Low Df Build-up Material for High Frequency Signal Transmission of Substrates

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Research Institute for Bioscience Products & Fine Chemicals
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Today's Presentation

1. Brief company introduction of Ajinomoto
2. Ajinomoto Build-up Film (ABF)
3. Low Df build-up material for high speed transmission of PKG
    1. GXT31, GZ41 and GY11
    2. ABF with very thin Cu transfer film

Ajinomoto Co., Inc.

Ajinomoto Co., Inc.

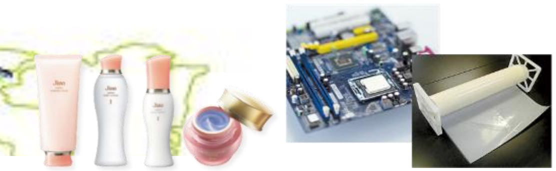
Bioscience Products & Fine Chemicals Division — Research Institute for Bioscience Products & Fine Chemicals — Functional Materials Group

R&D

Location ; Kawasaki-ku. Kawasaki-shi, Kanagawa

Foods

To become a global group of food companies centered on the world's No.1 seasoning business



Amino science (bioscience & fine chemical products)

To become a global company of Amino Science that contributes to humankind with the world's No. 1 amino acid technology.

Pharmaceuticals and Health

To become a group of health promoting companies with a scientific approach to good taste and health

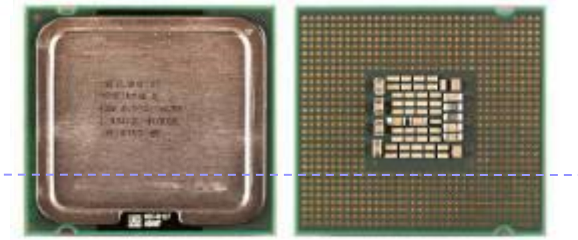
Ajinomoto Build-up Film (ABF)

