Underfill Training Report

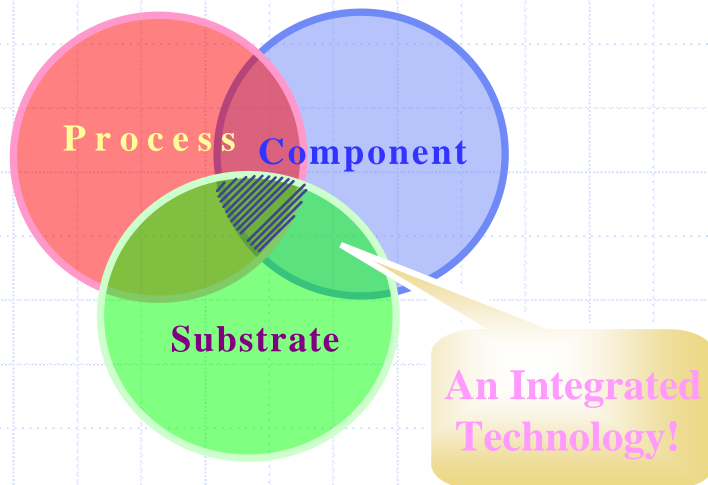
Content

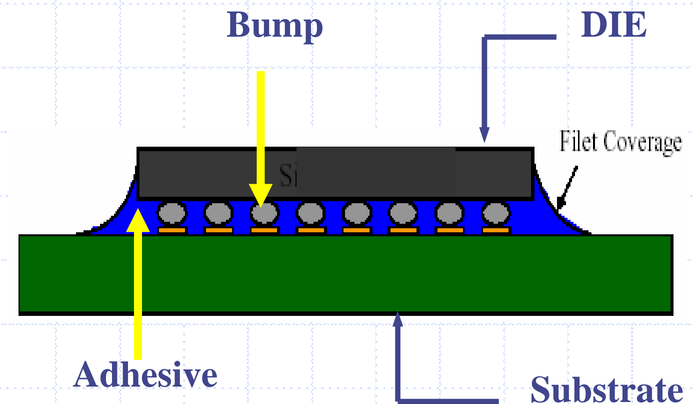
- Flip Chip Technology
- Underfill Process
- Underfill Machine
- Underfill Epoxy
- Underfill Failure Mode Analysis
- Applied Component and Foreground of Underfill

1.Flip Chip Technology

1.1 What is flip chip

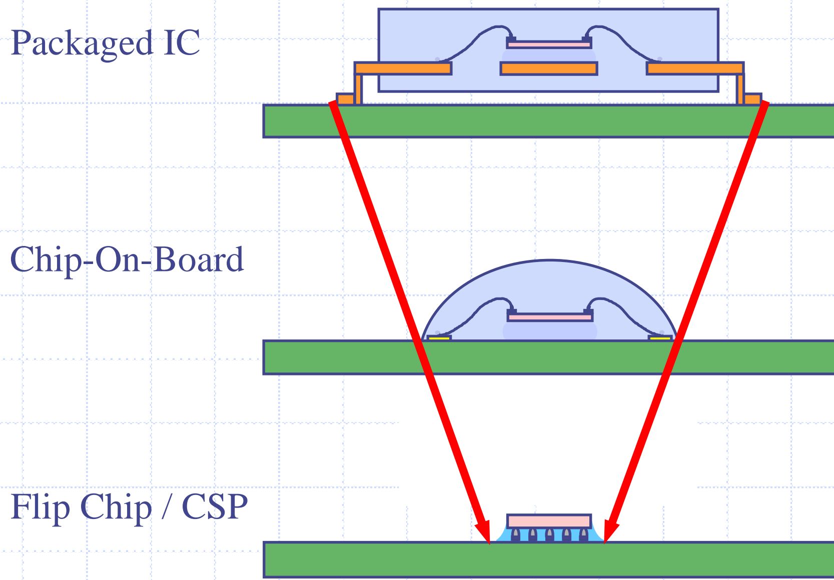
It is a chip connection technology which interconnects an IC chip to its next level of packaging in such manner that IC's active side faces to substrate.



