**
  - Precondition L3 found 1st open fail
  - FS/SS > 5%
  - TSOPII 44L DRAM

- **Root cause confirm**
  Surface Element Non-uniform (Wafer Process)

  (C, N, O, Si)
  (1) (2) (3) (4)

- **Advanced EFA**
  - Open failed on random pins
  - Die-surface delamination

  (SAT C-SCAN)

  Delamination layer

- **Advanced PFA**
  Ball-neck broken by die surface delamination

  (Scanning Electrical Microscope)

  (C, N, O, Si) (C, O, Si)
Typical TCT/TST Defect Mode

- Stress
  - 150°C Air
  - -65°C Air
  - 150°C Liquid
  - -65°C Liquid

- Weak point (expansion/shrinkage)

Die surface delamination to cause EMC lifted, ball-neck broken
**Failure Mode**

**TCT**

- **Failure found**
  - TCT 500C open fail
  - FS/SS=4/100
  - SOJ 40L 4M DRAM

- **Advanced EFA**
  - Open can be recovered and not stable while testing
  - SAT shows normal, no delamination

- **Root cause confirm**
  - Material changed
  - Change molding compound to provide

- **Advanced PFA**
  - Wedge bond broken but still connected

*(Scanning Electric Microscope)*
**Failure Mode**

**Failure found**
- TCT 1000C open fail
- FS/SS=1/45
- QFP 100L

**Root cause confirm**
Process:
- Waiting time from W/S->M/D control
- Enhance W/B parameter
Material
- Change molding compound
- Cleaning Lead-frame before W/B

**Advanced EFA**
- One pin open, 2\textsuperscript{nd} finger find delamination

**Advanced PFA**
Wedge bond broken to lift

*(Scanning Electric Microscope)*
**Failure Mode**

- **Failure found**
  - TCT 1000C function fail
  - FS/SS=1/200
  - TSOPII 54L 64M SDRAM

- **Root cause confirm**
  - LOC taped damaged (Bonding process)

- **Advanced EFA**
  - Only corner special block failed

- **Advanced PFA**
  - Passivation damaged under LOC tape

**Improvement:**
Change to long-tape LOC tape to balance force

- **TCT**

- **Cold air** -65°C
- **Hot air** +150°C

- **Failed block**

- **Optical Microscope, 500X**

Tung-Bao Lu
Failure Mode

- TCT 1000°C open fail
- FS/SS = 3/45
- miniBGA 8x10 48B

Advanced EFA
To identify substrate opened by probing substrate plating line and solder ball

Root cause confirm
Supplier improve

Poor quality substrate that can’t been stressed after temperature cycling tests, crack is found and through Cu-line to cause opened.

Advanced PFA
Substrate crack is found by DPA and SEM

Crack is found by SEM after top-side DPA made
Open Cu line crack
**Failure found**
- TCT 300C open fail
- FS/SS=40/200
- LCD Driver IC, TCP package
- Inner Lead Bonding Process (TAB)
- Can pass 30C/130C
- TCT condition: -65°C/+150°C/30min

**Root cause confirm**
- Inner lead dimension modify
- Material/Structure limit

**Advanced EFA**
- Open located on wide side
- Recovery after time aging

**Advanced PFA**
Lead broken near to bump
**Failure found**
- TCT 1000C open fail
- FS/SS=2/10 (2%)
- 256M SDRAM SODIMM module
- Solder ball connected
- Condition: -20°C/+90°C/30min

**Root cause confirm**
Modify PCB solder ball opening

**Advanced EFA**
- Open located on random packages
- Contact recovery (press package)

**Advanced PFA**
Solder crack on package side
Failure Mode

Failure found
- Customer find after SMT process
- TCP package
- fixed pin open

Root cause confirm
Change tape design, and all pass

Advanced EFA

Advanced RA
After TST 200C, about 50% all open
Typical Moisture (PCT, THB, HAST) Defect Mode

- Stress
  - Die surface delamination to cause EMC lifted, ball-neck broken
  - Al-pad corrosion

- Weak point
  - Metal migration
Failure Mode

**Failure found**
- PCT 240H open fail
- FS/SS=1/45
- PLCC 32L Flash

**Root cause confirm**
Change molding compound

**Advanced EFA**
- Open failed around corner special pins
- Serious die surface delamination

(Scanning Acoustic Tomograph)

**Advanced PFA**
Ball lightly lifted around corner pins

(Scanning Electrical Microscope)
Failure Mode

’elle: Failure found
- PCT 216H open fail
- FS/SS=1/45
- mBGA 48B (Substrate)

