19TH INTERNATIONAL CONFERENCE & EXHIBITION ON

DEVICE PACKAGING

FOUNTAIN HILLS, AZ • WWW.DEVICEPACKAGING.ORG • MARCH 13-16, 2023

TOPIC: *Novel Low Df Thermosetting Film and Photo Imageable Film*

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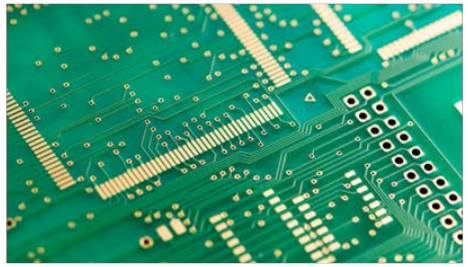
1. INTRODUCTION
～About TAIYO INK MFG

Taiyo Holdings Corporate Overview & Business Domain



Electronics Material
- for Printed Circuit Board
- for IC Package Substrate
- for Flexible Circuit Board
- for Build-up Structure

Medical & PHARMACEUTICALS

Others
- Energy
- Food
- IT Systems
- Other fine Chemicals Business

- Established: Sep.29 1953
- Capital: 9.8B JPY
- Employee: 2137

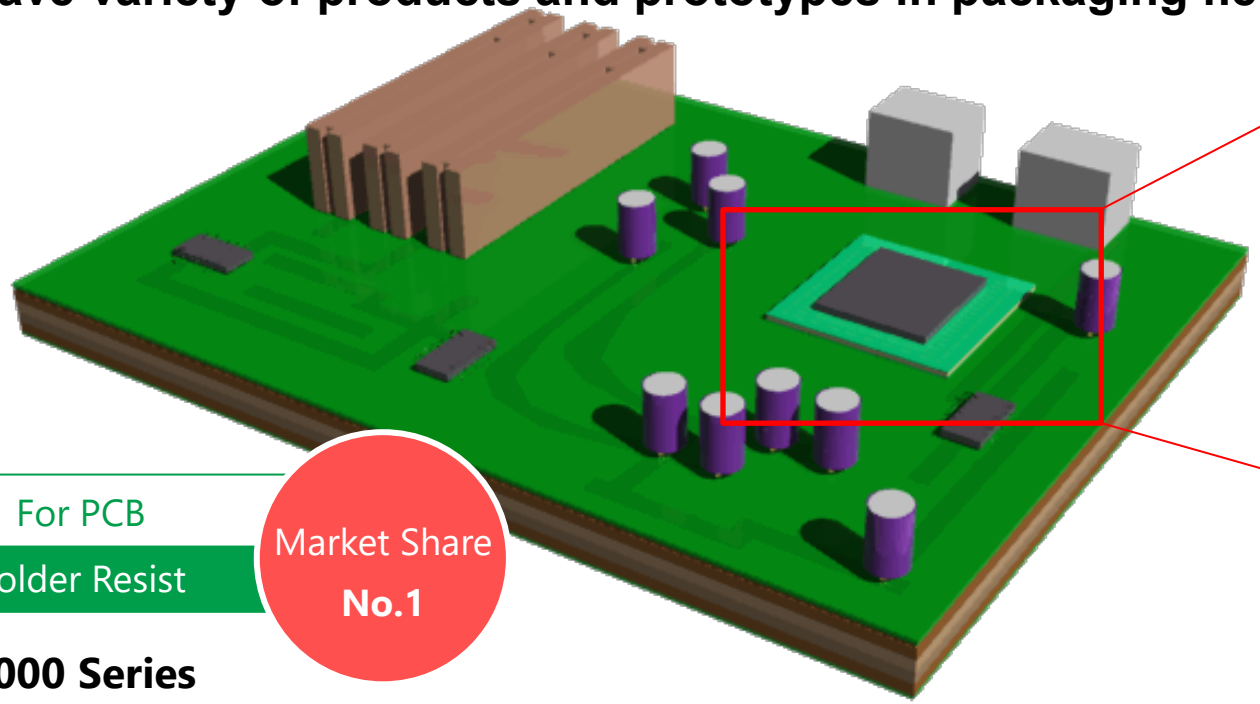
1. INTRODUCTION
～About TAIYO INK MFG

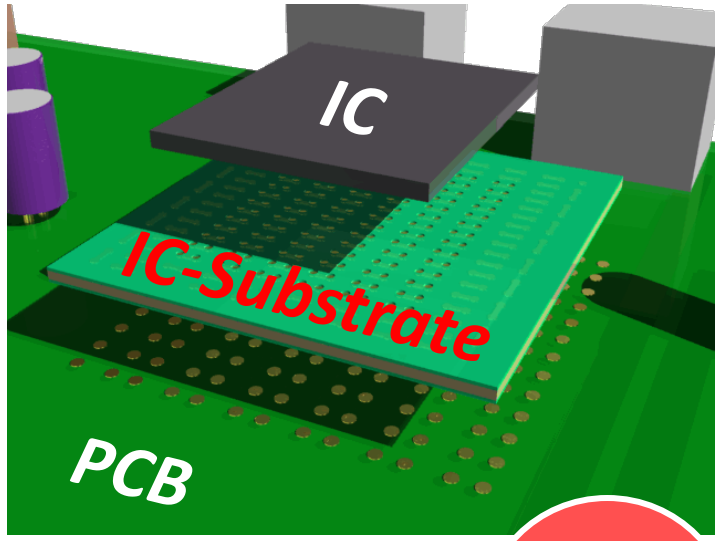
Electronics Business Group Network

1. INTRODUCTION

～Our product lineup

- **We have variety of products and prototypes in packaging field.**





For PCB
Solder Resist

Market Share **No.1**

PSR-4000 Series
PSR-2000 Series

JPCA Award 2022

- **Mold film**
- **Photo & Mold film**
- **New seed for fine line & low loss**
- **An isotropic conductive ink**
- **NiPdAu DFR**

JPCA Award 2020

For Package Substrates
Solder Resist

Market Share **No.1**

Liquid type: PSR-4000 AUS series
Dry film type: PSR-800 AUS series
Via filling ink Z,D series

Today's Agenda

For Package Substrates
Dielectric Material

- **Zaristo Series:(Thermal Curable)**
- **PVI Series:(Photo imageable)**

JPCA Award 2021

1. INTRODUCTION

～Background of this study

- There is increasing need to reduce transmission loss at mm wavelength.

Transmission loss (α) = Conductor loss (α_c) + Dielectric loss (α_d)

Conductor loss at unit length（αc)

$$\alpha_C = \frac{2.26\times10^8\times\sqrt{f}}{W}$$

Dielectric loss at unit length（αd)

$$a_d = 90\sqrt{\varepsilon_r}\tan\delta\times f$$

f : wavelength
W : Wiring width
ε_r : Dielectric constant
Tanδ : Dielectric loss

Substrate film → Low Dk, Df for decrease dielectric loss
→ Cu adhesion on smooth surface for decreasing conductor loss

1. INTRODUCTION

～Our strategy

Existing low Dk/Df films : poor physical property and process ability, since these were thermoplastic resins.

		Target Value	Epoxy film (Low Df type)	LCP, PPE, PPS
Electrical property	Dk (10GHz)	<3.2	× (3.4)	○
	Df (10GHz)	<0.003	× (0.005)	○
	Tg (C, TMA)	>180	× (160)	○ (× : PPS)
	Water absorption(%)	<0.1	× (0.4)	○
	HAST endurance (130C, 85%, 500hr)	○	○	–
Physical property	Thermosetting	○	○	×
	Low CTE (x-y axis)	<25ppm	○ (18)	× (○ : LCP)
	Low CTE (z axis)	<25ppm	○ (18)	×
	E'less Cu adhesion	>4N/cm	○ (4)	×
Process ability	Laser via	○	○	△
	desmear	○	○	△
	E'less Cu condition	○	○	×

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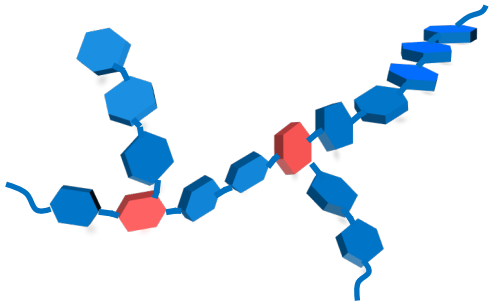
Convert thermoplastic PPE to thermosetting resin to improve the property.

