



Novel low warpage mold film for FO WLP/PLP application

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OUTLINE

- 1.Introduction
- 2.Motivation
- 3.Experiment and results
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Introduction ~About TAIYO INK MFG

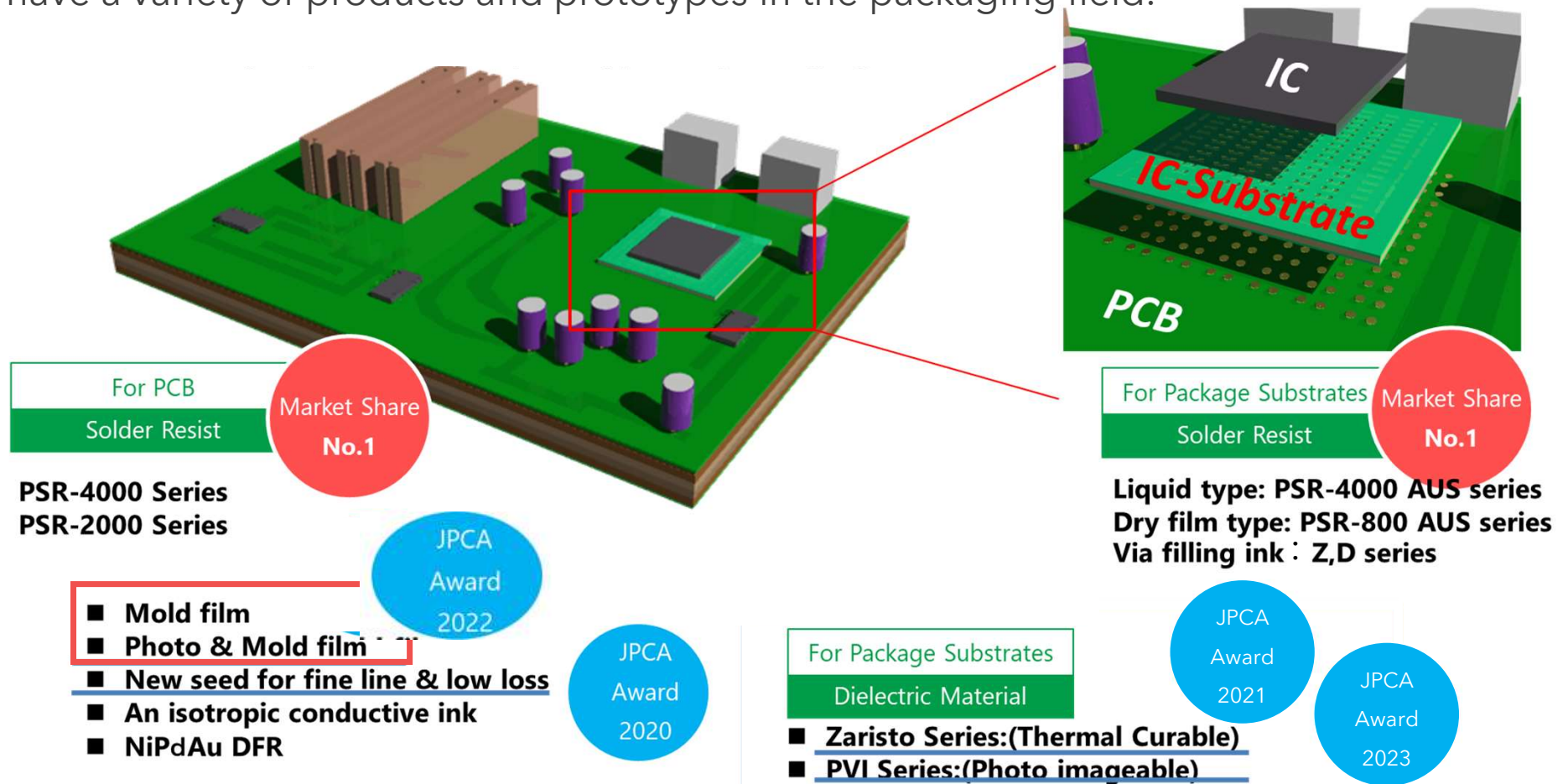
- ◆ We are the Global No.1 supplier of "Solder Masks" and supply various packaging materials.

Electronics Business Group Network



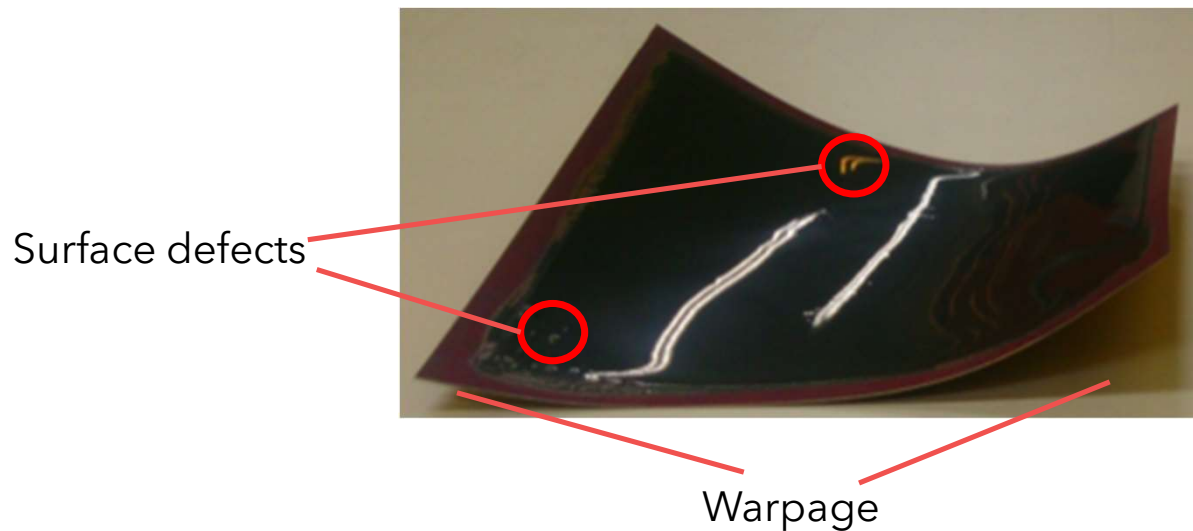
Introduction ~About TAIYO INK MFG

- ◆ We have a variety of products and prototypes in the packaging field.



