Underfill Training Report
Content

- Flip Chip Technology
- Underfill Process
- Underfill Machine
- Underfill Epoxy
- Underfill Failure Mode Analysis
- Applied Component and Foreground of Underfill
1. Flip Chip Technology

1.1 What is flip chip

It is a chip connection technology which interconnects an IC chip to its next level of packaging in such manner that IC’s active side faces to substrate.
1. Flip Chip Technology

1.2 The component - Flip chip

Shrinking electronic devices

Flip Chip bump configuration

Packaged IC
Chip-On-Board
Flip Chip / CSP

DIE
Substrate

Eutectic
UBM
Final pad
Passivation
1. Flip Chip Technology

1.3 Flex lamination layer (Cross section)

- Coverlayer/Base Layer
- Lamination Adhesive 1
- Copper Trace
- Lamination Adhesive 2
- Stiffener (Metal/Polyimide)

Dynamic Area

Rigid Area

Flex structure
1. Flip Chip Technology

1.4 Process Flow

- Pre-baking
- Solder Printing
- Chip Mounting
- Bonding
- Curing
- Underfill
- Reflow
- Cleaning
- Function Test
- X-Ray
- Final QC

Curing
Underfill
Reflow
Cleaning
Function Test

X-Ray
(C-mode Scanning
Acoustic Microscopy)

1.4 Process Flow
1.5 Why Underfill?

Underfill is required to encapsulate under the die to neutralize the effects of CTE mismatch.

Significance:

• Reduce stress due to thermal expansion
• Increase lifetime of connections
• Protect connections mechanically
• Reduce chance of contamination
1. Flip Chip Technology

1.5 Why Underfill?

CTE mismatch of varies components in Flip Chip package will cause high stress at the interconnection.

Underfill reduce Stress by distributing such stress over the entire chip area so the stress will not concentrated at the interconnections.
1. Underfill Technology

2.1 Relative process flow of underfill

- Reflow
- Reflow Inspection
- Pre-heater (In underfill machine)
- Post-heater (In underfill machine)
- Cen-heater (In underfill machine)
- Touch up
- Curing

Process control point:
- Underfill pattern
- Epoxy temperature
- Substrate temperature
- Curing condition
2. Underfill Technology

2.2 Control point in underfill process

- Underfill pattern selection

- Standard method: 70 - 100% of L
- Faster flow method: 70 - 100% of L
- Better filet shape method: 70 - 100% of L

I pattern - For small die sizes
L pattern - For large die sizes
I or L pattern + Seal pass
2. Underfill Technology

2.2 Control point in underfill process

- *Epoxy temperature when dispensing*

Epoxy’s viscosity profile

<table>
<thead>
<tr>
<th>Viscosity</th>
<th>Temp 1</th>
<th>Temp 2</th>
</tr>
</thead>
</table>

We select low viscosity temperature to insure epoxy can be dispensed out fluently and flow fast.
2. Underfill Technology

2.2 Control point in underfill process

- Substrate temperature when underfill

<table>
<thead>
<tr>
<th>Temp</th>
<th>Time</th>
<th>Reflow</th>
<th>Reflow Insp</th>
<th>Pre-heater</th>
<th>Cen-heater</th>
</tr>
</thead>
<tbody>
<tr>
<td>140℃</td>
<td>60sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110℃</td>
<td>30sec</td>
<td></td>
<td></td>
<td>Temp 2</td>
<td></td>
</tr>
<tr>
<td>95℃</td>
<td>40sec</td>
<td>Temp 3</td>
<td>Temp 4</td>
<td>Temp 5</td>
<td></td>
</tr>
</tbody>
</table>

Desired Temperature Profile When Underfill

Dispensing temperature control is let the temperature stable when the pallet in Cen-heater (Temp 3 to Temp 5).
2. Underfill Technology

2.2 Control point in underfill process

➢ Curing condition

Namics U8437-2 epoxy

Time of reaction rate X% at each temperature (min.)