2. FILM AND ITS PROPERTY

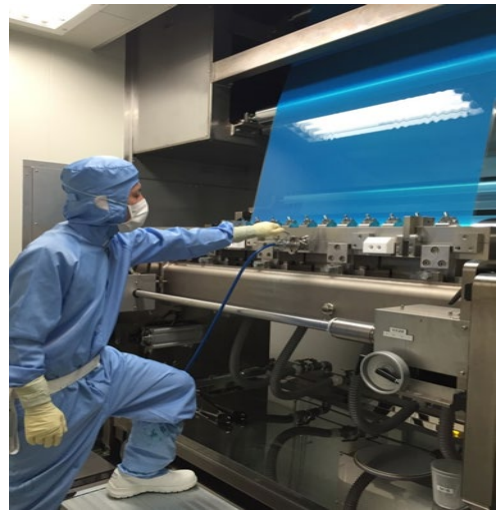
~ Film making process and electrical property

Synthesis of Novel Curable PPE

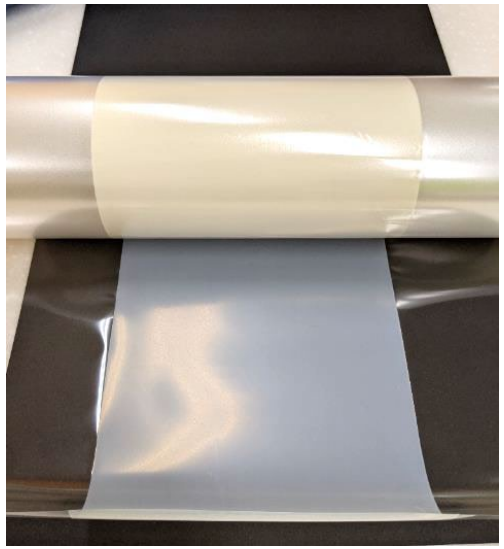


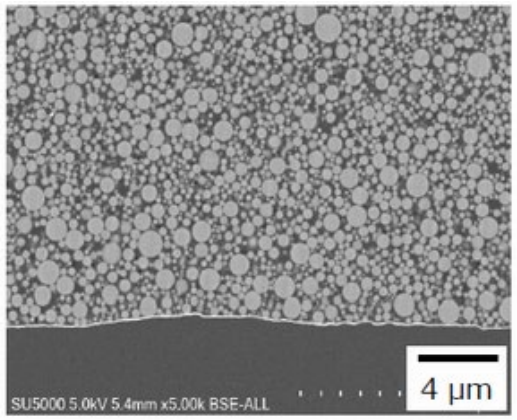
+ Formulating filler, initiator, crosslinking agents, and so on.

Film made by coating process



	Developed film
Dk (10 GHz)	3.1
Df (10 GHz)	0.0016
T_g (°C)TMA	195
CTE (xy, ppm)	18
CTE (z, ppm)	18
Water absorption (%)	0.04





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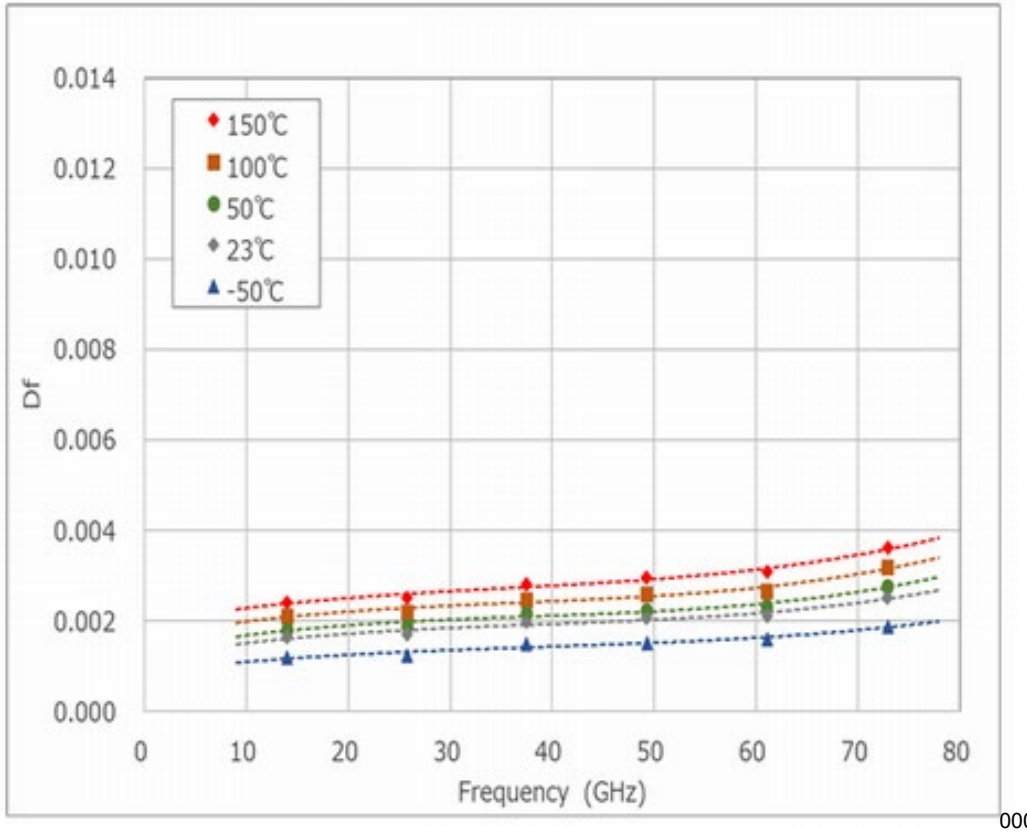
2. FILM AND ITS PROPERTY

~ Df : temperature dependence

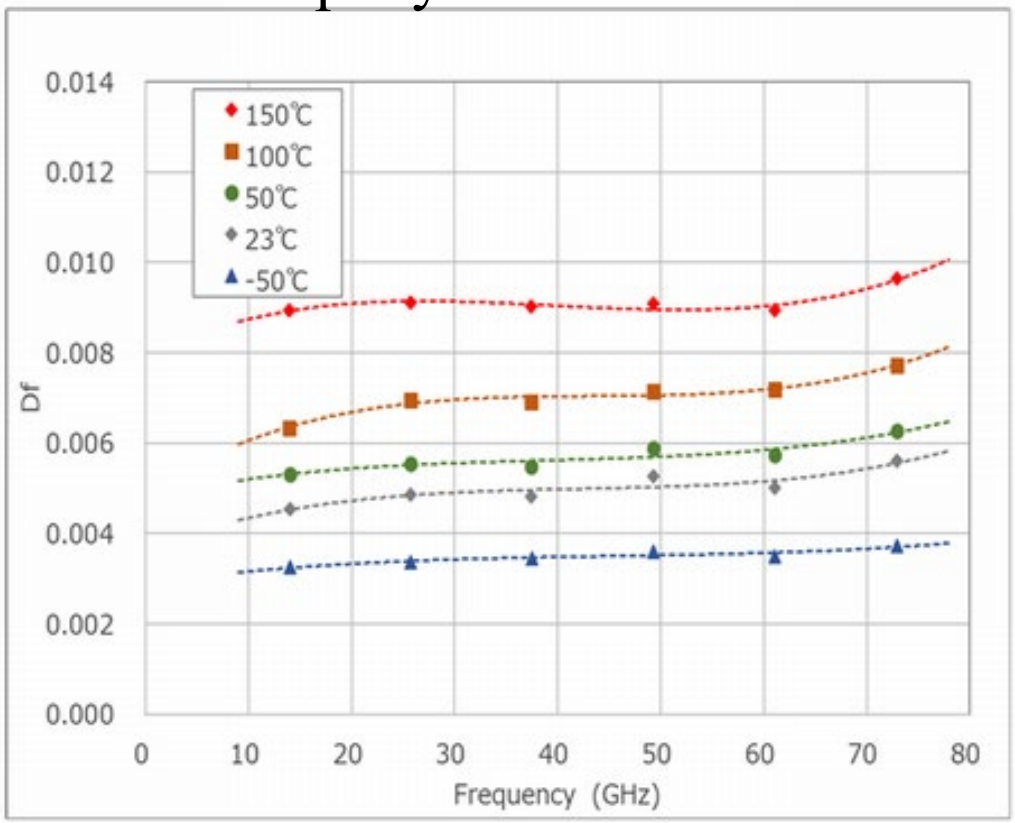
The novel PPE film showed lower increase of Df compared to that of epoxy film.