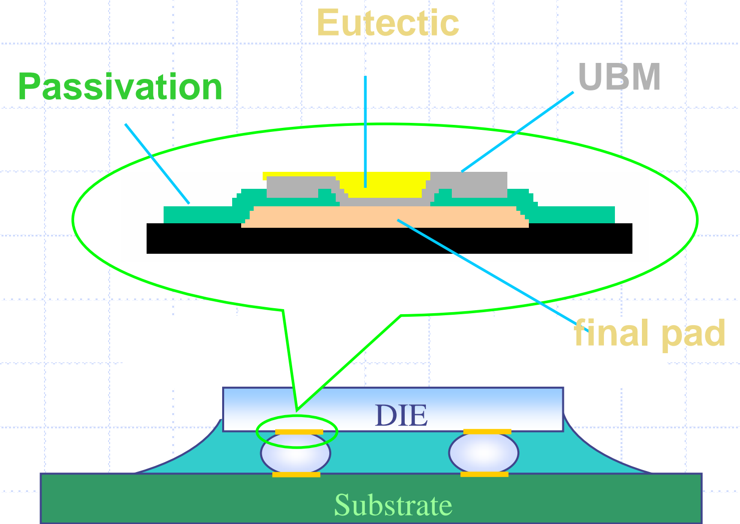


1.Flip Chip Technology

1.2 The component-Flip chip



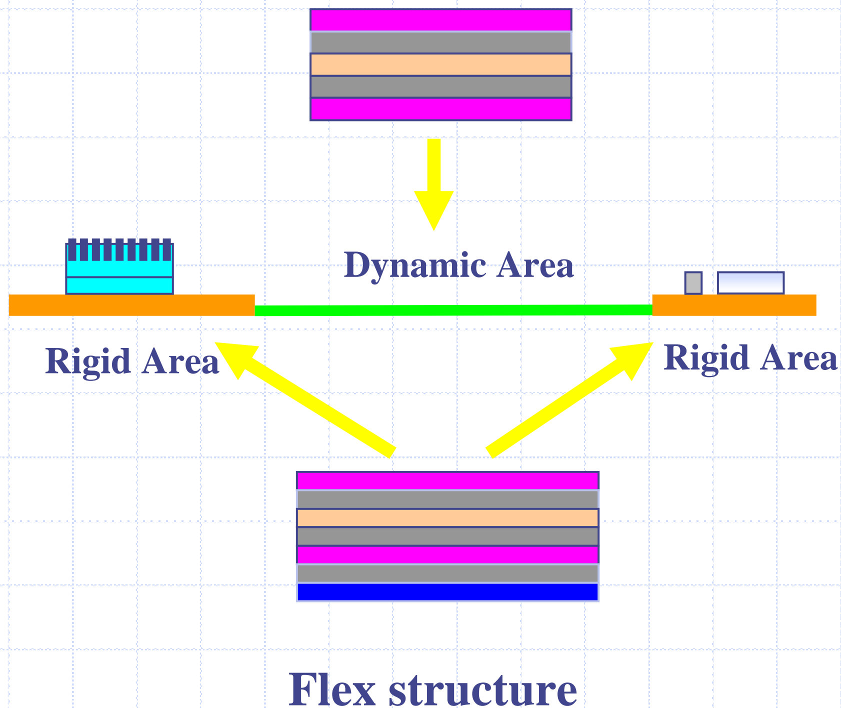
Shrinking electronic devices



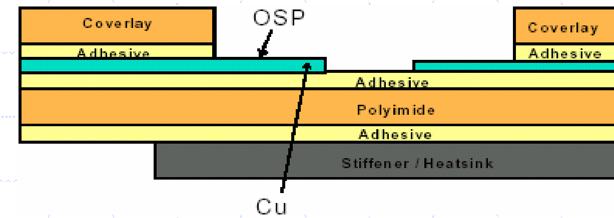
Flip Chip bump configuration

1.Flip Chip Technology

1.3 Flex lamination layer(Cross section)



Flex structure

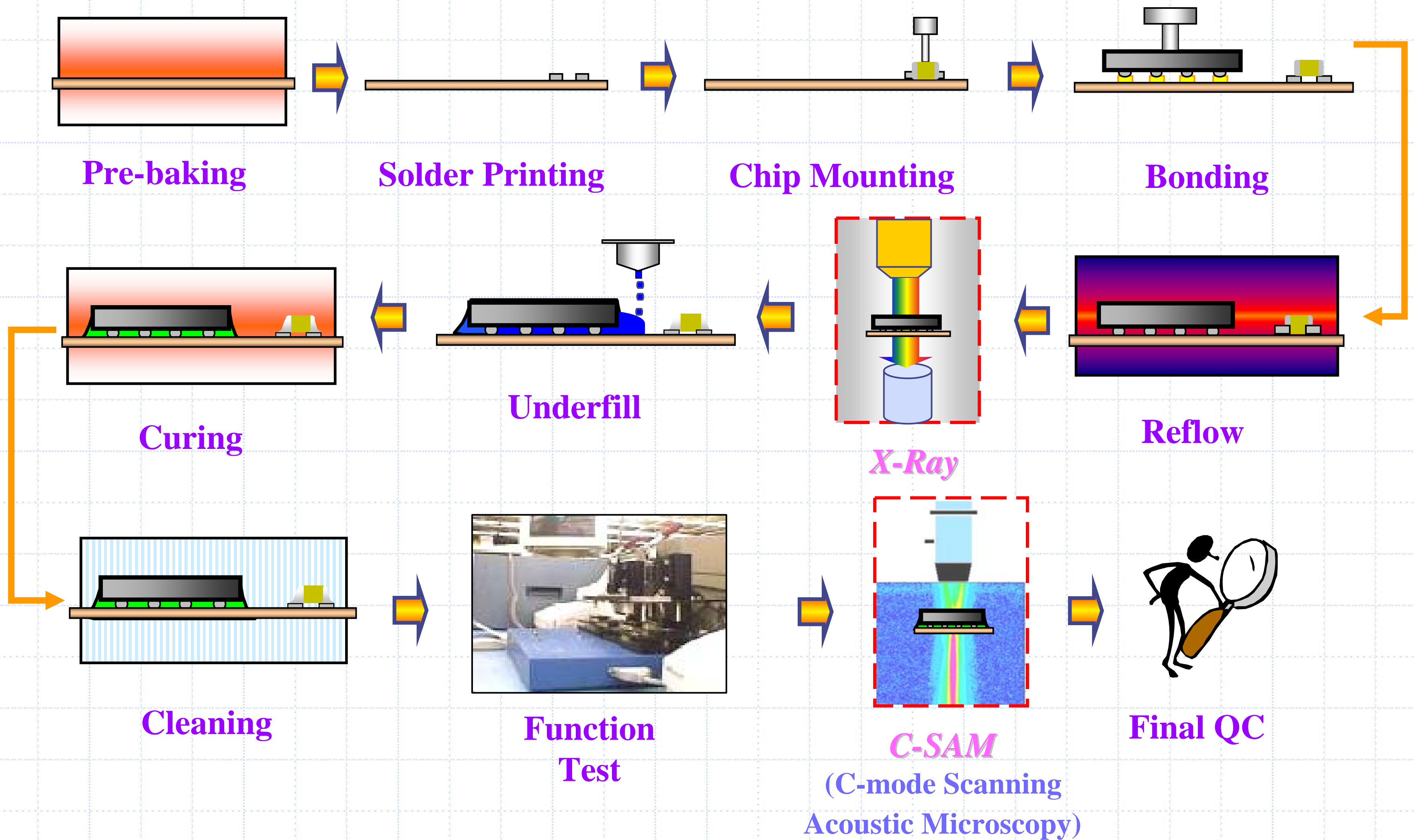


Pad cross-section

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

1.Flip Chip Technology

1.4 Process Flow



1.Flip Chip Technology

1.5 Why Underfill ?

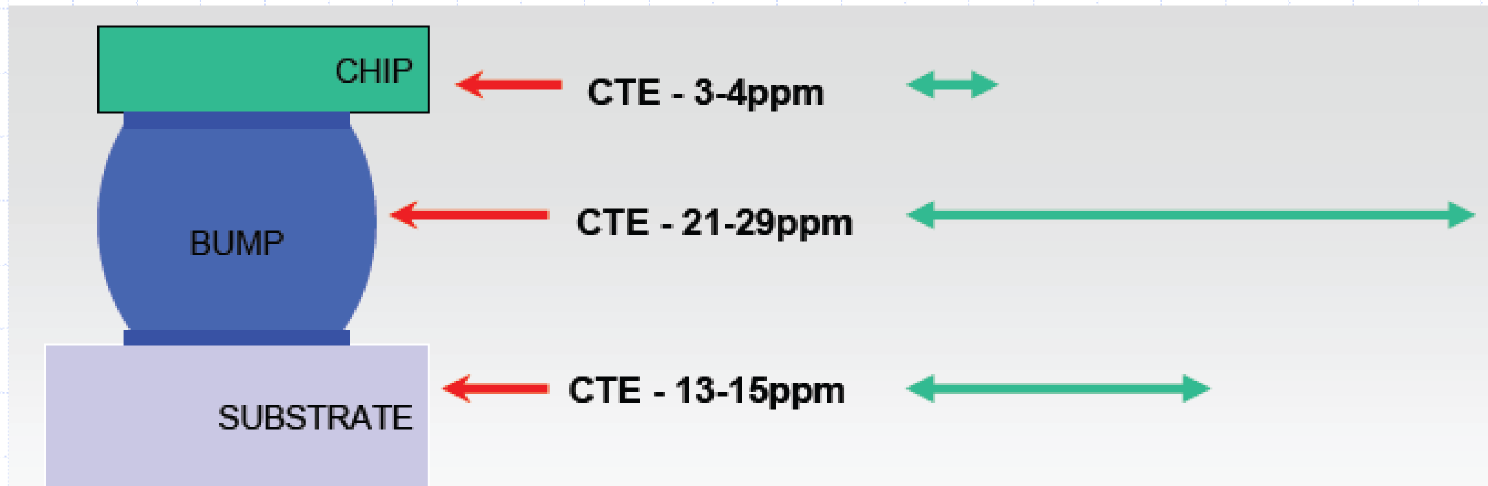
Underfill is required to encapsulate under the die to neutralize the effects of CTE mismatch.

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 ?

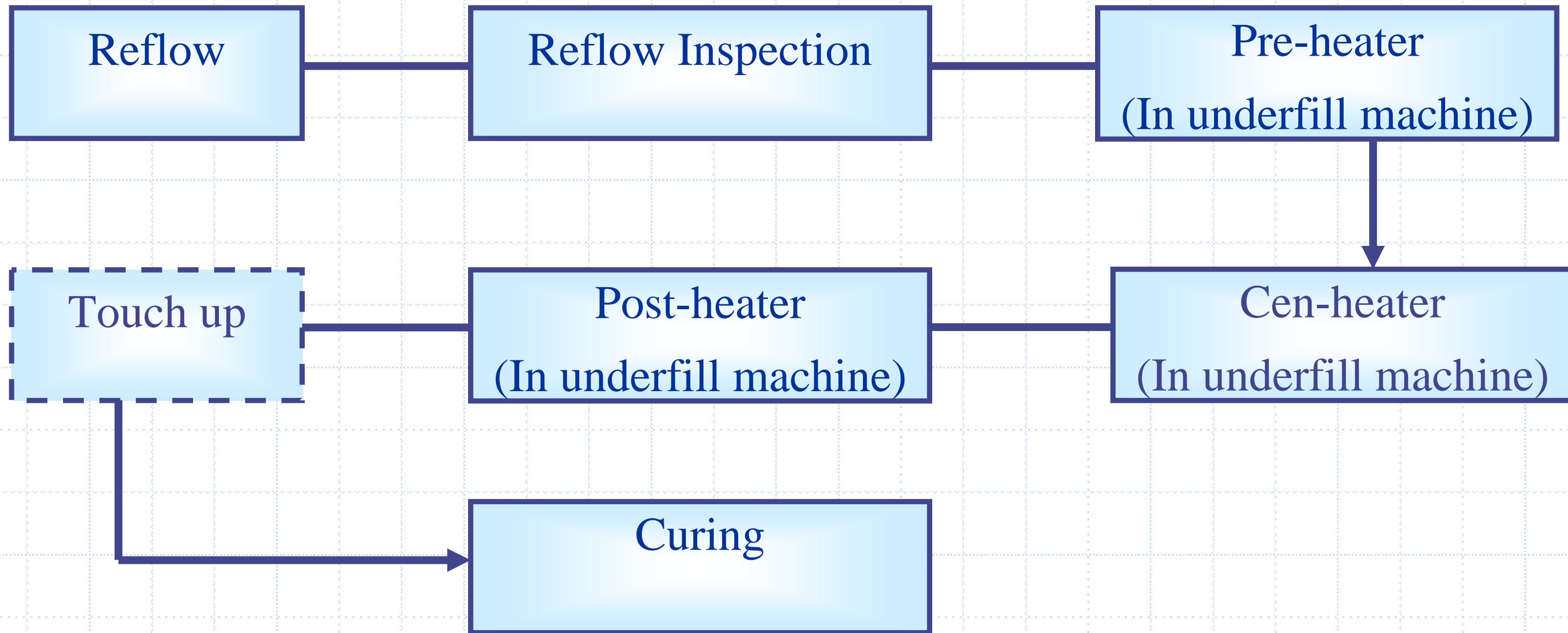


CTE mismatch of varies components in Flip Chip package will cause high stress at the interconnection.