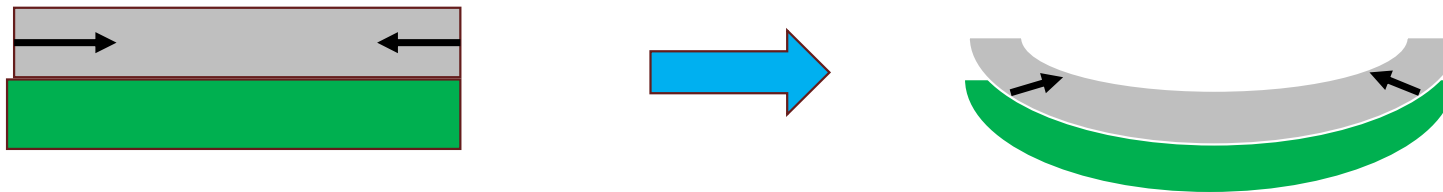
Development of the Novel Mold Film ~ Motivation

- ◆When large-area substrates were encapsulated using ordinary EMCs, warpage, uneven thickness and surface defects may occur.



Development of the Novel Mold Film ~ Motivation

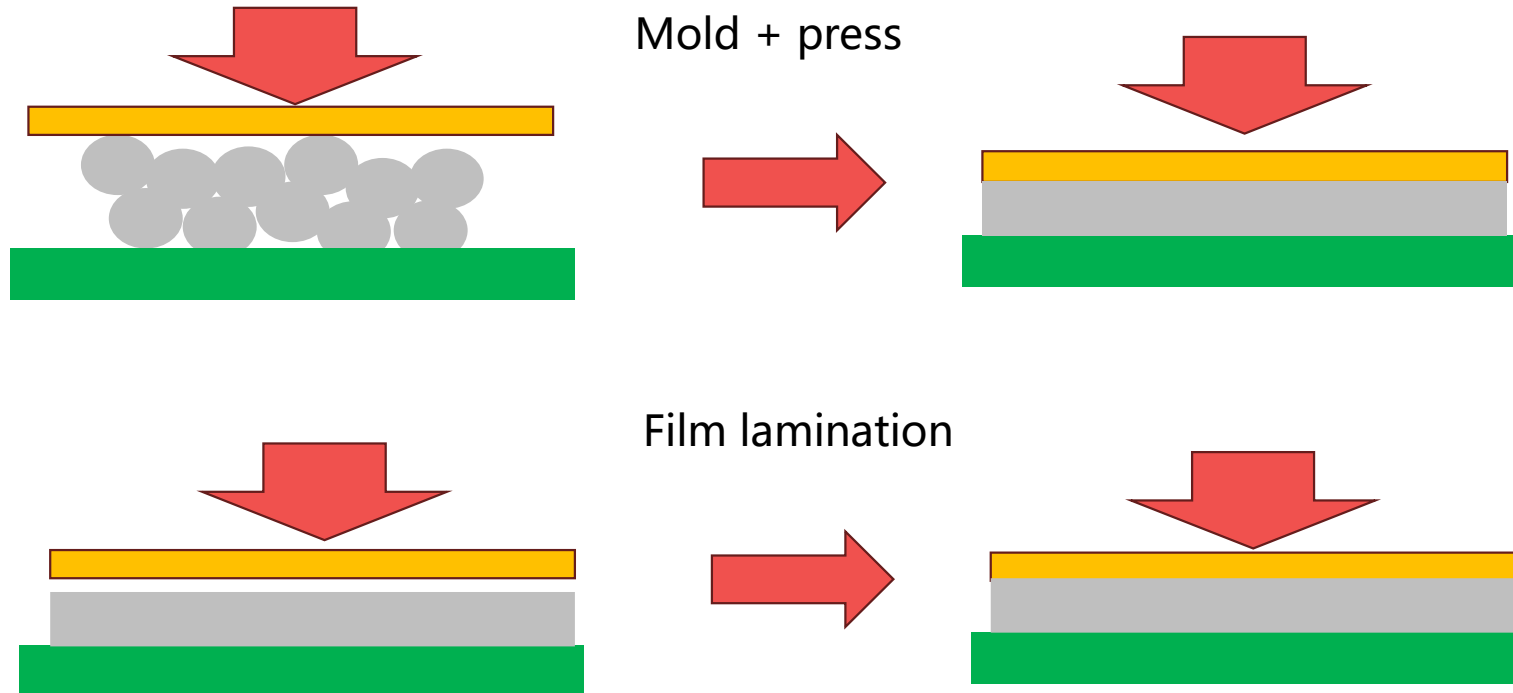
- ◆ When sealing a flat substrate, the resin layer shrunk and the stress generated by the shrinkage pulls the substrate below upward, causing smile-type warpage.



- ◆ Countermeasure : Decrease cure shrinkage of the upper layer → Film would be suitable
Decrease elastic modulus of the upper layer
Decrease CTE mismatch between the two layer