= Transmission loss would not increase with temperature.

The novel PPE film



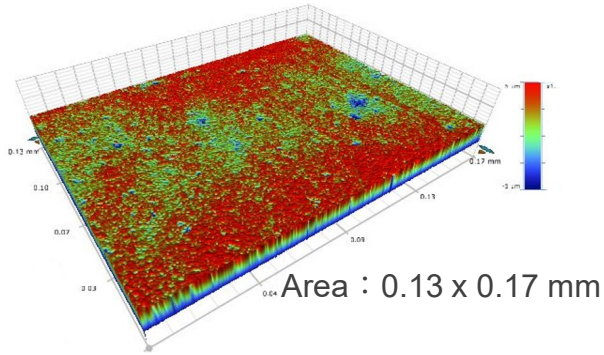
Epoxy based film

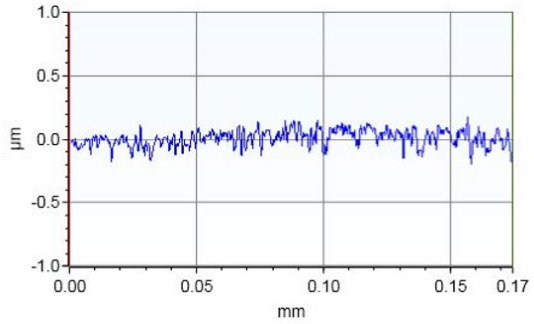


2. FILM AND ITS PROPERTY

～ E'less Cu adhesion

The novel PPE film showed good adhesion to E'less Cu even on the smooth surface Ra=ca.60nm.





Surface roughness after Desmear

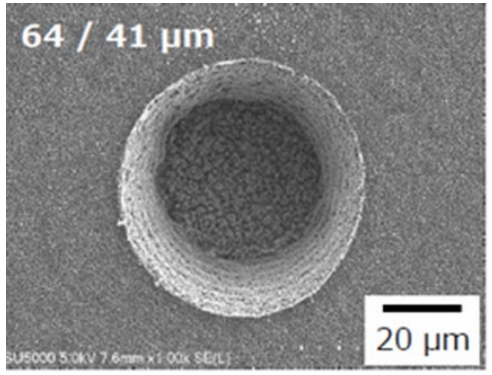
E'less Cu plating + electro Cu plating

		Criteria	The film
Surface roughness	After desmear process	<100nm	Ra=ca.50nm Pass
Peel strength E' less Cu	Initial	>3.0N/cm	4.5N/cm Pass
	85deg.C85% After 100hrs	>3.0N/cm	4.2N/cm Pass

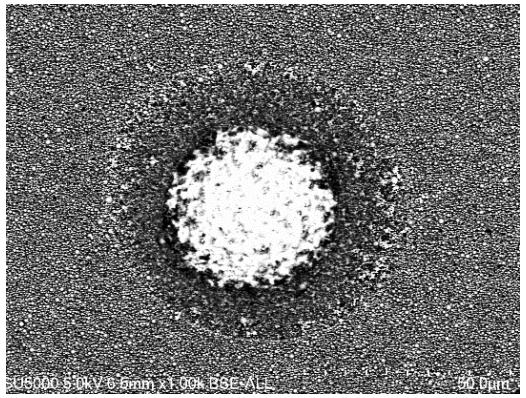
2. FILM AND ITS PROPERTY

~ Laser via process ability

The novel PPE film showed similar laser via process ability to that of the existing epoxy film.

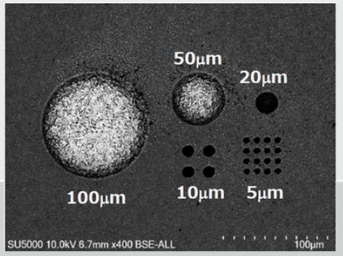
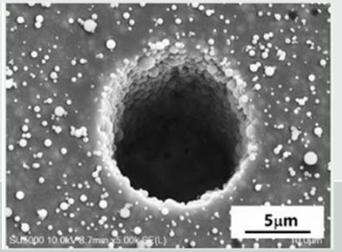
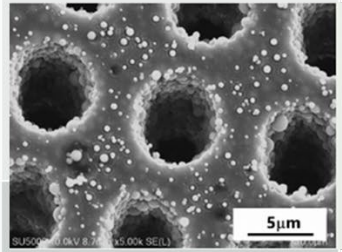


CO_2 laser via



Smear was depleted after ordinal desmear process

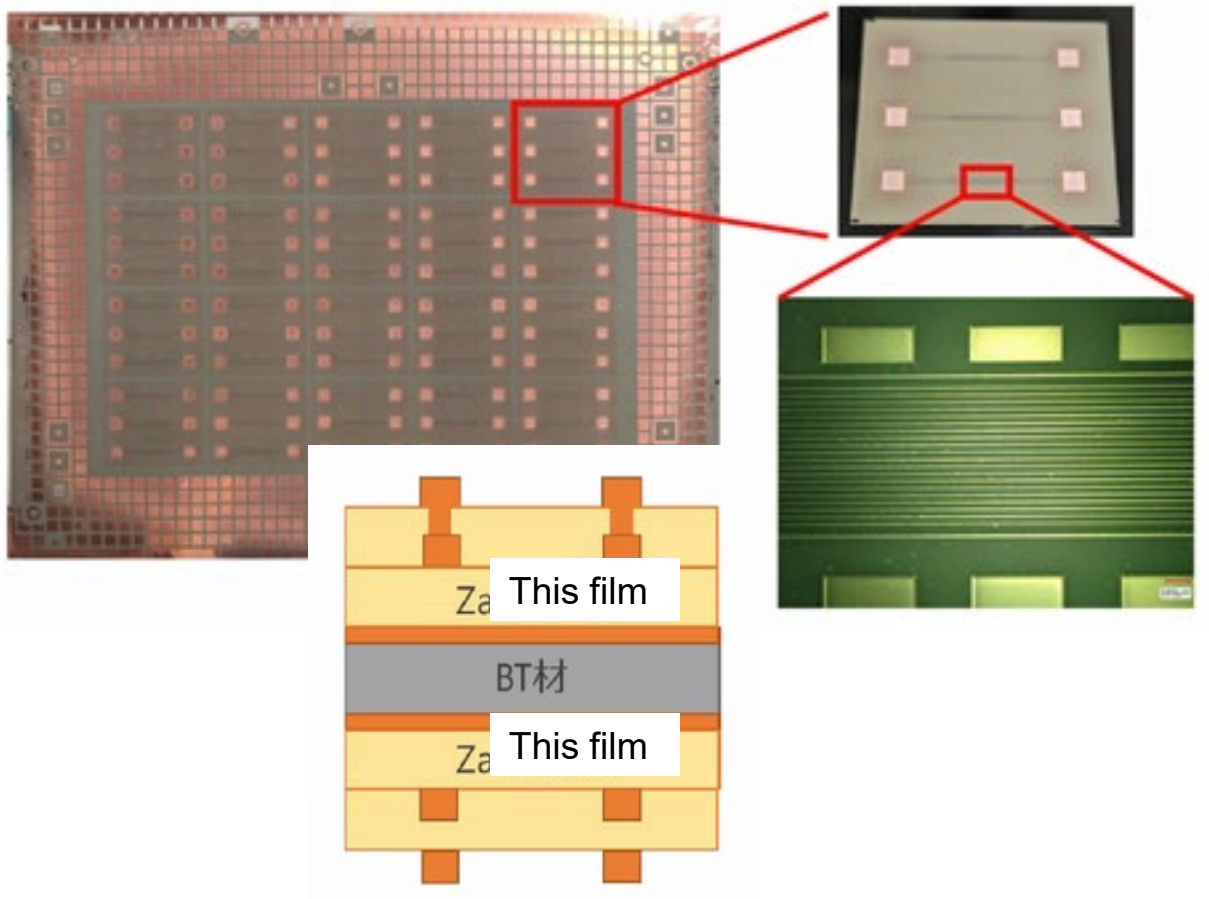
Chemical: Atotech
S.60℃ 5min
K:80℃ 20min
R:40℃ 5min