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



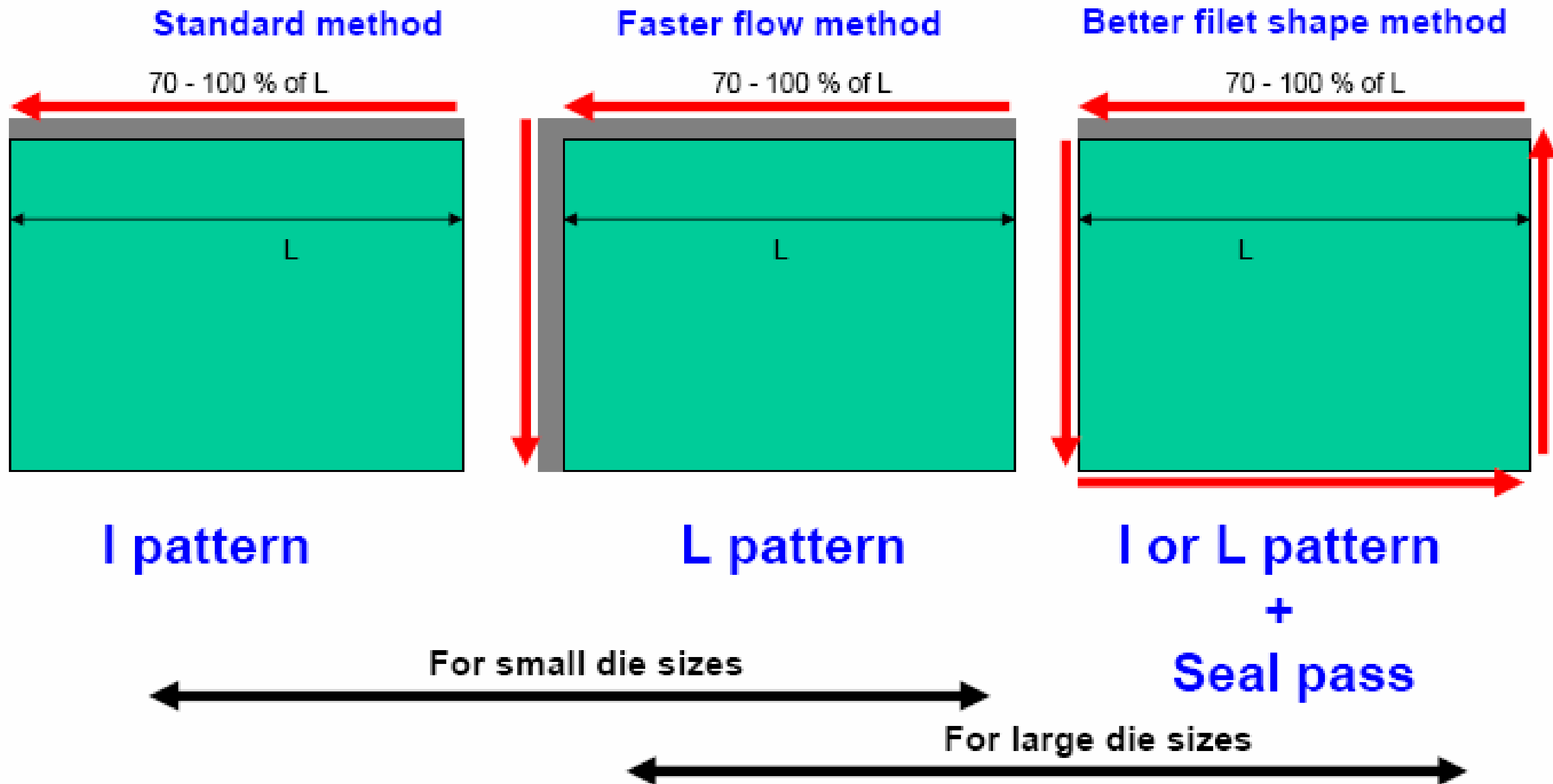
Process control point:

- Underfill pattern
- Epoxy temperature
- Substrate temperature
- Curing condition