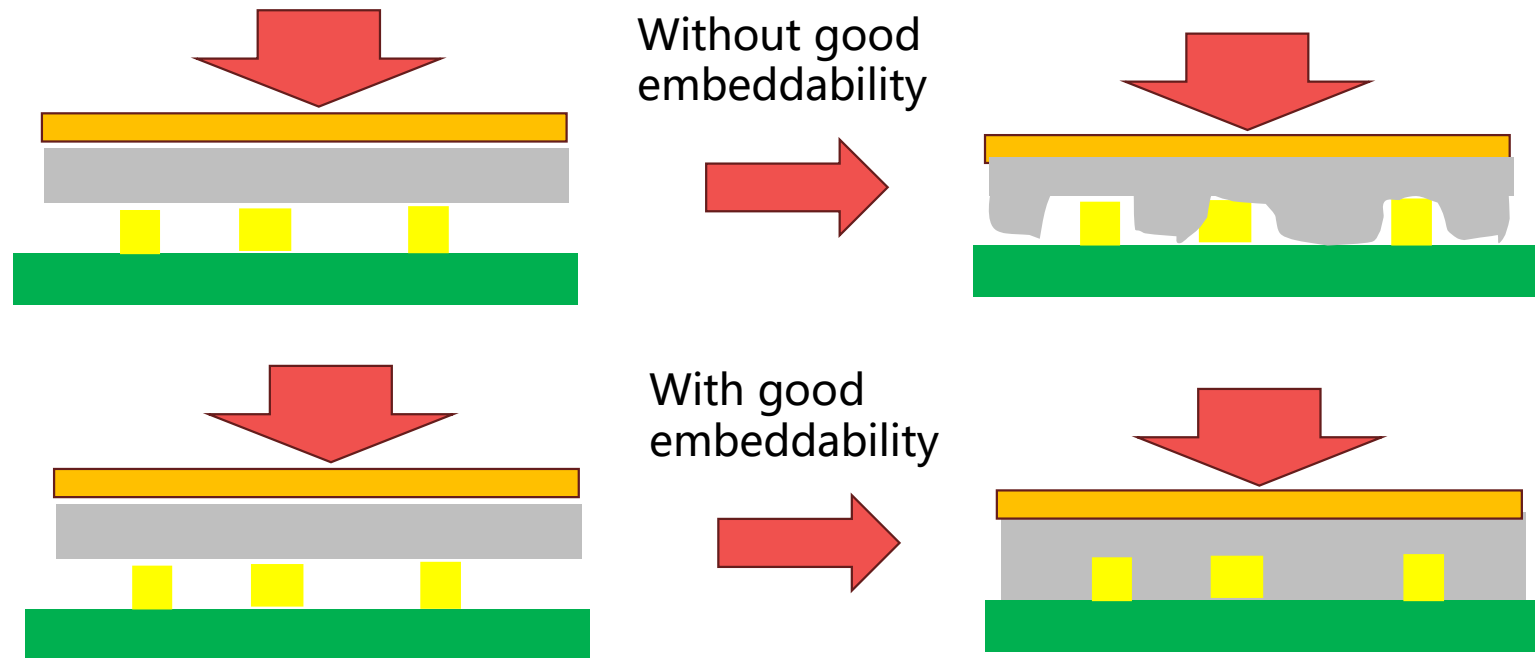
Development of the Novel Mold Film ~ Motivation

- ◆ Surface unevenness and surface defects could be reduced by using film lamination process. In case film lamination, uneven thickness and surface defects can be eliminated in the film before lamination.



Development of the Novel Mold Film ~ Motivation

- ◆ One problem with molding with film laminates is embeddability.
The film must have good embeddability.



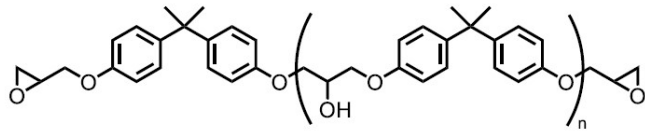
Development of the Novel Mold Film ~ Target

◆ We set the target value of ideal mold film.

		Target Value	EMC (conventional)
Warpage	Cure shrinkage	<0.3%	×
	CTE	<20ppm	○
	Elastic modulus	<8GPa	×
Process ability	Embeddability	○	○
	Surface defects	○	△
	Uniform Thickness	○	△
	E'less Copper plating	>0.3N/m	△
Physical property	T _g (DMA)	>180°C	×
	Elongation	>1%	×

Experiment and results ~Film Formation

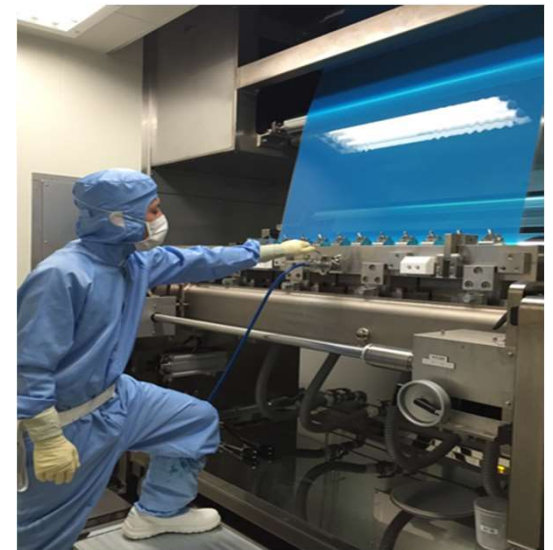
- ◆ Based on epoxy polymer, we have formulated various components. And we obtained the film through the coating process.



Base polymer
Epoxy polymer

+

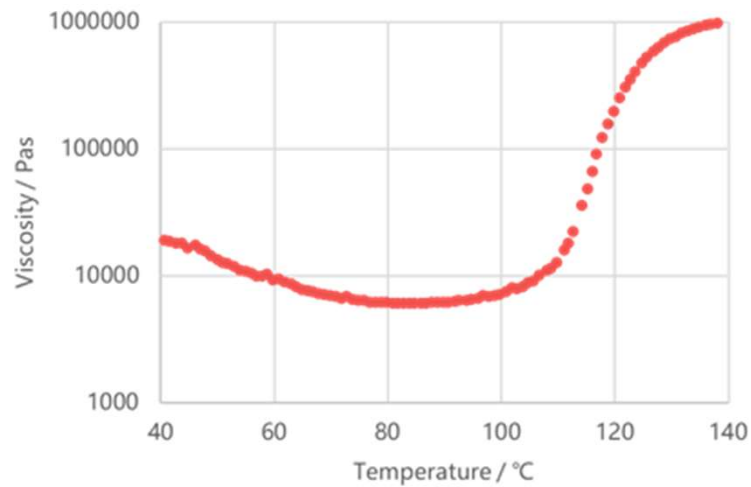
Formulating
crosslinking agents,
initiator,
filler,
and so on.