ABF Application

Electronic Products

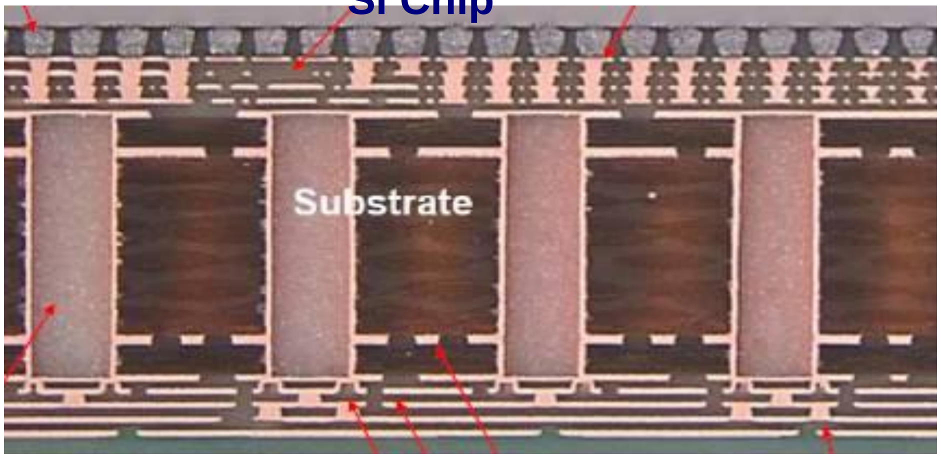
PCB

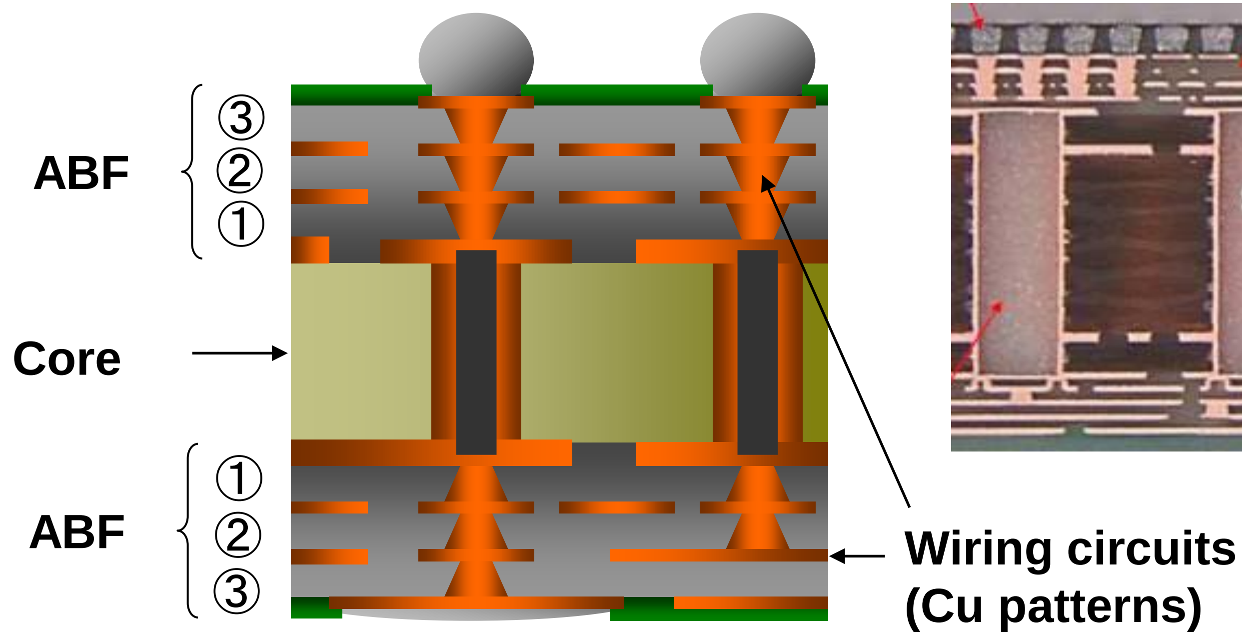
IC packages



Pkg Cross-section view

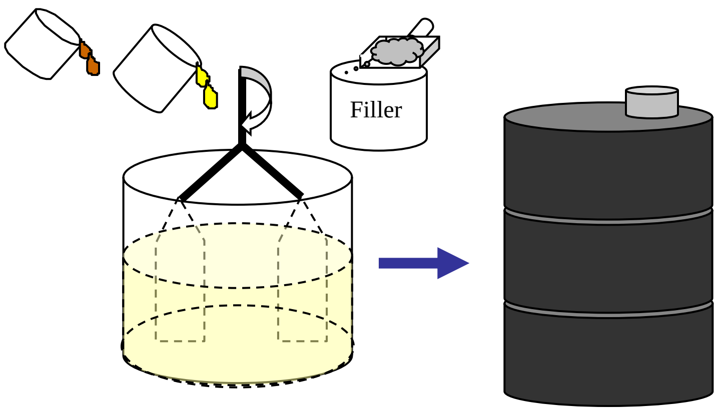
Si Chip