2.Underfill Technology

2.2 Control point in underfill process

➢ *Underfill pattern selection*

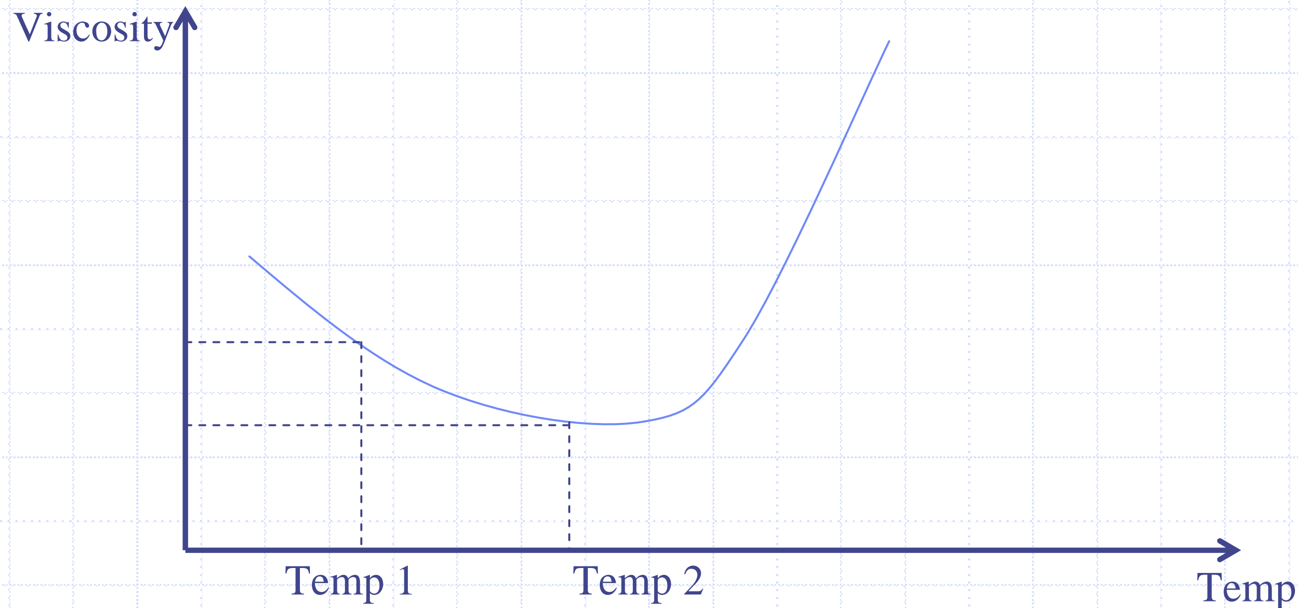


2.Underfill Technology

2.2 Control point in underfill process

- ***Epoxy temperature when dispensing***

Epoxy's viscosity profile

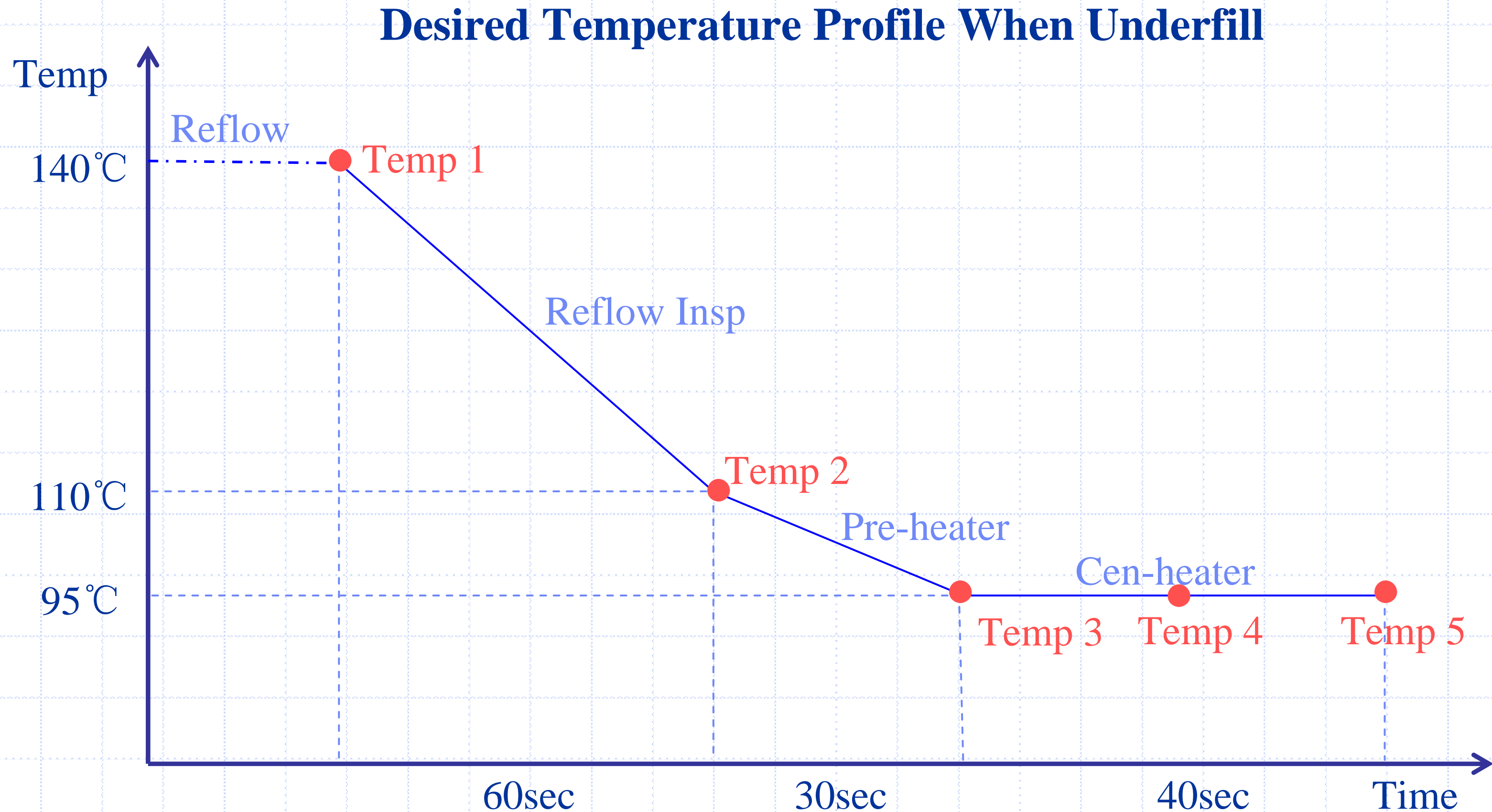


We select low viscosity temperature to insure epoxy can be dispensed out fluently and flow fast.

2.Underfill Technology

2.2 Control point in underfill process

- ***Substrate temperature when underfill***



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.）

Reaction rate （%）	Temperature(^{o}C)			
	120	150	170	200
5%	1.1	0.1	0.0	0.0
50%	14.5	1.1	0.2	0.0
90%	18.1	3.6	0.8	0.1
99%	96.1	7.2	1.6	0.2
99.9%	144.2	10.8	2.3	0.3
99.99%	192.2	14.4	3.1	0.4
99.999%	240.3	18.0	3.9	0.5

Insure the reaction rate surpass 99.99% is our control specification.

2.Underfill Technology

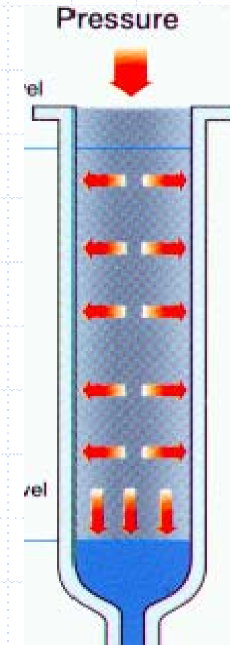
2.3 Process control in different underfill epoxy

Epoxy	**Item**		
	Epoxy Temp	Substrate Temp	Curing Condition
Namics U8433L	55~65C	95$\pm$5C	65C/15mins+150C/60mins
Namics U8437-2	50~60C	85$\pm$10C	150C/60mins
Hysol FP4530	55~65C	85$\pm$10C	165C/15mins
Hysol FP4549	/	85$\pm$10C	165C/30mins
Emerson E-1159	30C	50$\pm$10C	120C/30mins or 130/15mins