<table>
<thead>
<tr>
<th>Reaction rate (%)</th>
<th>Temperature(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>120</td>
</tr>
<tr>
<td>5%</td>
<td>1.1</td>
</tr>
<tr>
<td>50%</td>
<td>14.5</td>
</tr>
<tr>
<td>90%</td>
<td>18.1</td>
</tr>
<tr>
<td>99%</td>
<td>96.1</td>
</tr>
<tr>
<td>99.9%</td>
<td>144.2</td>
</tr>
<tr>
<td>99.99%</td>
<td>192.2</td>
</tr>
<tr>
<td>99.999%</td>
<td>240.3</td>
</tr>
</tbody>
</table>

Insure the reaction rate surpass 99.99% is our control specification.
## 2. Underfill Technology

### 2.3 Process control in different underfill epoxy

<table>
<thead>
<tr>
<th>Epoxy</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Epoxy Temp</td>
</tr>
<tr>
<td>Namics U8433L</td>
<td>55~65C</td>
</tr>
<tr>
<td>Namics U8437-2</td>
<td>50~60C</td>
</tr>
<tr>
<td>Hysol FP4530</td>
<td>55~65C</td>
</tr>
<tr>
<td>Hysol FP4549</td>
<td>/</td>
</tr>
<tr>
<td>Emerson E-1159</td>
<td>30C</td>
</tr>
</tbody>
</table>
3. Underfill Machine

3.1 Develop history of dispense valve

➢ Air pressure time control

Now we use this for manual underfill

Ideal for use in low cost assembly areas

Very little maintenance
Low cost

Dispensed volume changes depending on the fill level of the syringe
3. Underfill Machine

3.1 Develop history of dispense valve

➢ Auger pump

- Easy to Clean

- Used for small dots dispensing of silver / solder paste and encapsulants

- Accuracy 3 to 5% typical in the 10 to 100mg range

DV-8K
3. Underfill Machine

3.1 Develop history of dispense valve

➤ Linear pump (DP-3K)
3. Underfill Machine

3.1 Develop history of dispense valve

➢ Dispense Jets

Dispenses adhesive material from a distance of 0.5 mm to 3 mm

Eliminates movement on the Z-axis between dots

Jet dispenser cycles every 10 ms (360,000 cycle/h)

DJ-2K
3. Underfill Machine

3.2 DJ-9K Instruction

- Piston Stroke Adjust
- Standard Dove Tail Adapter
- Material Feed Tube
- Integrated Temperature Control
- Nozzle/Seat Assembly
3. Underfill Machine

3.2 DJ-9K Instruction

- Needle
- U-cup
- Fluid chamber
- O-Ring
- Seat
- Nozzle
- Stroke adjustment knob
- Spring
- Load button
- Needle
- TCA
3. Underfill Machine

3.2 DJ-9K instruction

Parameter setting on Toshiba FPCA

a. Seat: 15 mil

b. Nozzle: 6 mil

b. Stroke length: 15 unit

c. Valve1 fluid air digital gauge: 15 psi

d. Valve on/off time: 4/4 msec

e. Needle heater temperature: 60°C

f. Substrate temperature: 90~100 (setting: 135)

h. Dispensing gap: 55~75 mil

i. Dispensing distance: 8~10 mil
3. Underfill Machine

3.3 Structure of Asymtek underfill machine: M-620 and X-1020

M-620

X-1020

Display

Dispensing Jet

Power

Urgency Switch
3. Underfill Machine

3.4 X-1020 machine

- Software
- Vision / Lighting
- Heating
- Height Sense
- Motion Control
- MFC & CPJ

Help File
3. Underfill Machine

3.4 X-1020 machine

How to edit a program

1. Teach fiducial mark in workpiece to establish all sample’s location (Two circular metal point on pallet);

2. Create pattern and teach fiducial mark on samples;

3. Edit weight control line in pattern, this will establish underfill pattern, epoxy volume, dispensing gap, dispensing distance and other parameter;

4. Edit how the program running and teach each sample’s location.
For optimal Production, a Program should contain three elements:

1. A Program File (dispensing commands, process commands, etc.)
2. A Fluid File (contains all relative parameters like dispense gap, dispense speed to each dot.)
3. A Vision File (saved automatically when teaching a program)
4. A Recipe File (above three elements, when saved and assembled, are collectively called a Recipe.)