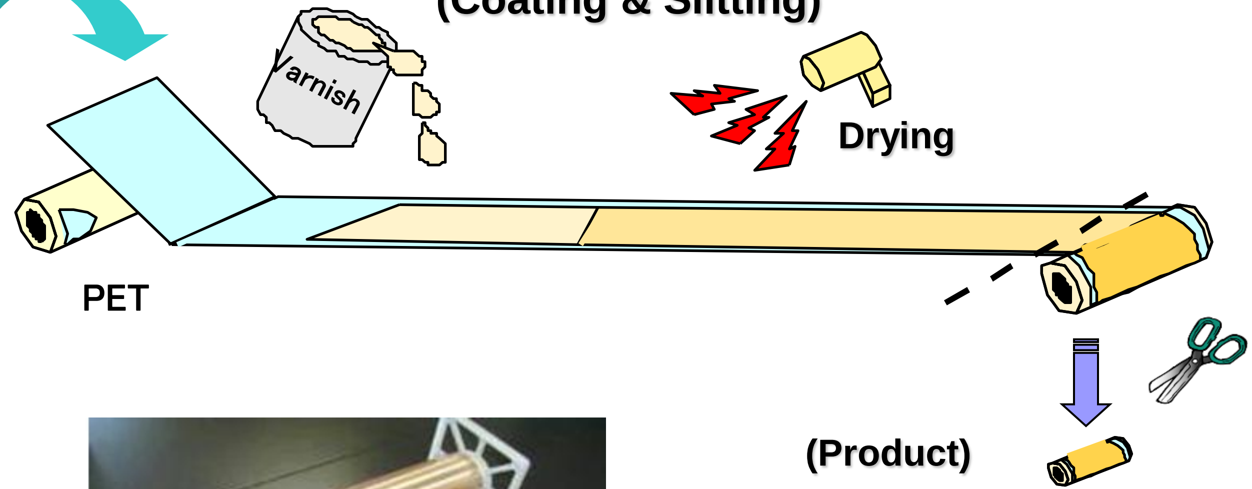
Outline of ABF production

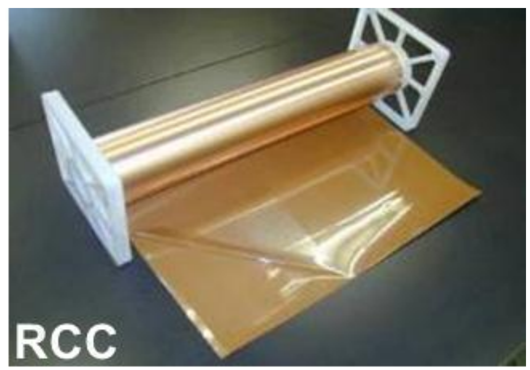
STAGE 1
(Varnish Production)

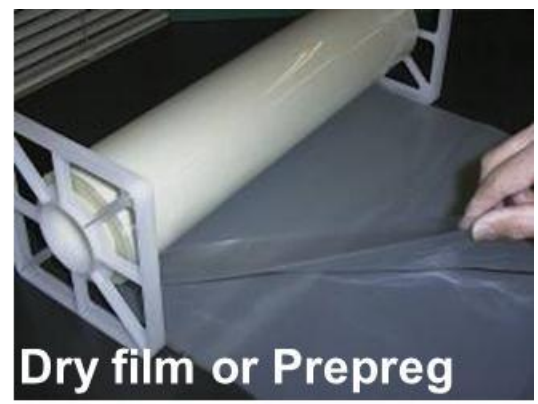


Mixing

STAGE 2
(Coating & Slitting)