	Excimer laser		
	Total	Target:10umΦ	Target:5umΦ
Picture			
Top (umΦ)			
Bottom (umΦ)		9	4
Ratio(%)		82	67

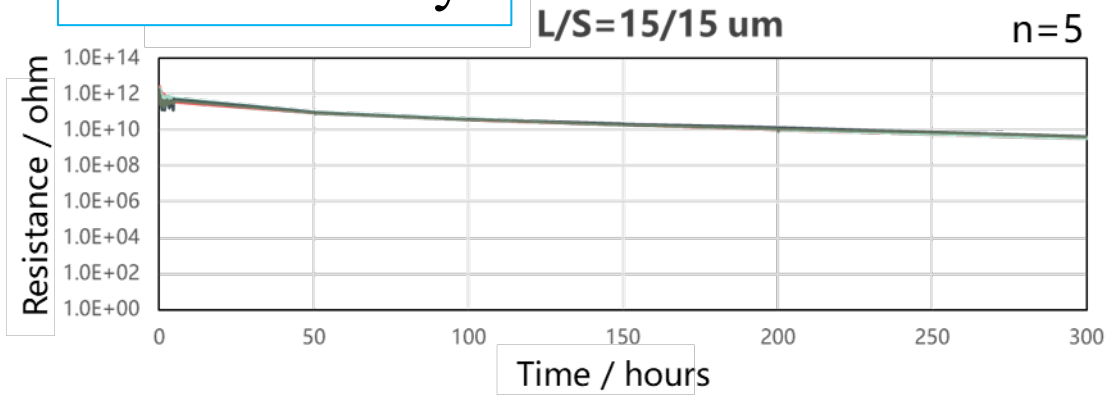
3. PERFORMANCE OF THE FILM

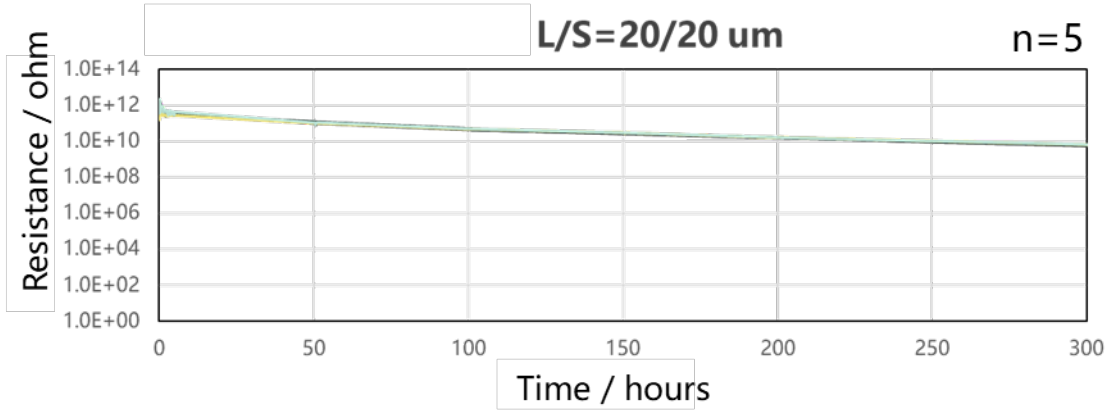
～ Making stacked substrate and reliability

We have made stacked substrate using the novel PPE film, with comb electrode L/S=15/15μm、20/20μm by SAP process, and measured B-HAST (135℃, 85RH, DC5V).