3. Underfill Machine

3.4 X-1020 Machine

How to save a program
3. Underfill Machine

3.4 X-1020 machine

FKV 2A0-U-9K-M-H-01 Program

Asymtek FmNT v4.8 - Programming Window

File Edit Program Setup Run View Help

Program: fkv2a0_2a0u9kmh01.fmw
Fluid1: FKV2A0
Fluid2:

1. FIND SUBSTRATE HEIGHT: (6.539, 4.169)
2. LOOP PASS: FROM 1 TO 4
3. DO MULTIPASS: line2 AT (3.297, 3.411)
4. DO MULTIPASS: line2 AT (7.641, 3.430)
5. DO MULTIPASS: line2 AT (5.990, 3.450)
6. DO MULTIPASS: line2 AT (4.334, 3.470)
7. DO MULTIPASS: line2 AT (2.678, 3.486)
8. DO MULTIPASS: line2 AT (1.023, 3.509)
9. DO MULTIPASS: line1 AT (0.829, 3.418)
10. DO MULTIPASS: line1 AT (1.624, 3.402)
11. DO MULTIPASS: line1 AT (1.280, 3.391)
12. DO MULTIPASS: line1 AT (4.938, 3.358)
13. DO MULTIPASS: line1 AT (6.588, 3.343)
14. DO MULTIPASS: line1 AT (0.246, 3.323)
15. NEXT LOOP:
16. PURGE: AT VALVE 1 PURGE LOC FOR 0.000 secs, VALVE 1
17. END:
3. Underfill Machine

3.4 X-1020 Machine

FKV 2A0-U-9K-M-H-01 Program

<table>
<thead>
<tr>
<th>Line</th>
<th>Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>START PASS: FOR PASS 1</td>
</tr>
<tr>
<td>2</td>
<td>WEIGHT CONTROL: 0.800, 1, ...</td>
</tr>
<tr>
<td>3</td>
<td>RESET MULTIPASS TIMER:</td>
</tr>
<tr>
<td>4</td>
<td>END PASS:</td>
</tr>
<tr>
<td>5</td>
<td>START PASS: FOR PASS 2</td>
</tr>
<tr>
<td>6</td>
<td>WEIGHT CONTROL: 0.640, 1, ...</td>
</tr>
<tr>
<td>7</td>
<td>END PASS:</td>
</tr>
<tr>
<td>8</td>
<td>START PASS: FOR PASS 3</td>
</tr>
<tr>
<td>9</td>
<td>AWAIT MULTIPASS TIMER: 11 second[s] - waiting for underfill</td>
</tr>
<tr>
<td>10</td>
<td>WEIGHT CONTROL: 0.300, 3, ...</td>
</tr>
<tr>
<td>11</td>
<td>WEIGHT CONTROL: 0.360, 3, ...</td>
</tr>
<tr>
<td>12</td>
<td>WEIGHT CONTROL: 0.300, 3, ...</td>
</tr>
<tr>
<td>13</td>
<td>WEIGHT CONTROL: 0.360, 3, ...</td>
</tr>
<tr>
<td>14</td>
<td>END PASS:</td>
</tr>
<tr>
<td>15</td>
<td>START PASS: FOR PASS 4</td>
</tr>
<tr>
<td>16</td>
<td>END PASS:</td>
</tr>
<tr>
<td>17</td>
<td>END:</td>
</tr>
</tbody>
</table>
### 4. Underfill Epoxy