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

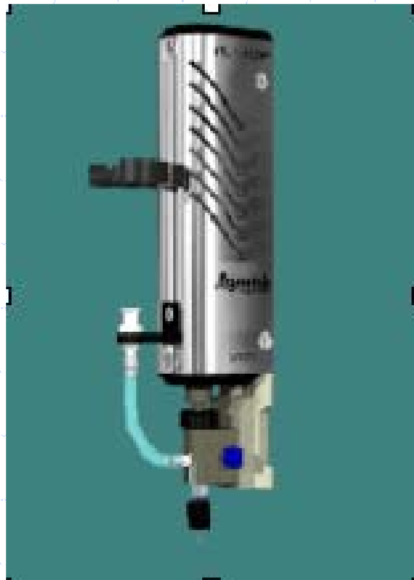
Very little maintenance
Low cost

Dispensed volume changes depending on the fill level of the syringe

3.Underfill Machine

3.1 Develop history of dispense valve

- ***Auger pump***



DV-8K

- 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

3.Underfill Machine

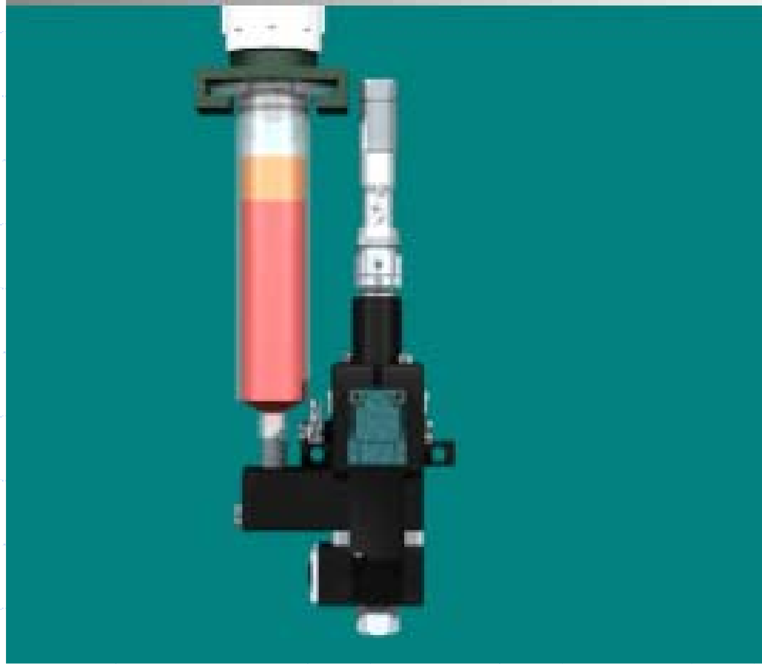
3.1 Develop history of dispense valve

- ***Linear pump(DP-3K)***

3.Underfill Machine

3.1 Develop history of dispense valve

- ***Dispense Jets***



DJ-2K

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

Eliminates movement on the Z-axis between dots

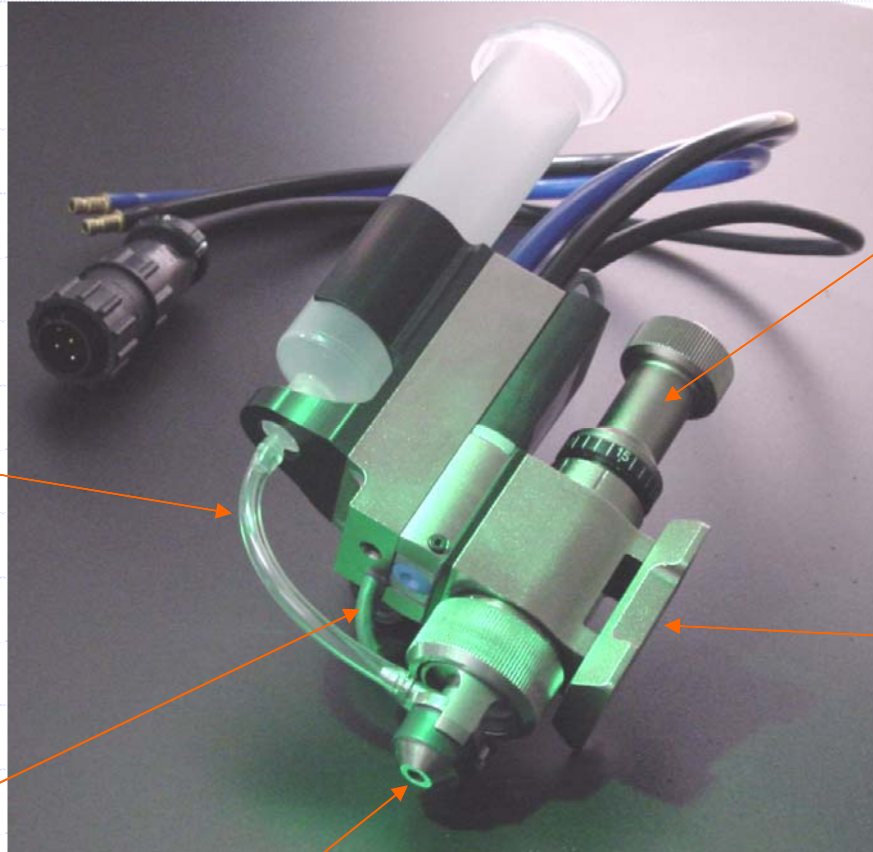
Jet dispenser cycles every 10 ms (360,000 cycle/h)

3.Underfill Machine

3.2 DJ-9K instruction

Piston Stroke Adjust

Material Feed Tube



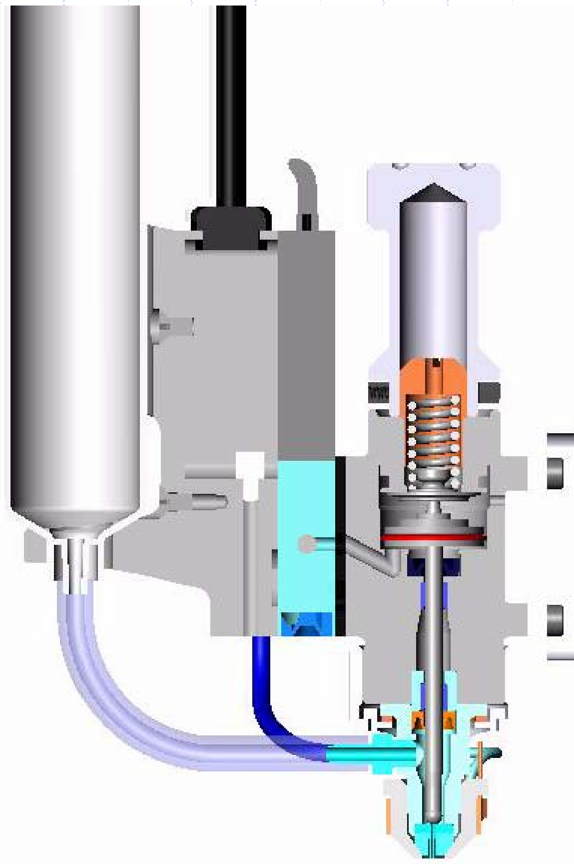
Standard Dove Tail Adapter

Integrated Temperature Control

Nozzle/Seat Assembly

3.Underfill Machine

3.2 DJ-9K instruction



Stroke adjustment knob

Needle

U-cup

Spring

Load button

Fluid chamber

O-Ring

Seat

Nozzle

Needle

TCA

3.Underfill Machine

3.2 DJ-9K instruction

Parameter setting on Toshiba FPCA

a. Seat:15mil

b. Nozzle:6mil

b. Stroke length:15unit

c. Valve1 fluid air digital gauge: 15psi

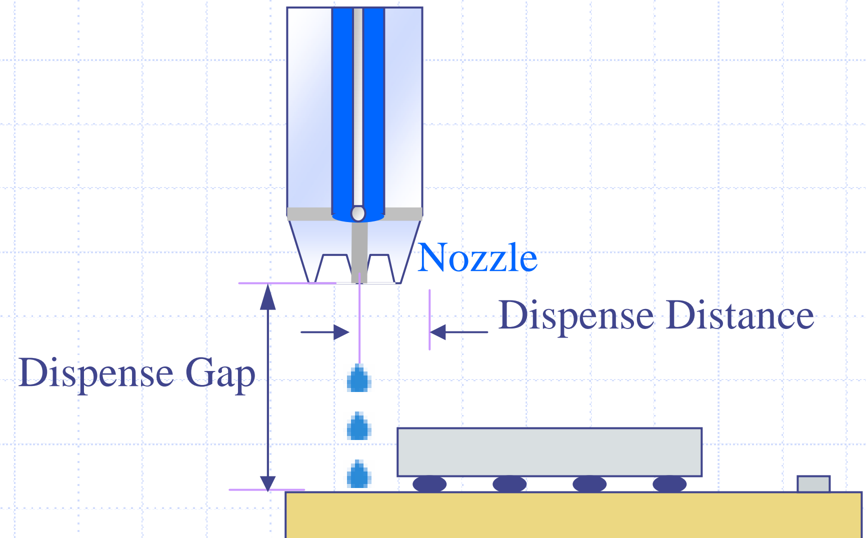
d. Valve on/off time: 4/4msec

e. Needle heater temperature: 60C

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

h. Dispensing gap: 55~75mil

i. Dispensing distance: 8~10mil

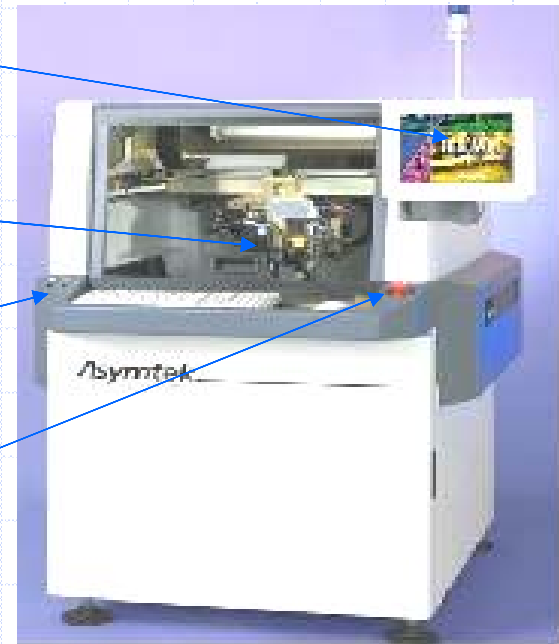


3.Underfill Machine

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

M-620

X-1020



Display

Dispensing Jet

Power

Urgency Switch

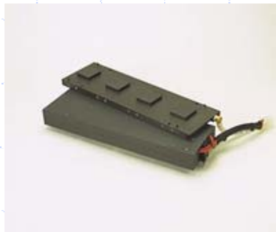
3.Underfill Machine

3.4 X-1020 machine

Software

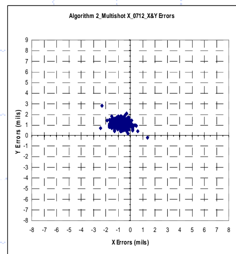
Help File

Vision / Lighting

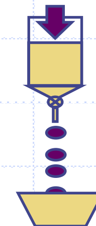


Heating

Height Sense



Motion Control



MFC & CPJ

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.