Good reliability

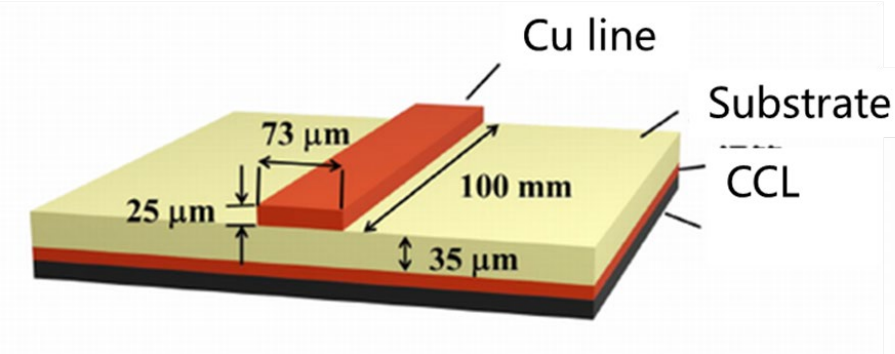


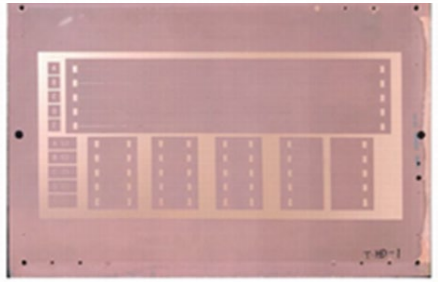


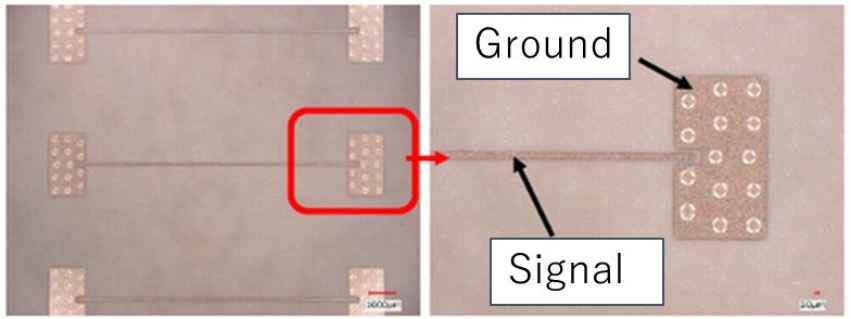
3. PERFORMANCE OF THE FILM

～ Making stacked substrate and reliability

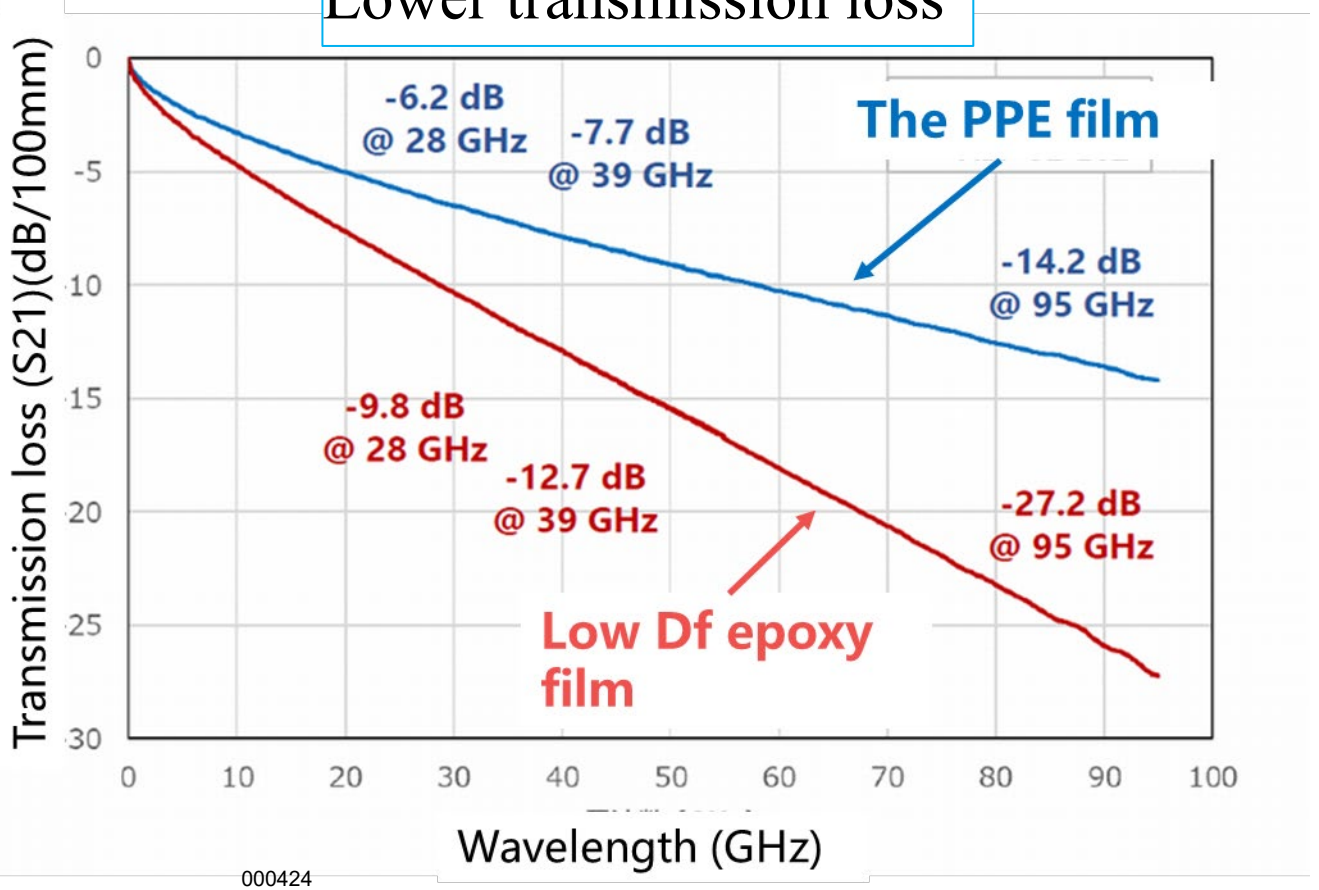
We have made strip line substrate using the novel PPE film and the epoxy film, and measured its transmission loss.







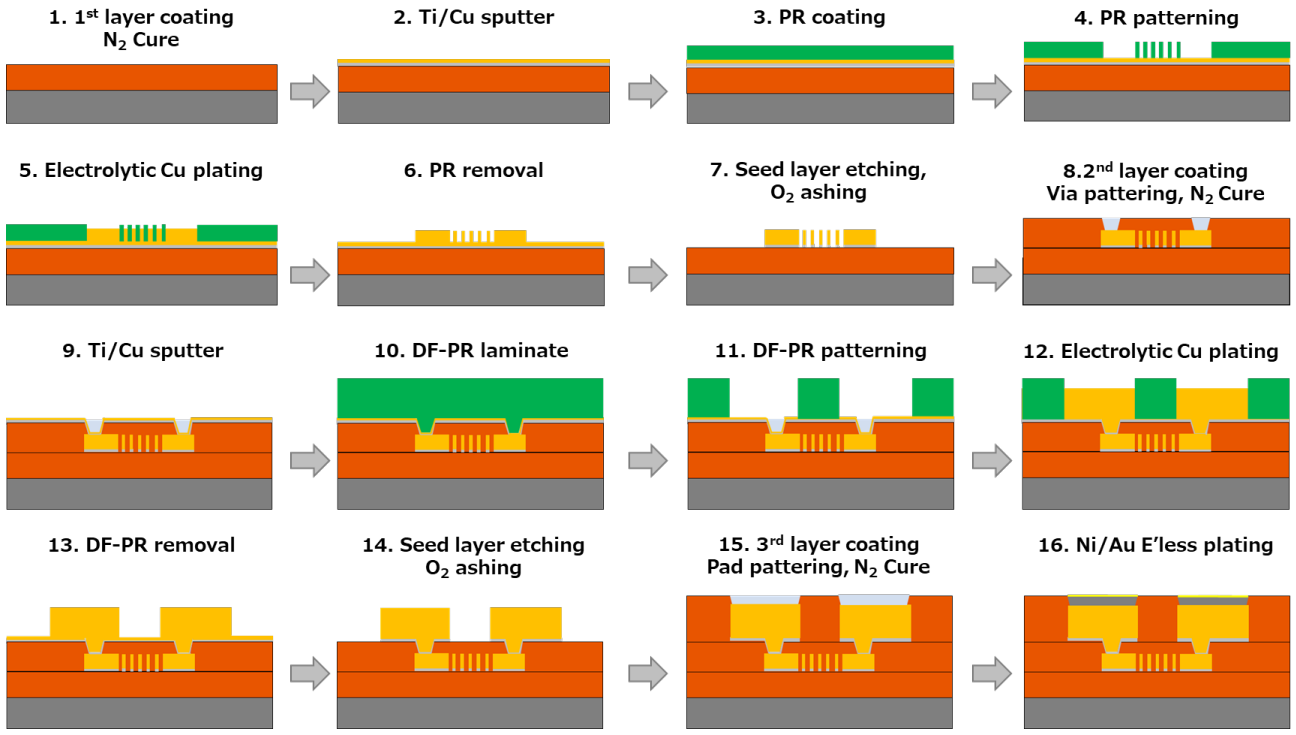
Lower transmission loss

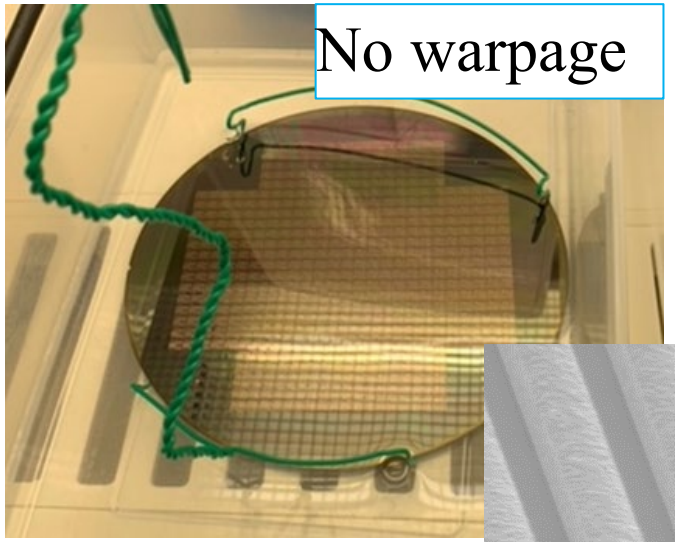


3. PERFORMANCE OF THE FILM

～Making RDL of the chiplet

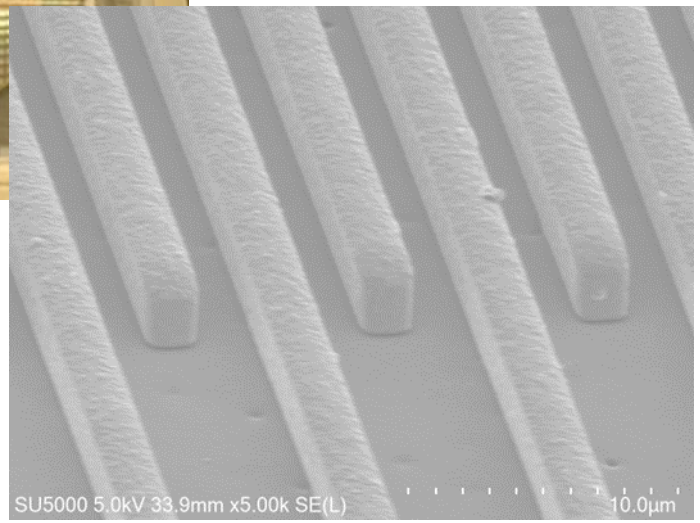
We have made 3 layers RDL stacked on Si wafer, with L/S=2/2μm.