#### 4.1 Epoxy datasheet (Namics U8437-2)

<table>
<thead>
<tr>
<th>ITEM</th>
<th>UNIT</th>
<th>U8437-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filler content</td>
<td>wt%</td>
<td>55</td>
</tr>
<tr>
<td>Density</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>Colour</td>
<td>-</td>
<td>Black</td>
</tr>
<tr>
<td>Viscosity</td>
<td>Pa.s</td>
<td>40</td>
</tr>
<tr>
<td>Gel time (150°C)</td>
<td>sec</td>
<td>40</td>
</tr>
<tr>
<td>Tg (TMA)</td>
<td>C</td>
<td>137</td>
</tr>
<tr>
<td>CTE (TMA) &lt;Tg</td>
<td>ppm/C</td>
<td>32</td>
</tr>
<tr>
<td>&gt;Tg</td>
<td>ppm/C</td>
<td>100</td>
</tr>
<tr>
<td>Bending modulus</td>
<td>Gpa</td>
<td>8.0</td>
</tr>
<tr>
<td>Bending strength</td>
<td>Mpa</td>
<td>130</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>Gpa</td>
<td>7.0</td>
</tr>
<tr>
<td>Poisson ratio</td>
<td>-</td>
<td>0.33</td>
</tr>
<tr>
<td>Volume resistivity Initial</td>
<td>ohm.cm</td>
<td>&gt;1.0X10^15</td>
</tr>
<tr>
<td>(500V) after PCT</td>
<td></td>
<td>&gt;1.0X10^13</td>
</tr>
<tr>
<td>Moisture absorption (after PCT)</td>
<td>wt%</td>
<td>1.4</td>
</tr>
<tr>
<td>Dielectric constant (1MHz)</td>
<td>-</td>
<td>3.5</td>
</tr>
<tr>
<td>Dielectric loss tangent (1MHz)</td>
<td>-</td>
<td>0.007 (0.7%)</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>W/m.K</td>
<td>0.67</td>
</tr>
<tr>
<td>Purity (after PCT)</td>
<td>Cl</td>
<td>2</td>
</tr>
<tr>
<td>Purity (after PCT)</td>
<td>Na</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Purity (after PCT)</td>
<td>K</td>
<td>&lt;1.0</td>
</tr>
<tr>
<td>Alpha ray emission</td>
<td>cont/cm^2.hr</td>
<td>&lt;.001</td>
</tr>
</tbody>
</table>

PCT: 121°C 2 atm 20 hours
4. Underfill Epoxy

**HOW TO USE**

- Standard dispensing condition
- Needle: 18-23G
- Temperature:
- Curing condition: 150°C x 20min (Standard)
- 165°C x 60min (High reliability temperature reflow)
- Storage condition: Below -20°C

For a 10CC syringe, over 1 hours is needed for the syringe to return to room temperature.

**POT-LIFE**

- Double Viscosity at 25°C > 72 hours

**ADHESION STRENGTH (2x2mm chip)**

- Shear strength: 30kgf
- (Si Chip vs FR-4)

**FLUIDITY TEST**

- Test condition
- Substrate: FR-4
- Chip: Glass
- Gap: 50um
- Temperature: 70°C

![Fluidity Test Graph]
4. Underfill Epoxy

4.2 Property of process control

- Viscosity

Epoxy’s viscosity affects the dispense method and machine parameter.

- Double viscosity time (Epoxy’s use life)

*52# Spindle 50rpm at 30°C*
4. Underfill Epoxy

4.2 Epoxy property on process control

- **Gel time**
  
  Epoxy’s gel time is the time of epoxy from liquid to gel, underfill flow time should short than gel time.

- **Moisture absorption**
  
  Moisture absorption is the ability of epoxy absorb moisture, low moisture absorption is good because more moisture in epoxy can cause epoxy can’t be cured completely.

- **Curing schedule**
  
  Curing is made epoxy’s molecular structure from chain to net, after this, epoxy become harden and firmed.
4. Underfill Epoxy

4.2 Epoxy property on function

- **Filler content**
  Affect epoxy’s CTE, viscosity and bending strength

- **Tg**
  Epoxy’s glass transition temperature, high Tg avoid high temperature cause defect because after the epoxy changed into glass state, its molecular distance become big, it will cause CTE changed acutely and the epoxy become breakable.