3.Underfill Machine

3.4 X-1020 machine

How to save a program

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

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

Asymtek FmNT v4.8 - Programming Window

File Edit Program Setup Run View Help

Program: fkv2a0 gr01-u-9k-m-h-01.fmw Fluid1: FKV231 Fluid2: Pattern Name: Workpiece

line1
line2
Workpiece

```
1   FIND SUBSTRATE HEIGHT: (6.539, 4.169)
2   LOOP PASS: FROM 1 TO 4
3   DO MULTIPASS: line2 AT (9.297, 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 (-0.029, 3.418)
10  DO MULTIPASS: line1 AT (1.624, 3.402)
11  DO MULTIPASS: line1 AT (3.280, 3.381)
12  DO MULTIPASS: line1 AT (4.938, 3.358)
13  DO MULTIPASS: line1 AT (6.588, 3.343)
14  DO MULTIPASS: line1 AT (8.246, 3.323)
15  NEXT LOOP:
16  PURGE: AT VALVE 1 PURGE LOC FOR 0.000 secs, VALVE 1
17  END:
```

For Help, press F1 | Jog Device: Dispenser | inch

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 gr01-u-9k-m-h-01.fmw Fluid1: FKV231 Fluid2: Pattern Name: line1

```
1   START PASS: FOR PASS 1
2   WEIGHT CONTROL: 0.800, 1, ...
3   RESET MULTIPASS TIMER:
4   END PASS:
5   START PASS: FOR PASS 2
6   WEIGHT CONTROL: 0.640, 1, ...
7   END PASS:
8   START PASS: FOR PASS 3
9   AWAIT MULTIPASS TIMER: 11 second(s) - waiting for underfill
10  WEIGHT CONTROL: 0.300, 3, ...
11  WEIGHT CONTROL: 0.360, 3, ...
12  WEIGHT CONTROL: 0.300, 3, ...
13  WEIGHT CONTROL: 0.360, 3, ...
14  END PASS:
15  START PASS: FOR PASS 4
16  END PASS:
17  END:
```

For Help, press F1 | Jog Device: Dispenser | inch

4.Underfill Epoxy

4.1 Epoxy datasheet (Namics U8437-2)

ITEM		UNIT	U8437-2
Filler content		wt%	55
Density		-	1.6
Colour		-	Black
Viscosity		Pa.s	40
Gel time(150C)		sec	40
Tg(TMA)		C	137
C.T.E(TMA)	<Tg	ppm/C	32
	>Tg		100
Bending modulus		Gpa	8.0
Bending strength		Mpa	130
Young's modulus		Gpa	7.0
Poisson ratio		-	0.33
Volume resistivity (500V)	Initial	ohm.cm	>1.0X1015
	after PCT		>1.0X1013
Moisture obsorption (after PCT)		wt%	1.4
Dielectric constant (1MHz)		-	3.5
Dielectric loss tangent (1MHz)		-	0.007 (0.7%)
Thermal conductivity		W/m.K	0.67
Purity (after PCT)	Cl	ppm	2
	Na		<1.0
	K		<1.0
Alpha ray emision		cont/cm2.hr	<.001

PCT: 121C 2atm 20hours

4.Underfill Epoxy

HOW TO USE

Standard dispensing condition

Needle :18-23G

Temperature :

Curing condition :150Cx20min(Standard)

:165Cx60min(High reliability temperature reflow)

Storage condition :Below -20C

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

POT-LIFE

Double Viscosity at 25C:>72hours

ADHESION STRENGTH(2x2mm chip)

Shear strength:30kgf

(Si Chip vs FR-4)

FLUIDITY TEST

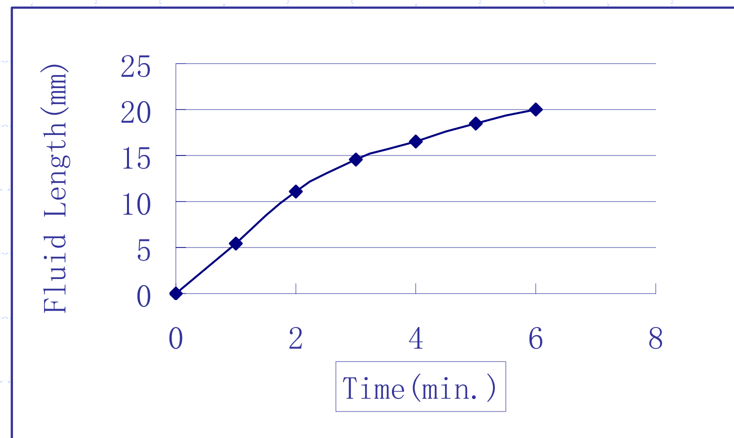
Test condition

Substrate :FR-4

Chip :Glass

Gap :50um

Temperature :70C



4.Underfill Epoxy

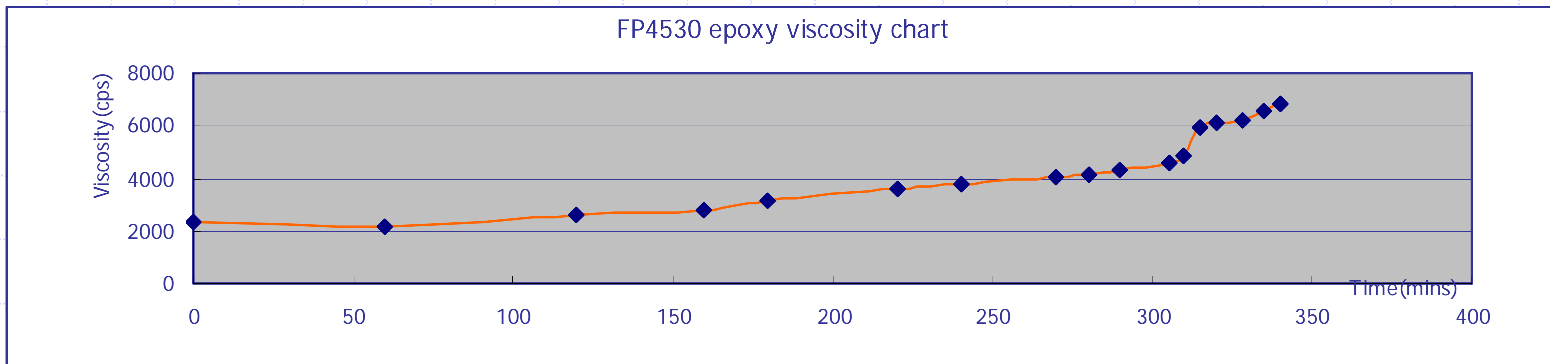
4.2 Property of process control

- Viscosity

  Epoxy's viscosity affect the dispense method and machine parameter.

- Double viscosity time(Epoxy's use life)

  52# Spindle 50rpm at 30C



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.

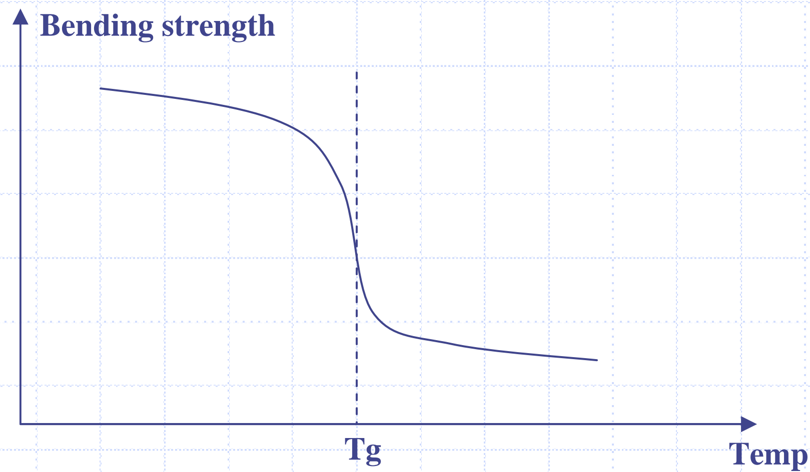
- C.T.E.