No warpage

Good
L/S=2/2μm line



3. PERFORMANCE OF THE FILM

～Conclusion

The novel PPE film would be a good candidate for lower transmission loss substrate.

		Target Value	Epoxy film (Low Df)	PPE	Developed PPE film
Electrical property	Dk (10GHz)	<3.2	× (3.4)	○ (2.6)	○ (3.1)
	Df (10GHz)	<0.003	× (0.005)	○ (0.0025)	○ (0.0022)
	Tg (℃, TMA)	>180	× (160)	○ (195)	○ (195)
	Water absorption(%)	<0.1	× (0.4)	○ (0.03)	○ (0.04)
	HAST endurance (130℃, 85%, 500hr)	○	○	—	○
Physical property	Thermosetting	○	○	×	○
	Low CTE (x-y axis)	<25ppm	○ (18)	×	○ (18)
	Low CTE (z axis)	<25ppm	○ (18)	×	○ (18)
	E'less Cu adhesion	>4N/cm	○ (4)	×	○ (4)
Process ability	Laser via	○	○	×	○
	desmear	○	○	△	○
	E'less Cu condition	○	○	×	○

4. PHOTO TYPE INSULATION FILM

~ Background

Normally, photo type liquid Poly Imide was used as RDL layer.

It had its disadvantages, but there were no promising candidates in existing materials.

		Target Value	Epoxy film (conventional)	Photo PI (conventional)	Photo Solder Resist film (conventional)
Electrical property	Dk (10GHz)	<3.4	○	○	○
	Df (10GHz)	<0.02	○	○	○
Physical property	Tg (℃, TMA)	>150	○	○	○
	Low CTE	<25ppm	○	×(ca.50-60)	×(ca.40-50)
Process ability	Curing temperature	>180℃	○	×(ca.250)	○
	Lamination stacking	OK	○	×(Wet process)	○
	Via formation	Photo process	× (Laser)	○	○
	desmear	No	× (Required)	○	○
	E'less Cu condition	Wet	○	○	×
		Dry (sputter)	○	○	○

4. PHOTO TYPE INSULATION FILM

~ Criteria

There would be below 4 criteria for promising RDL material.

1: Film type : For simple process ensuring surface flatness.

2: Photo imageable : For simple process ensuring via formation.

3: Electroless cupper plating : For simple process ensuring wire formation.

4: Low CTE and low curing temperature : For avoiding warpage.

4. PHOTO TYPE INSULATION FILM

~ Developed film

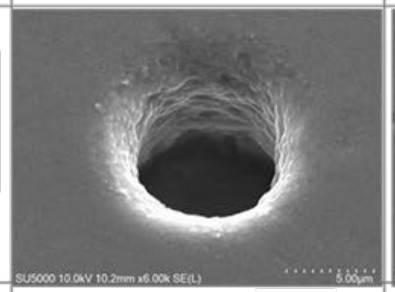
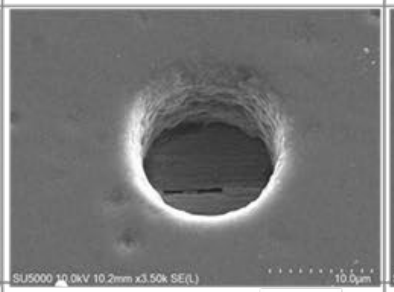
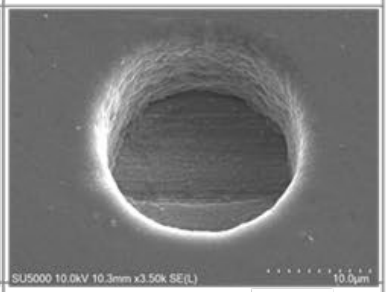
We had developed photo type insulation film for RDL.

It had passed the 4 criteria for promising RDL material.

Material properties

	Dk (10GHz)	Df (10GHz)	CTE (α1)	Tg (°C) TMA	Tg (°C) DMA
PVI-3	3.4	0.015	25ppm	150	150

Micro-via with 15μmt PID (i-line stepper)

Dose (mJ)	150		
Via ϕ	ϕ 10 um (×6000)	ϕ 15 um (×3500)	ϕ 20 um (×3500)
SEM Image 4~5/41 Sensitivity			
Top/Bottom	9.5/7.8 um	14.9/13.3 um	19.8/17.4 um

Cu plating adhesion

Uyemura desmear-free new process (Adhesion promoter)

PVI-3 formed

▽

UV + Reformer

▽

E'less Plating

▽

Electrolytic Plating

	Peel strength
E'less Cu	4.5 N/cm

4. PHOTO TYPE INSULATION FILM

~ Developed film

The film showed good B-HAST endurance.

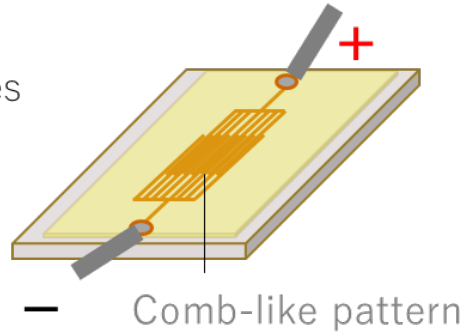
BHAST between lines

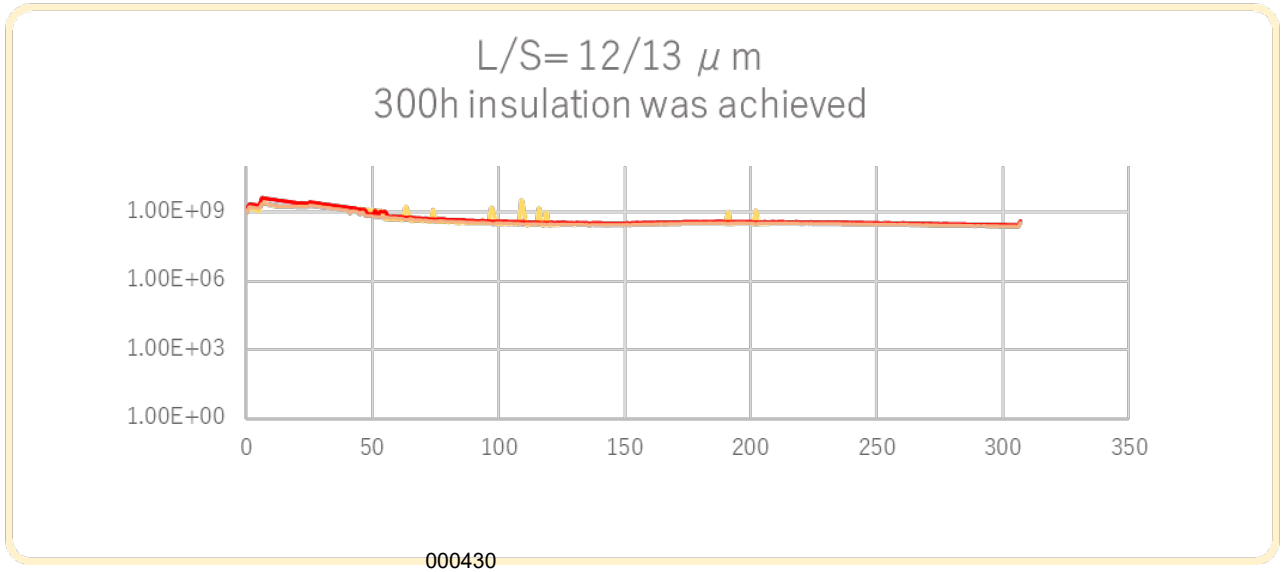
Preconditioning :125 deg.C/24 h⇒ 85 deg.C/60%/168 h ⇒ Reflow 260 deg.C/3 times