’elle: Root cause confirm
- Change molding compound

’elle: Advanced EFA
- Open failed
- Die-surface delamination

’elle: Advanced PFA
1st bonding lifted from device pad

(Scanning Acoustic Tomograph)

(Scanning Electrical Microscope)
Failure found
- PCT 96H open fail
- FS/SS=3/45
- mBGA 48B (Substrate)

Advanced EFA
- Open failed around corner special pins
- Substrate surface delamination

Root cause confirm
- Change molding compound
- Change substrate solder resistance

Advanced PFA
2nd Bonding finger lifted from substrate
**Failure Mode**

- **Failure found**
  - PCT 240H leakage failed
  - FS/SS=1/45
  - TSOPII 40L 4M DRAM

- **Root cause confirm**
  Gate oxide damaged (Wafer Process)

- **Advanced EFA**
  Leakage failed on Pin 31 (LCAS)
  For Normal Pin: Vcc=5.5V, VI=0~5.5V, Leakage Current $\cong 0$
  For Failed Pin: Vcc=5.5V, VI=0V, Leakage Current $\cong -3.2mA$

- **Advanced PFA**
  Hot-spot is found around failed pin

(Scanning Electrical Microscope) (Liquid Crystal Microscope)
Failure Mode

**THB**

- **Failure found**
  - THB 500H Open/Leakage failed
  - FS/SS=7/32
  - SOJ 40L 4M DRAM

- **Advanced EFA**
  - Open/leakage failed on random pins
  - Serious die surface delamination

- **Root cause confirm**
  - Reliability ovens over-stressed

- **Advanced PFA**
  - Ball lightly lifted around failed pins

(Scanning Electrical Microscope)

(Scanning Acoustic Tomograph)
Typical HT/LT-SLT Defect Mode

- IMC Layer Crack (Au-Ball Lift)
Un-predicting Reliability Failure Mode – Ion Migration

Copper Migration

Temperature-Humidity-Voltage/Bias

Solder Migration

Evaluation: Tandem pattern + Dew Cycling Test
Un-predicting Reliability Failure Mode – Tin Whisker

EIA JESD22-A12, May, 2005
“Measuring Whisker Growth on Tin and Tin Alloy…”

This document is not qualification standard !!!

<table>
<thead>
<tr>
<th>Stress Type</th>
<th>Ref. Spec.</th>
<th>Test Conditions</th>
<th>Recommendations [1], [2], [3]</th>
</tr>
</thead>
</table>
| Temperature Cycling              | JESD22-A104    | Min Temperature -55 to -40 (+0/-10) °C  
Max Temperature +85 (+10/-0) °C  
air to air; 5 to 10 minute soak;  
~3 cycles/hour                   | Inspection Intervals | 500 cycles                       | Minimum Duration | 1000 cycles |
| Ambient Temperature / Humidity Storage |              | 30 ±2 °C and 60 ±3% RH                                                        | 1000 hours                     | 3000 hours       |
| High Temperature / Humidity Storage |              | 60 ±5 °C and 87 ±3/-2% RH                                                       | 1000 hours                     | 3000 hours       |
# Reliability and Failure Mechanism

<table>
<thead>
<tr>
<th>Process Step</th>
<th>Failure Mechanism</th>
<th>Failure Mode</th>
<th>Detect R. Test</th>
</tr>
</thead>
</table>
| Implantation  | - Junction leakage due to crystal defects  
- Implantation effects (Isolation & Channel)  
- Hot carrier effect                  | Degradation of BV Leakage or Short | HTOL, LTOL ESD, EOS |
| Oxidation     | - Silk bulk defect - thin oxide  
- Particle contamination Si surface  
& on oxide layer  
- Dielectric breakdown                | Short circuit Increase in Leakage | HTOL ESD, EOS |
| Photolithography | - Photoresist particle defect & pinholes  
- Photoresist contamination  
- Masking problem                      | Open circuit Increase in Leakage | HTOL, LTOL THB |
| Wire bonding  | - Ball missing & intermetallic  
- Compound, bonding problem  
- Pad contamination  
- Over bonding condition  
- Underlayer cracking  
- Loop & wire sagging problem         | Open circuit Intermittent open Leakage Resistance | TCT, TST, PCT THB |
| Package       | - Corrosion due to bulk or lead-to-EMC gap moisture penetration  
- Poor material                        | Open Surface leakage solderability | TCT, TST, PCT THB |

(refer to: Samsung/quality assurance/reliability)