Film made by coating process

Experiment and results ~ Embeddability

- ◆ Sufficient embeddability was ensured by lowering the melt viscosity in the B-stage state after coating film formation. Conventional vacuum lamination process could be applied.



Vacuum lamination condition

Temp. 50~60°C

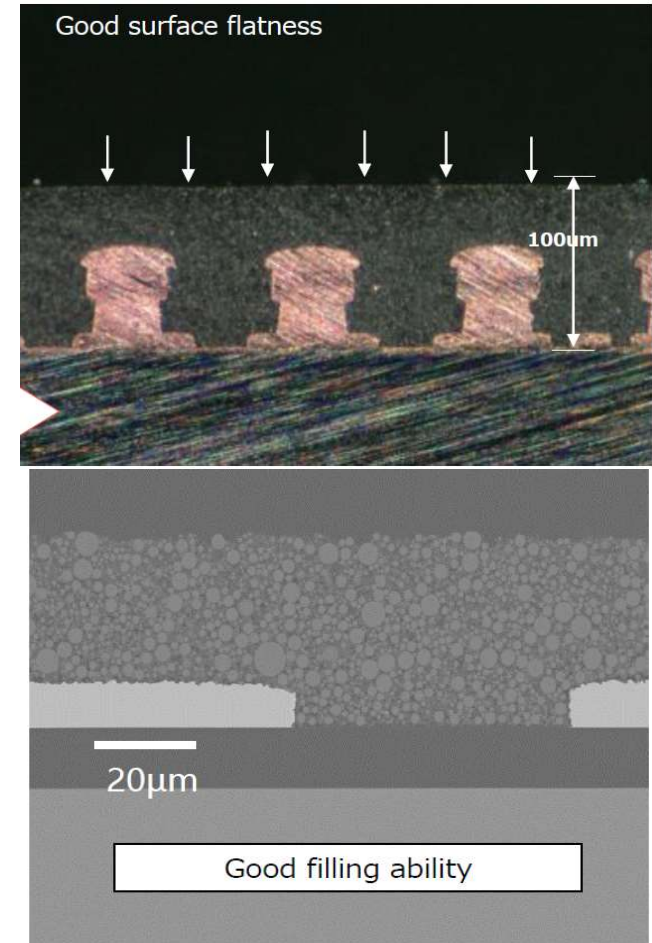
Pressure 0.5MPa

Vacuum 30sec

Laminate 60sec

Cure condition

180°C 30-60min

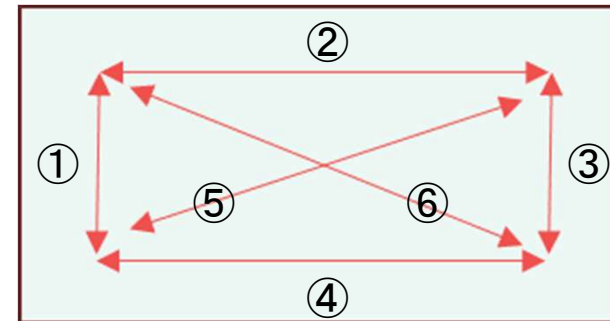


Experiment and results ~ Curing shrinkage

- ◆ The film showed very low or no curing shrinkage. It would be suitable for reducing warpage.

	Before curing (mm)	After curing (mm)	Shrinkage rate(%)
①	80.5	80.5	0
②	123.5	123.5	0
③	81.5	81.5	0
④	124.5	124.5	0
⑤	149.5	149.5	0
⑥	147.0	147.0	0

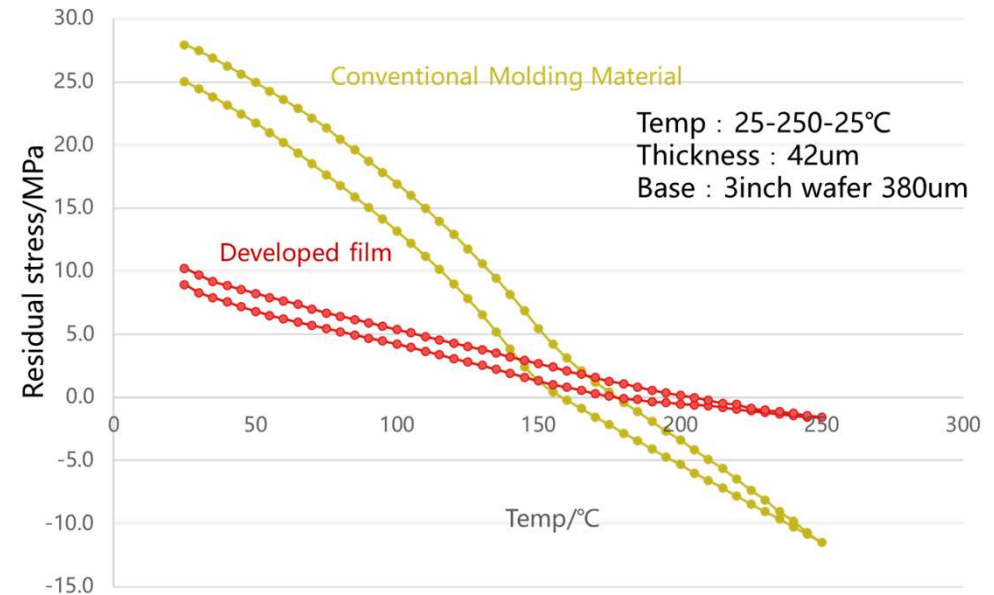
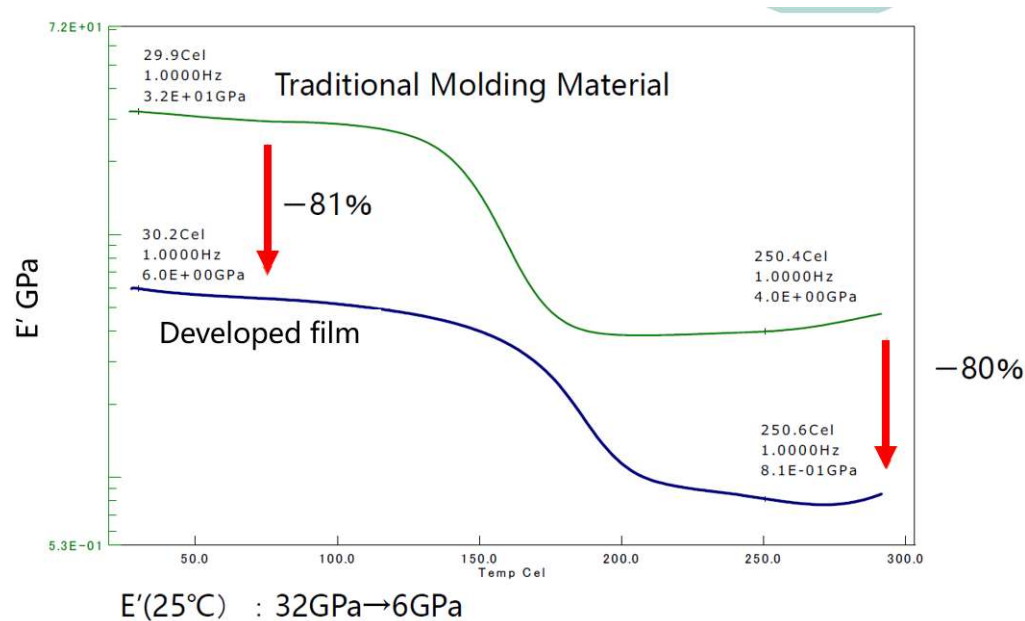
* The developed film was laminated on PI.