- **C.T.E.**
  Underfill epoxy is filled to reduce the C.T.E mismatch of chip and FPC, so the epoxy’s CTE should near to chip and substrate’s C.T.E.
4. Underfill Epoxy

4.2 Epoxy property on function

- Bending strength

\[ Bending\ strength \]

Bending strength is the combine intensity between chip and FPC, it changed acutely when the temperature achieved to epoxy’s Tg point.
4. Underfill Epoxy

4.2 Epoxy property on function

- Bending strength

*Shear tester is used to test bending strength, shear knife go ahead with a constant speed, if the epoxy was separate from FPC, the shear knife will stop and a value will be showed on force gauge.*
4. Underfill Epoxy

4.2 Epoxy property on function

- **Thermal conductivity**
  Thermal conductivity is epoxy’s capability to transfer heat, to the hard disk driver, high thermal conductivity epoxy is acceptable.

- **Volume resistivity**
  A concept in electrostatic, it shows material’s electric conduct capability.

- **Dielectric constant**
  A coefficient which express material’s insulating capability. To underfill epoxy, the high dielectric constant value, the better to use.
4. Underfill Epoxy

4.4 Ideal epoxy in underfill process

- High Tg/Low CTE/Low Modulus
- Low stress, Improve thermal shock, temp cycle
- Good adhesion to all different surfaces
- High bonding strength
- High Moisture Resistance
- Fast flow
- Productivity
- Fast cure
- Productivity
4. Underfill Epoxy

4.4 Ideal epoxy in underfill process

- Low Shrinkage

  Low warpage

- Low pot life

  Stable in process

- No Void

  Dispensability

- No filler separation

  Uniform flow

- No toxicity
4. Underfill Epoxy

4.5 Defect analysis

Visual defect
- Island epoxy
- Excess epoxy
- Poor epoxy
- Others

Function defect
- Void
- Epoxy Fatigue
4. Underfill Epoxy

4.5 Defect analysis

- Void

![Volatile void](image1)

- Capture void

- General cause & solution in process
  
  - ✓ Substrate temperature is not matched for underfill
    
    ---- >> Refer to epoxy’s datasheet and select proper temperature
  
  - ✓ Dispense pattern is not suitable for die shape
    
    ---- >> Optimize underfill pattern
  
  - ✓ Dispense volume is not enough
    
    ---- >> Dispensing with sufficient epoxy volume
  
  - ✓ Viscosity of underfill epoxy is high
    
    ---- >> Use fresh underfill epoxy
4. Underfill Epoxy

4.5 Defect analysis

- Volatile void

- Cause & solution
  - ✓ Absorb moisture of FPC
    - --> Dispensing duly after reflow
  - ✓ Poor wetting parts on substrate by flux residue exists
    - --> Reduce flux residue
4. Underfill Epoxy

4.5 Defect analysis

- Volatile void

Moisture absorption changed profile
4. Underfill Epoxy

4.5 Defect analysis

- Capture void

The flow speed > The penetrate speed >>> Capture void

✓ Cause & solution

✓ Dispense pattern is not suitable for bump layout
  -- >>> Select proper dispense pattern

✓ Die size is too big
  -- >>> Optimize dispense method and select proper epoxy
4. Underfill Epoxy

4.5 Defect analysis

- Capture void

- Underfill time too short in seal pass

- Cause & solution
  - Underfill time too short
    -- >> Waiting for epoxy penetrate the whole chip then do seal pass
4. Underfill Epoxy

4.5 Relative test

*C-SAM (SAM=Scanning acoustic microscopy)*

C-SAM is a test method which use ultrasonic scan to establish solder layer, underfill layer is integrated or not.

Reflection of the ultrasonic beam at interfaces with impedance mismatch, e.g. surface, back wall, defects, layer interfaces...

*Cross section*

Transverse section test, skive the sample to a surface (to void layer or filler delamination layer and so on) and will get a view at the layer you want.
<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hard Disk Driver</td>
<td>3mmX3mm</td>
</tr>
<tr>
<td>Microprocessor</td>
<td>25mmX25mm (Biggest)</td>
</tr>
<tr>
<td>Memory</td>
<td></td>
</tr>
</tbody>
</table>

**6. Flip Chip Applied Component**