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



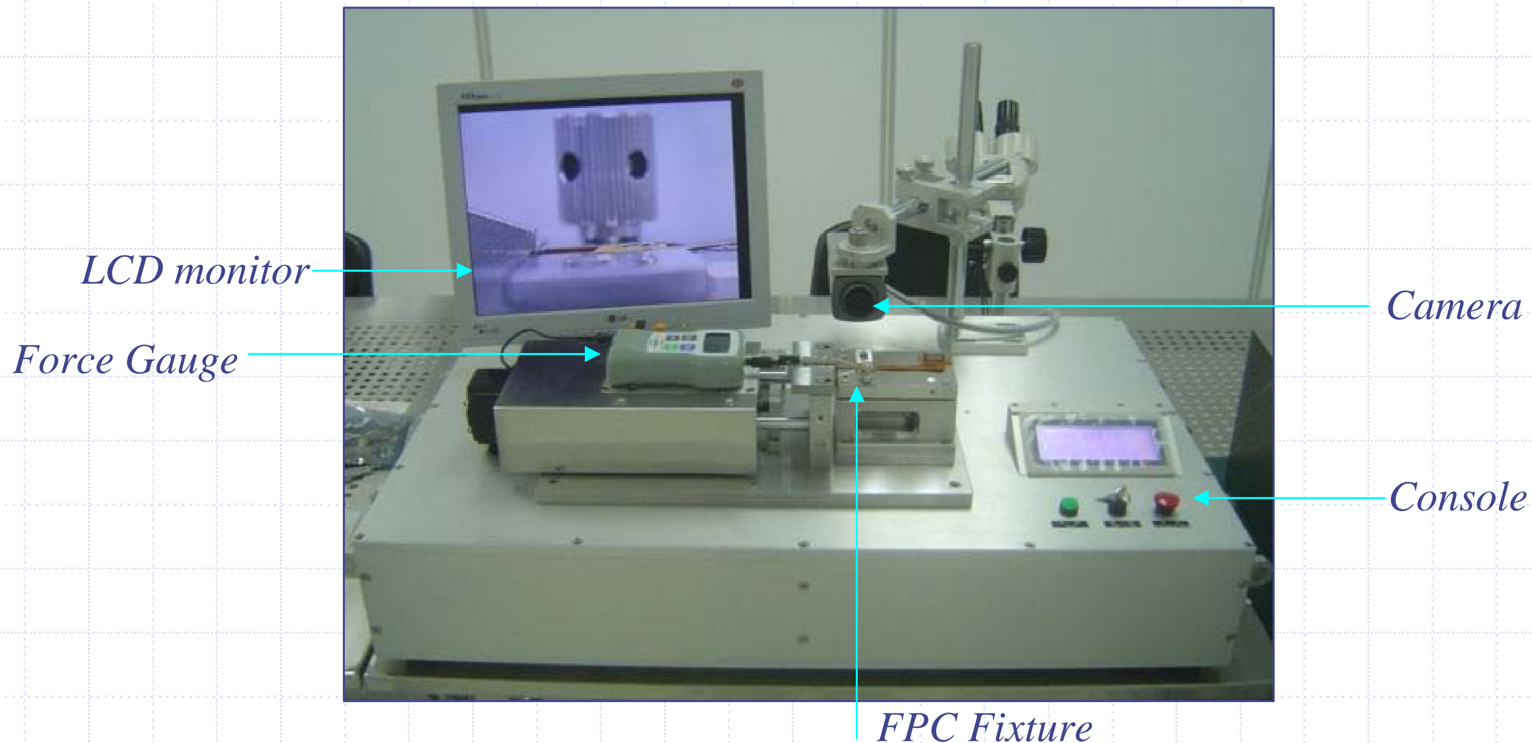
Bending strength is the combine intensity between chip and FPC,it changed acutely when the temperature achieved to epoxy’s Tg point.

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

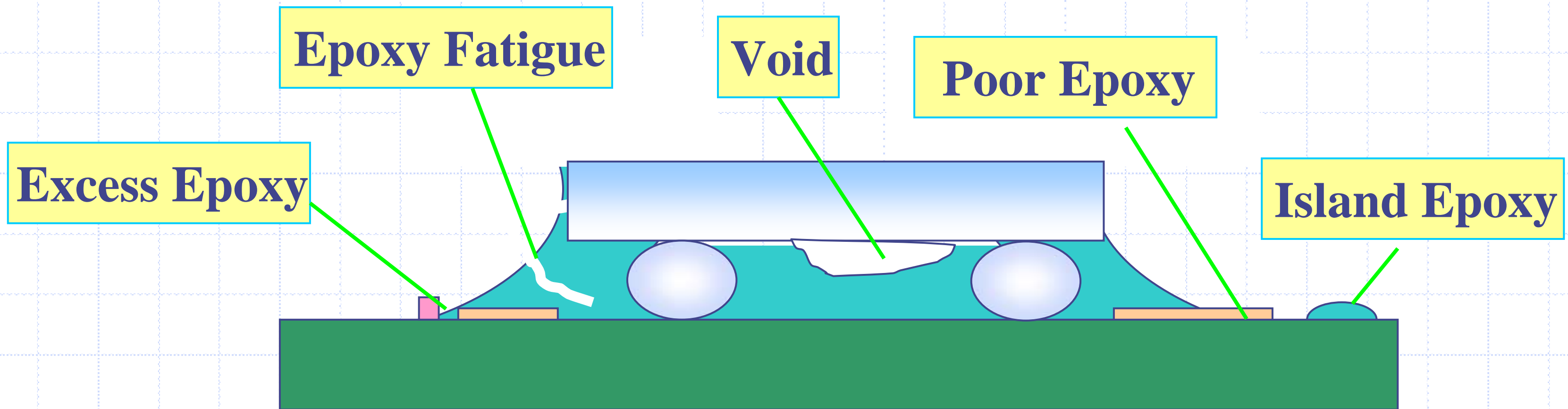
+ No filler separation

Uniform flow

+ No toxicity

4.Underfill Epoxy

4.5 Defect analysis



Visual defect

- Island epoxy
- Excess epoxy
- Poor epoxy
- Others

Function defect

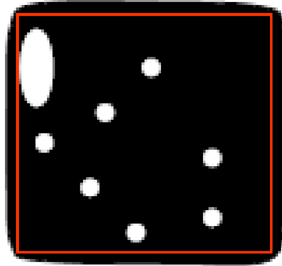
- Void
- Epoxy Fatigue

4.Underfill Epoxy

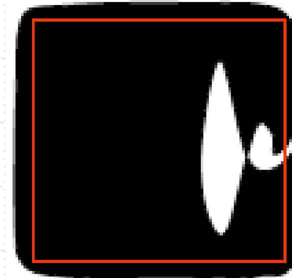
4.5 Defect analysis

- Void

Volatile void



Capture void

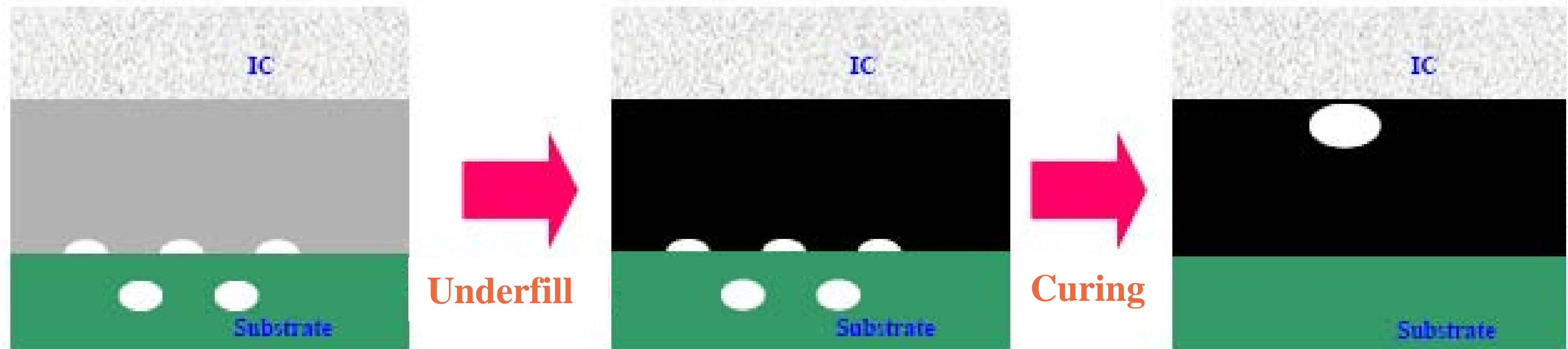


- General cause&solution in process
  - ✓ Substrate temperature is not matched for underfill
  - ---- >> Refer to epoxy's datasheet and select proper temperature
  - ✓ Dispense pattern is not suitable for die shape
  - ---- >> Optimize underfill pattern
  - ✓ Dispense volume is not enough
  - ---- >> 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