Using a metallic direct measure having a JQ0309009 certification number, the minimum unit of 0.5 mm was read and measured.

Experiment and results ~ Elastic modulus, Residual stress

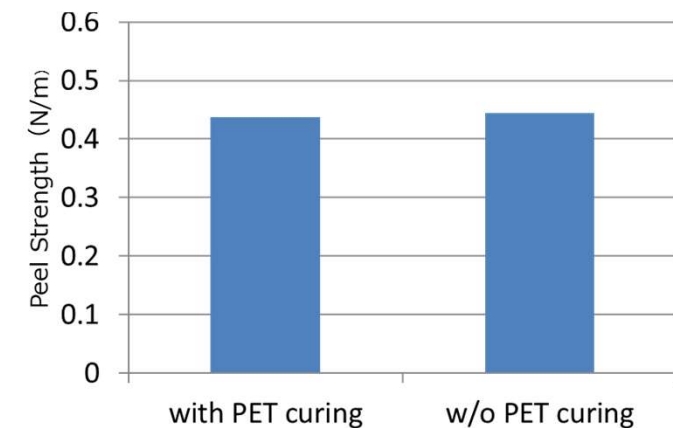
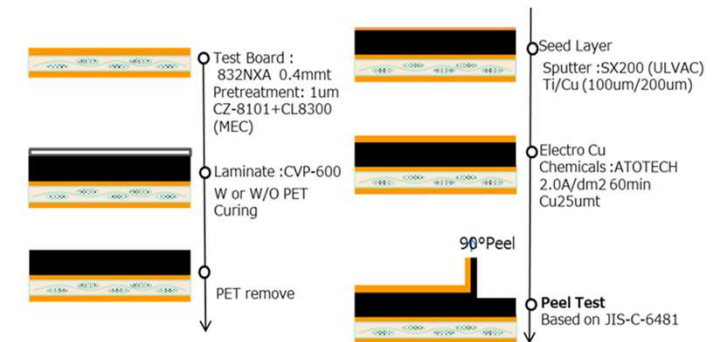
- ◆ Compared to conventional molding material, the film showed very low elastic modulus. And the film laminated on Si wafer showed lower residual stress. These would be suitable for reducing warpage.



Experiment and results ~ Physical properties

- Physical properties of the film was shown below. It's high Tg, low CTE, low CTE change, low young modulus and elongation would be suitable for molding film. Peel strength of dry type E'less copper plating was good.

		Developed film	
Cure Condition	°C/min	180C×60min	Box Oven
Tg (DMA)	°C	190-200	DMA method (5°C/min)
Storage Modulus @30C @250C	GPa	6-7 0.5-0.6	
CTE α_1 <Tg	ppm	15	TMA method (10°C/min)
CTE α_2 >Tg	ppm	40	
Young's Modulus	GPa	6.0-7.0	C-96/23/65 Tensile method @ r.t
Tensile Strength	MPa	60-65	
Elongation	%	1.5-2.5	
Water absorption	%	0.5	
Dk (10GHz)		3.5	C-96/23/65 SPDR method @23°C
Df (10GHz)		0.014	



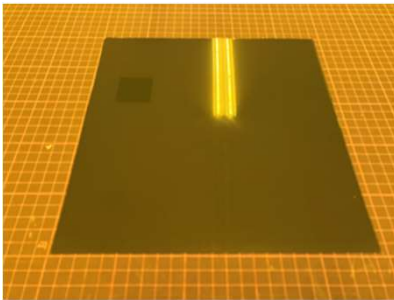
Experiment and results ~ Warpage test

- ◆ The film was vacuum laminated on the glass substrate (thickness 0.3mm, 250mm X 250mm). After laminating several layers and curing, the laminated substrate showed very low warpage. And there observed no surface defects and thickness unevenness.

Laminated on the glass one side.