B-HAST : 130deg.C,85% / 5 V (Failure criteria:1.0E+6 ohm)

Chamber : HASTEST® MODEL PC-R8D (Hirayama)

Measurement : MIGRATION TESTER MODEL MIG-8600B (IMV)



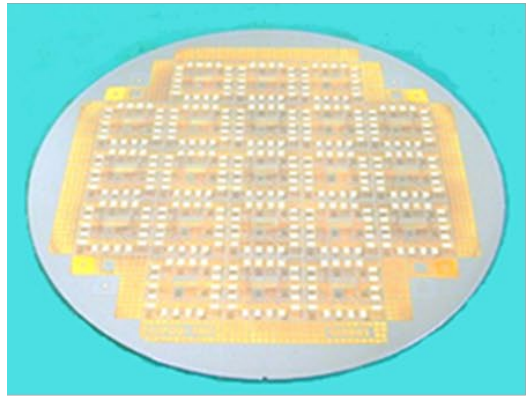


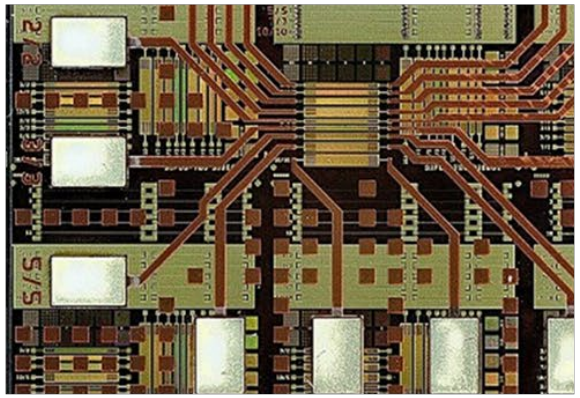
4. PHOTO TYPE INSULATION FILM

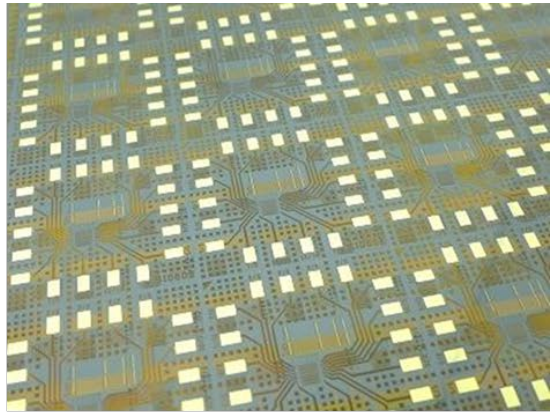
~ Developed film

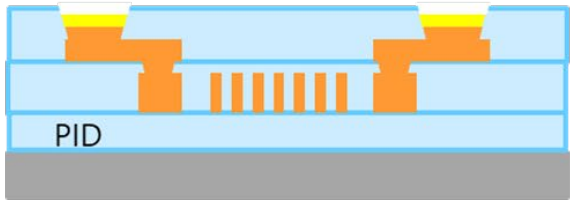
We had made below 3 layer RDL on 8 inch Si wafer.

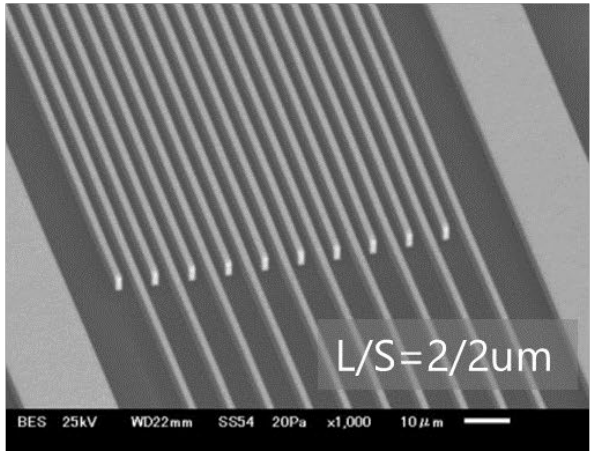
There observed no warpage.