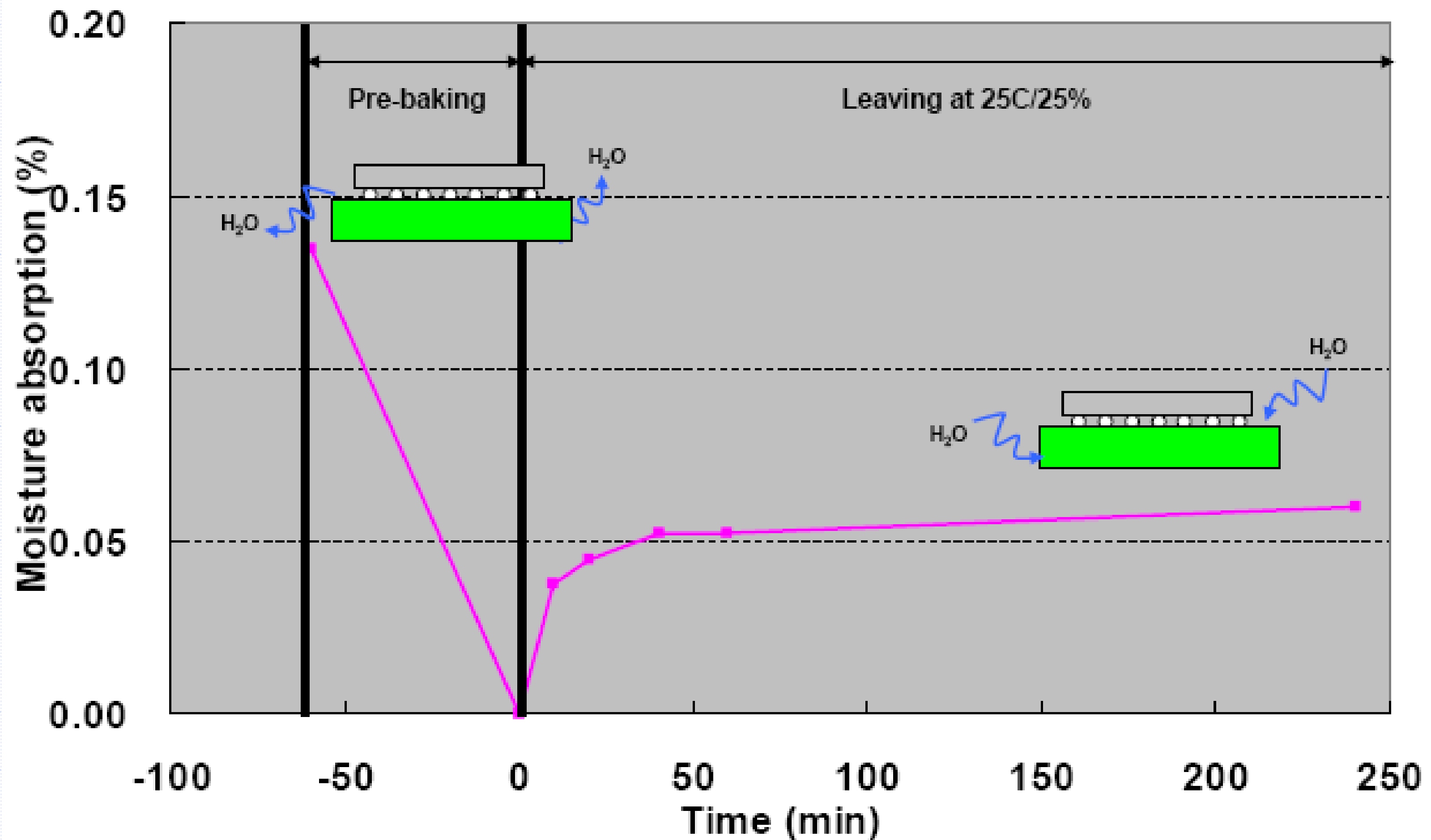
✓ Poor wetting parts on substrate by flux residue exists

-- >> Reduce flux residue

4.Underfill Epoxy

4.5 Defect analysis

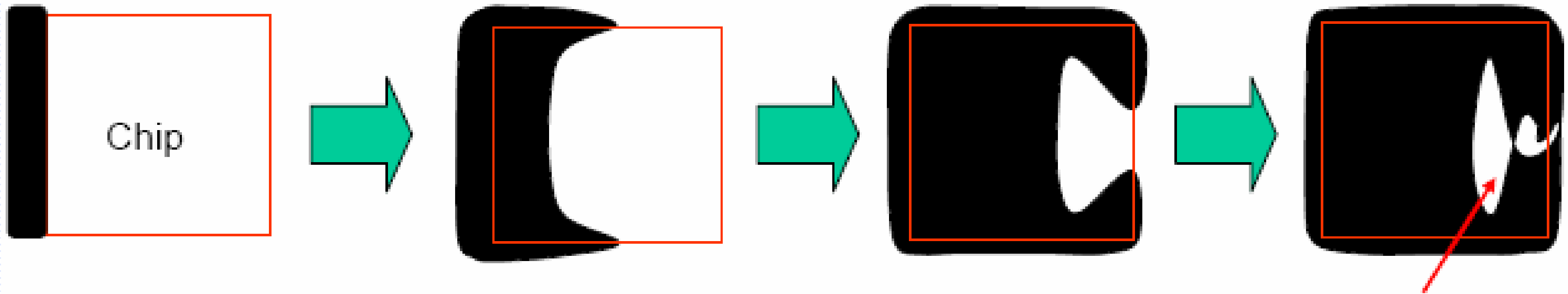
- Volatile void



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

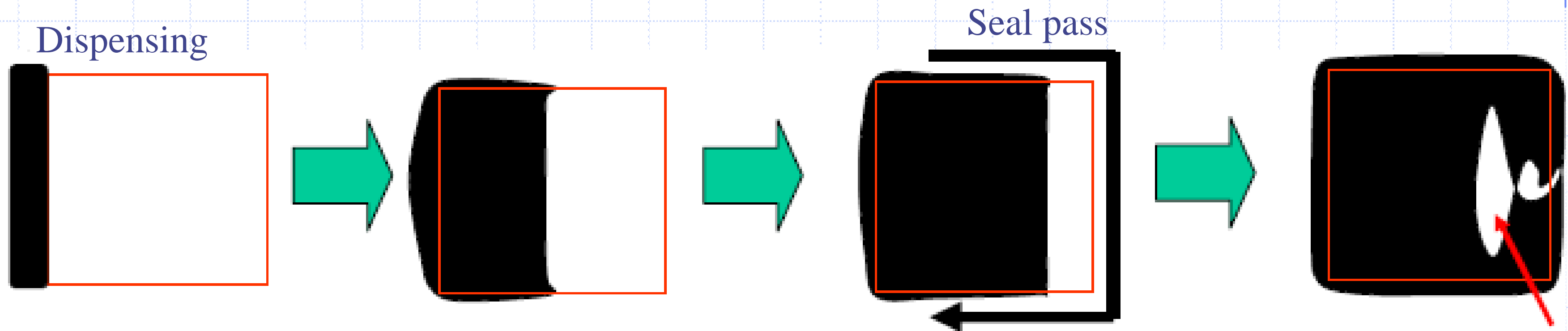
-- >> Optimize dispense method and select proper epoxy

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=Scaning 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,,f.e. surface, back wall,defects,layer interfaces…

Cross section

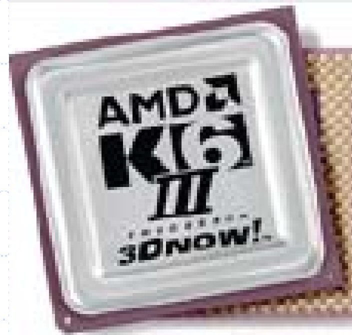
Transverse section test, skive the sample to a surface (to void layer or filler delamination layer and so on) and will get a view at the layer you want.

6.Flip Chip Applied Component

Hard Disk Driver

3mmX3mm

Microprocessor



25mmX25mm
(Biggest)

Memory