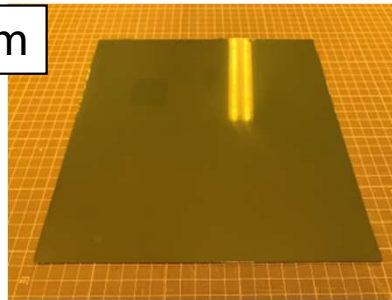
2 layer

0mm



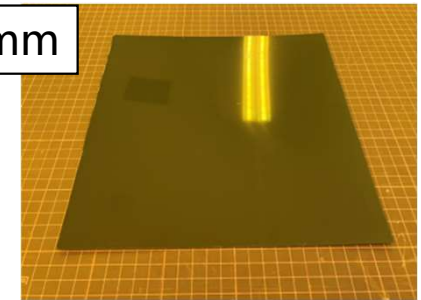
4 layer

0.5mm



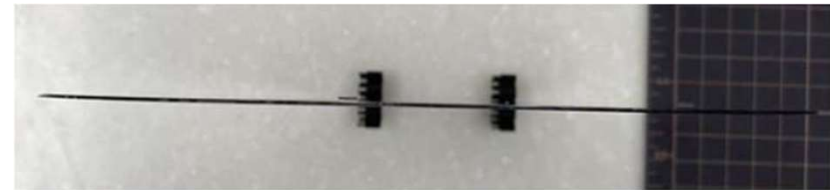
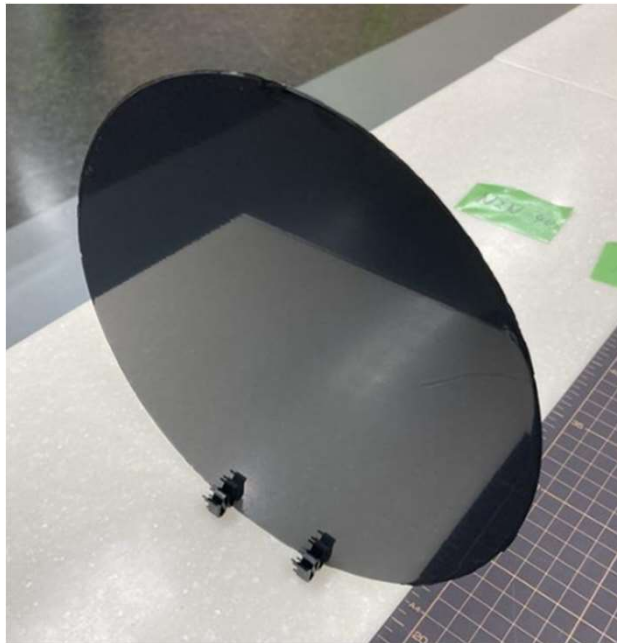
6 layer

2.5mm



Experiment and results ~ Warpage test

- ◆ The film was vacuum laminated on 8 inches Si wafer and cured.
The laminated substrate showed very low warpage.
And there observed no surface defects and thickness unevenness.



Experiment and results ~ ITRI presentation at SEMICON Taiwan 2023

- Taiwan ITRI has developed a 5-stacked-layer RDL module and presented it at "SEMICON TAIWAN 2023", which showed very low or no warpage even panel level package. It used the developed mold film as a mold layer and the novel photo imageable film as RDL layer.

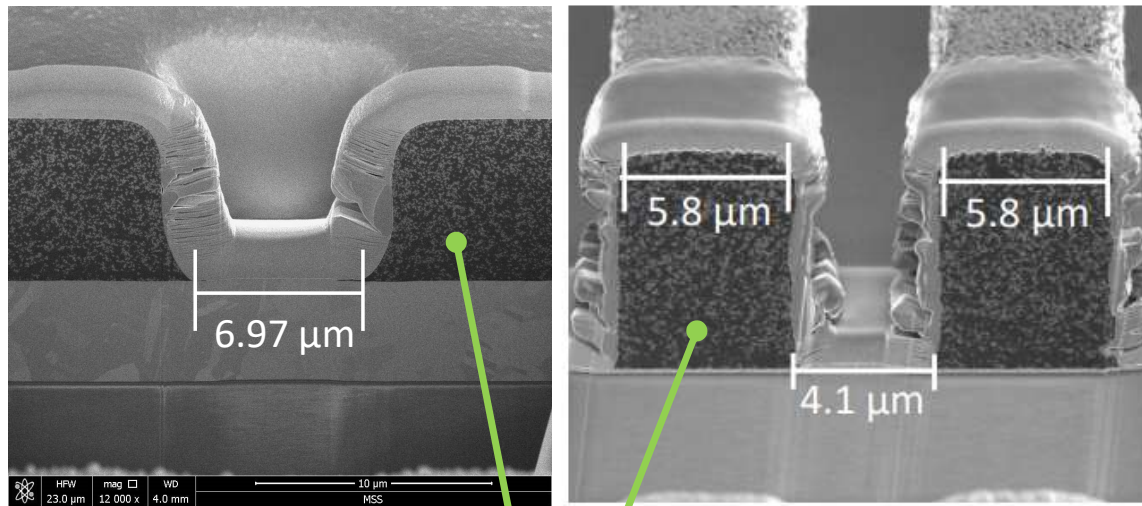
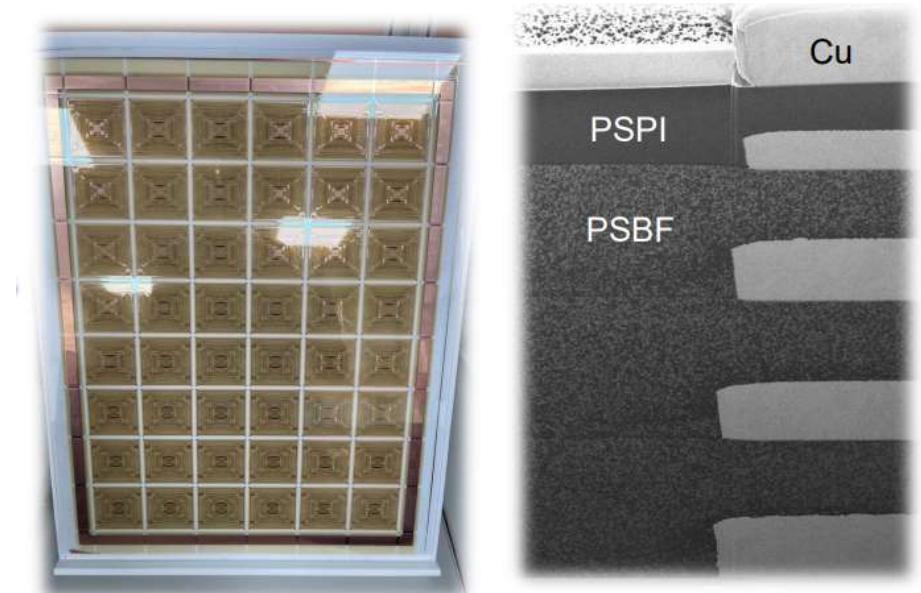


Photo imageable film (March 20, 14:00 WP2)
Laminated by the mold film.