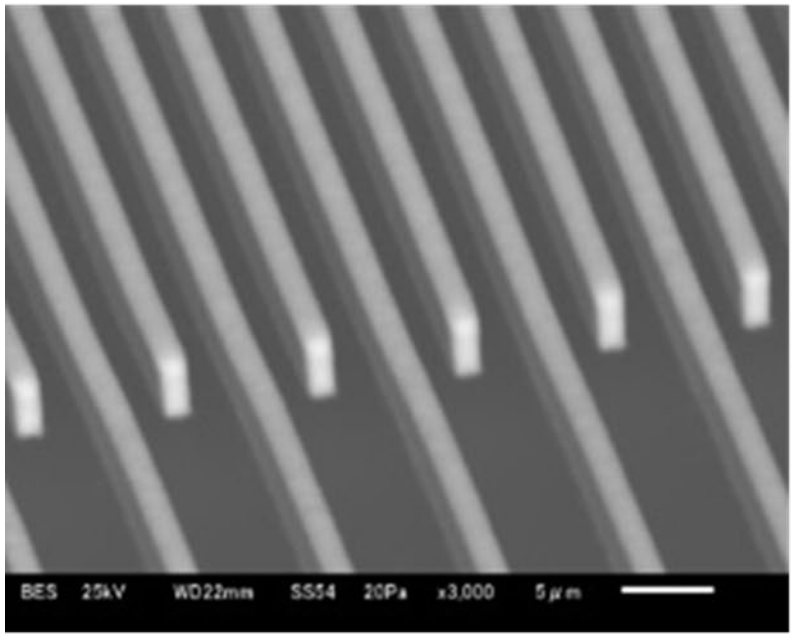


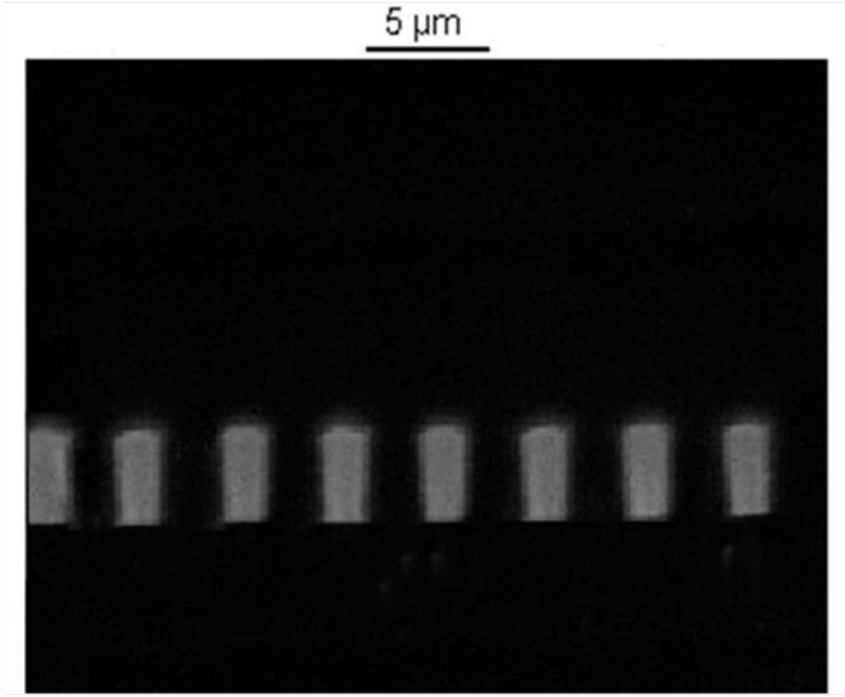
4. PHOTO TYPE INSULATION FILM

~ Developed film

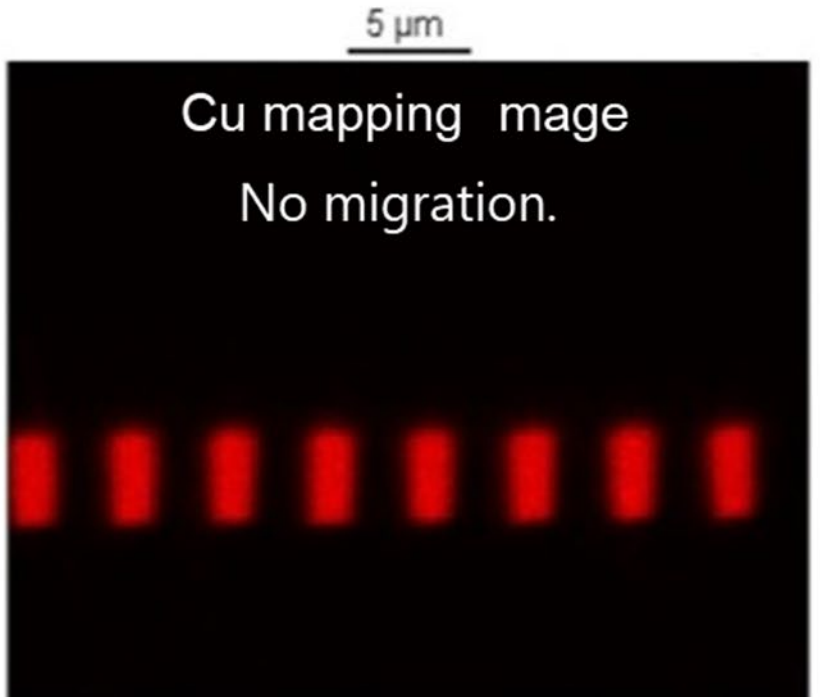
The film showed good embeddability, and good B-HAST endurance.

Initial: Cross section





After B-HAST 300hr



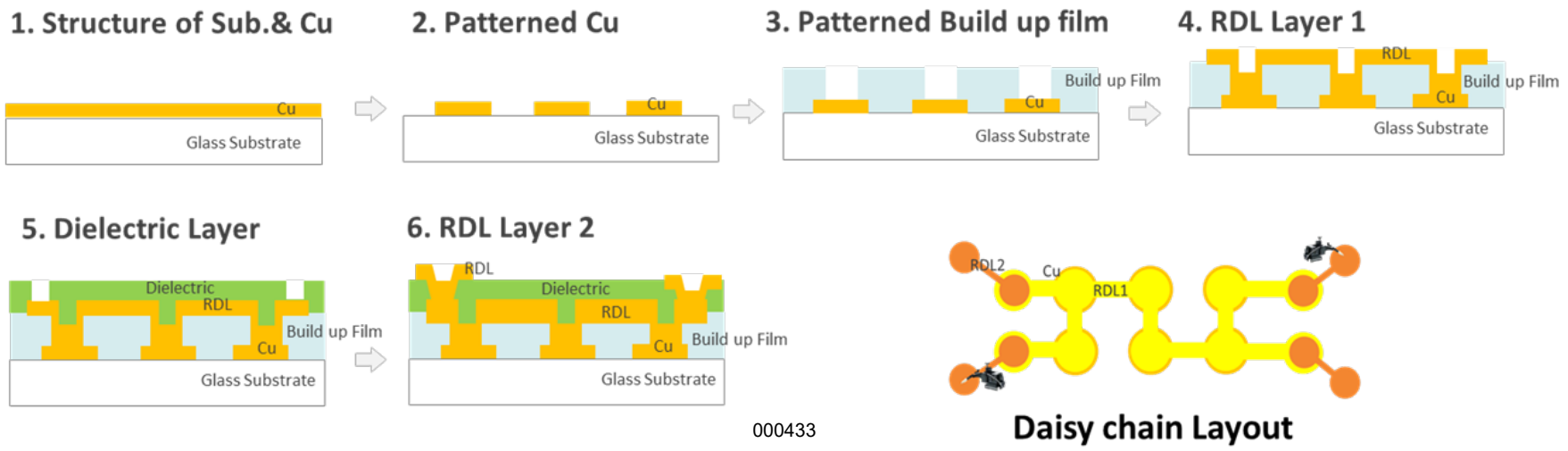
4. PHOTO TYPE INSULATION FILM

~ Brief introduction

ITRI had presented new RDL formation process by using our photo type insulation film at SEMICON TAIWAN 2022.

High resolution & Low Temp. process RDL Structure by Using Digital Lithography for IC substrate Applications

- ITRI has developed a redistribution layer (RDL) structure by using digital lithography & low temp. sputtering technologies. And it achieves in a high resolution & low Temp. process structure that can be used as a good solution to minimize the thermal budget in IC substrate production.



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4. PHOTO TYPE INSULATION FILM

~ Brief introduction

High resolution & Low Temp. process RDL Structure by Using Digital Lithography for IC substrate Applications

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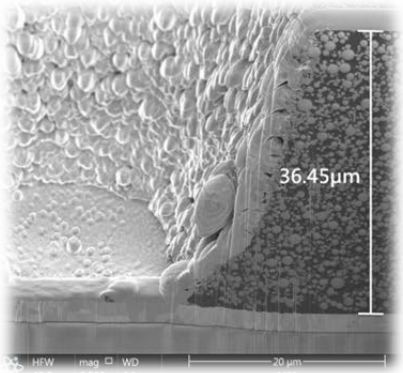
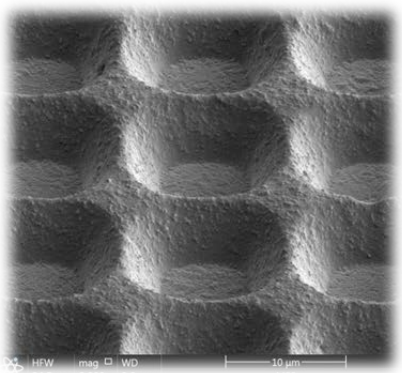
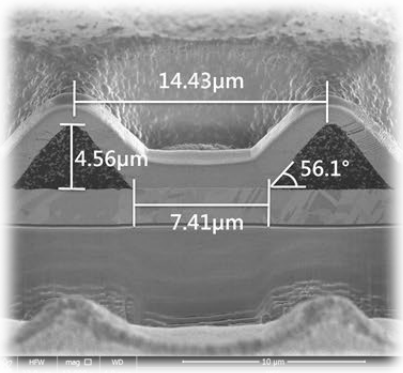
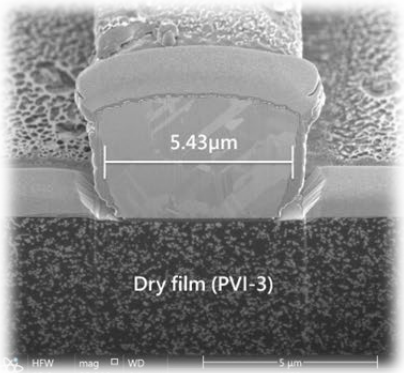


X'view of Build up Film (TAIYO)



Via size of PVI-3 by DLT





X'view of Trace on PVI-3

Items	This Tech.	Competitor
PID Type	Dry film	Dry film
Max. Process Temp.	180 ˚C	250ºC
PID Resolution	7 µm	10 µm

PID: Photo Image Dielectric

5. CONCLUSION

1: We have synthesized “the novel thermosetting PPE resin” and made low Dk/Df film by formulating the resin and other compounds.

2: The film showed lower Df compared to that of the existing epoxy film, especially at high temperature.

3: The film showed good physical property and process ability. The stacked substrate of the film showed good reliability, and strip line on the film showed lower transmission loss compared to that of the existing epoxy film.

- The film would be a good candidate for substrate film of high wavelength.

4: We have developed the photo type insulation film, which could be used for RDL and substrate.

Q & A

Logo of Affiliation