5 RDLs Stacking with PSPI & PSBF
(warpage < 0.5 mm@37×47 cm²)
Laminated by the developed mold film.

Experiment and results ~ Conclusion

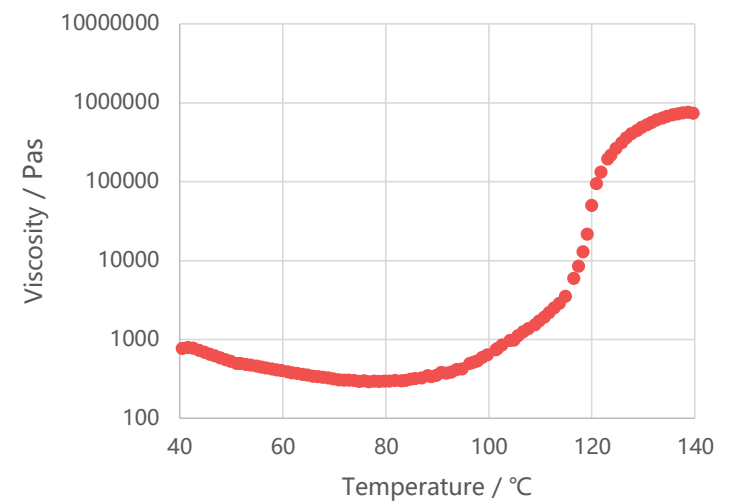
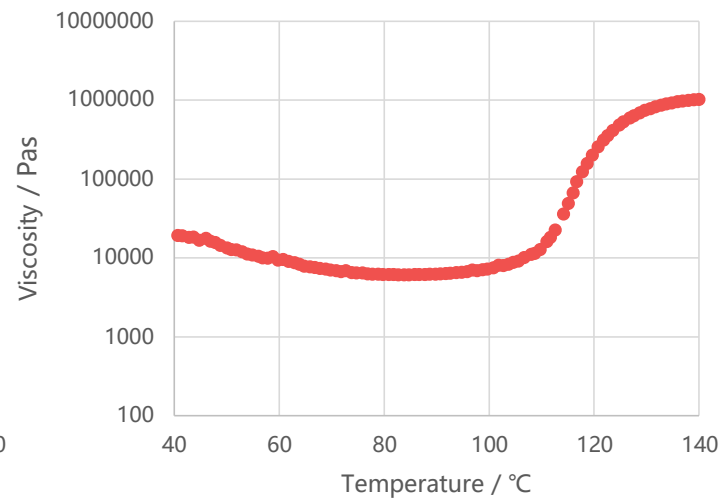
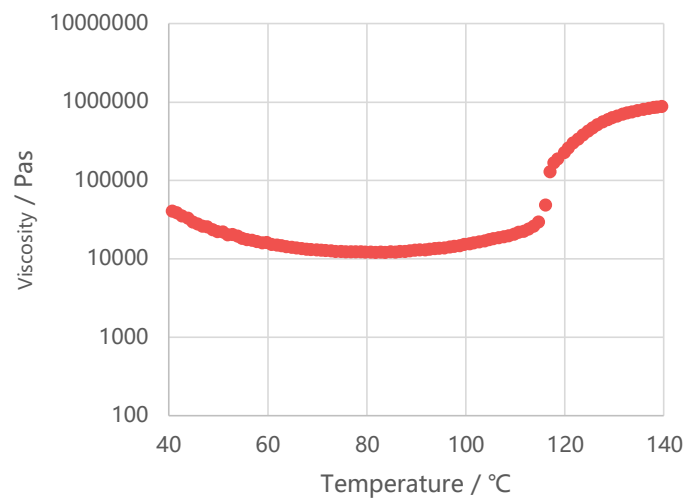
- ◆ The developed film passed the setting target value for ideal mold film.

		Target Value	EMC (conventional)	Developed film
Warpage	Cure shrinkage	<0.3%	×	○ (0)
	CTE	<20ppm	○	○ (15)
	Elastic modulus	<8GPa	×	○ (6-7)
Process ability	Embeddability	○	○	○
	Surface defects	○	△	○
	Uniform Thickness	○	△	○
	E'less Copper plating	>0.3N/m	△	○ (0.45)
Physical property	Tg (DMA)	>180°C	×	○ (190-200)
	Elongation	>1%	×	○ (1.5-2.5)

Variation of the mold film ~ Variation of the melting viscosity

- ◆ We have developed the variation of the mold film.

Below case, variations with different melt viscosities were developed depending on whether it is better or worse for the resin to flow under the die.



Variation of the mold film ~ Heat conductive type

- ◆ We have developed the variation of the mold film.

Below case, 3W/mK heat conductive mold film.

Item		Unit	CELLFIL MD100HS(TR77429)
Cure Condition		°C × min	180°C × 60min
Tg (DMA)		°C	180-190
Storage Modulus	@30°C	GPa	10-20
	@250°C	GPa	1.0-1.5
Tg (TMA)		°C	150-160
CTE α1 <Tg		ppm	4-6
CTE α2 >Tg		ppm	10-15
Young's Modulus		GPa	7.0-8.0
Tensile Modulus		MPa	20-40
Elongation		%	0.5-1.0
Water Absorption		%	No data
5% Weight Loss		°C	No data
Thermal Conductivity		W/m · K	3.1

Variation of the mold film ~ Magnetic type

- ✓ Achieved 2 in 1 property with optimizing filler size and resin formula.
- ✓ Insulation reliability with fine pitch, good permittivity and good laser-via formation.

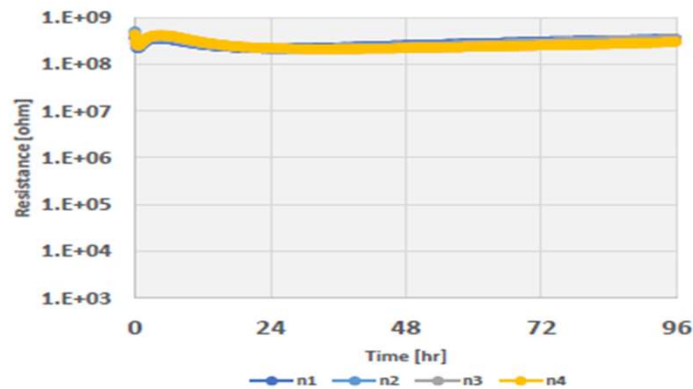
■ Permittivity

Items		2 in 1 material
Magnetic property @100MHz	μ'	3.3 – 3.5
	$\tan\delta$	≤ 0.02

■ B-HAST

Test Board: L/S=12um/13um

B-HAST: 130deg.C/85%RH/96hr/DC2V



■ Laser-via formability

Laser : **CO2**

Device : HITACHI LC-2K212

Mask : 1.9mm

Pulse : 2.0μs

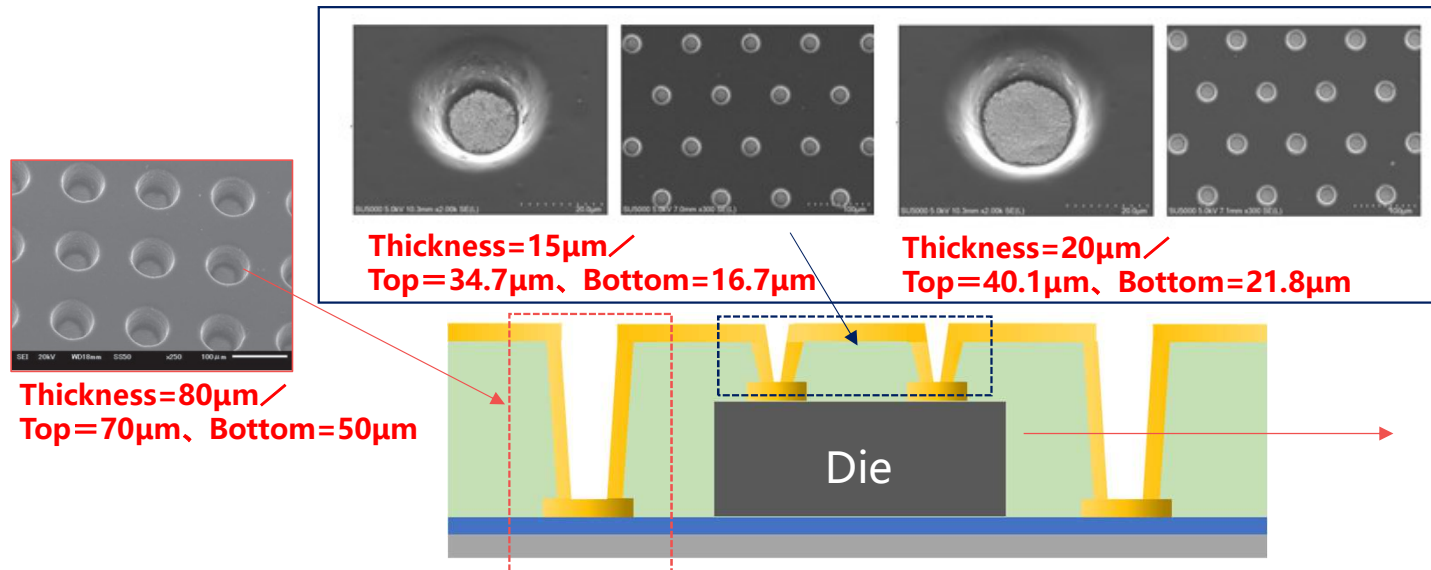
Top view	Side view	Parameter	condition
		Thickness (μm)	40
		Output (W)	1.0
		Shot (cycle)	3
		Mode	cycle
		Top (μm)	56
		Bottom (μm)	50
Top view	Side view	Parameter	condition
		Thickness (μm)	120
		Output (W)	2.0
		Shot (cycle)	10
		Mode	Burst
		Top (μm)	85
		Bottom (μm)	48

Variation of the mold film ~ Photo imageable type

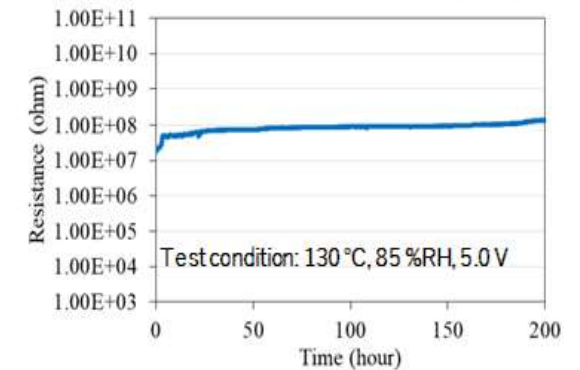
- ◆ We have developed the variation of the mold film.

Below case, photo imageable type mold film.

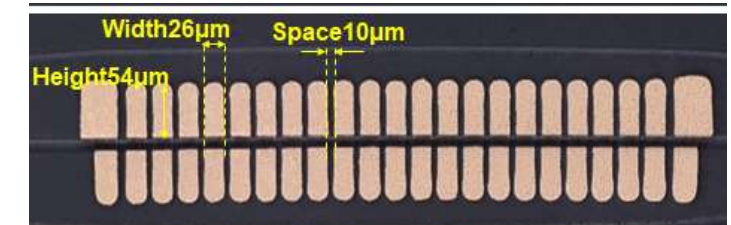
- Surface Flatness
- High Thickness(40~180 μm)
- Low Warpage
- Excellent Gap Filling Ability(Space=10 μm)



Insulation Reliability (between layers, 20 μm gap)



Excellent Gap Filling Ability



Application__For Embedded Wafer Level Packaging / Power Module etc...

Conclusion

- ◆ In order to developing the novel low warpage mold,
 - 1: We had developed film type mold.
 - 2: It showed lower warpage, lower surface defect and higher thickness evenness.
 - 3: Some variations of the mold film were also developed.

It could be a good candidate for FO-WLP and FO-PLP mold.