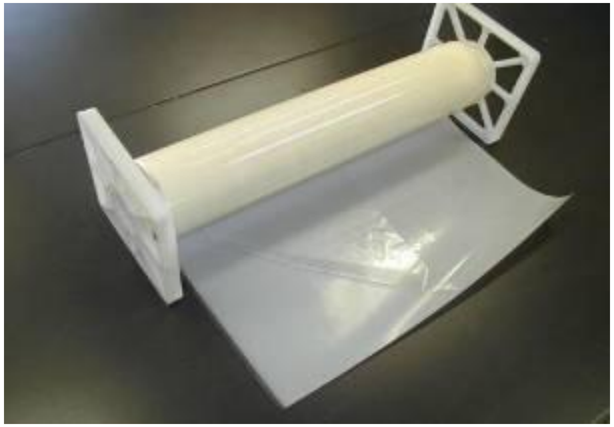




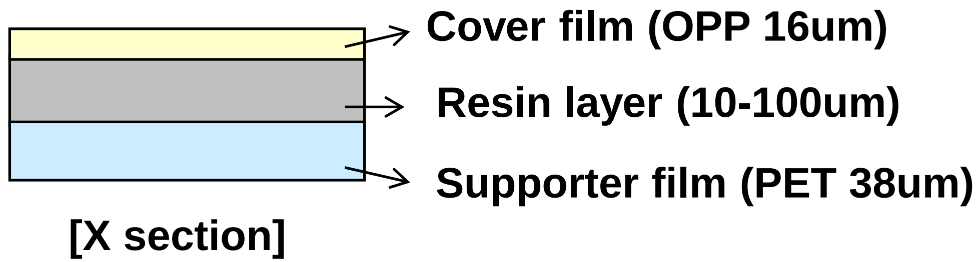
STAGE 3

QC/QA, Sales
& Technical service

ABF / Construction and Type



ABF : 3-layer construction



Roadmap of ABF

1999	2001	2003	2005-	2011-
ABF-SH →	ABF-SH9K →	ABF-GX3 →	ABF-GX13 →	ABF-GX92 →

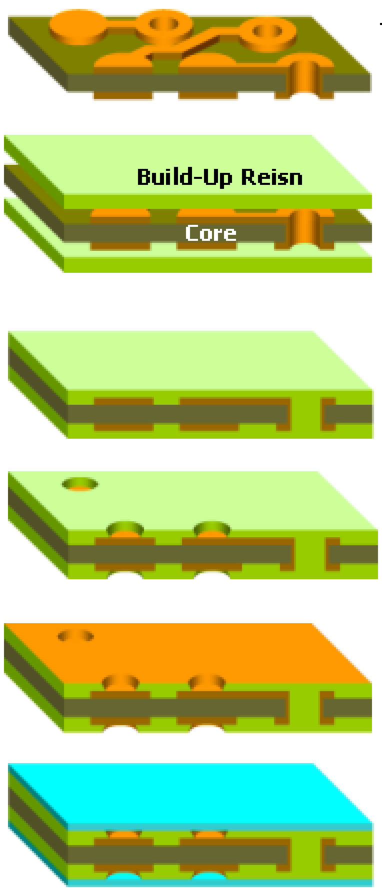
To get high insulation reliability

Halogen Free

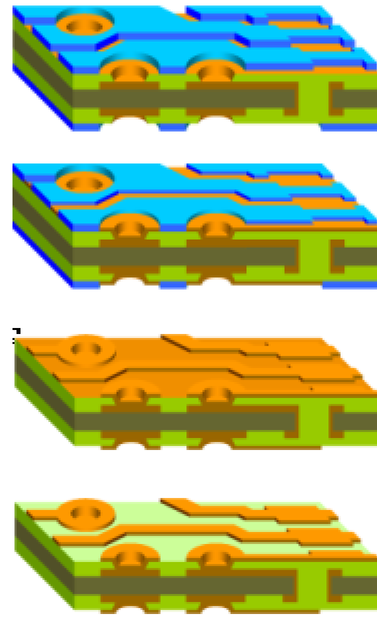
Lower CTE
⇒ narrower via pitch (Stacked) connection reliability

ABF has been improved with the progress of IC.

Outline of manufacturing substrate using ABF

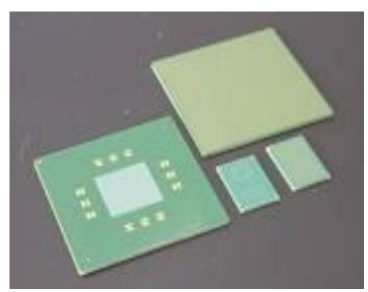


1. Preparation of core-boards Cu surface treatment & pre-drying (130-190degC*30min)
2. ABF placement on both side and vacuum lamination & metal hot-press
3. Pre-cure in a hot air clean over, 180degC*30min
4. Via formation by CO2 or UV-YAG laser
5. Desmear & E'ls Cu plating and drying (100-150degC*30min)
6. Dry Film lamination

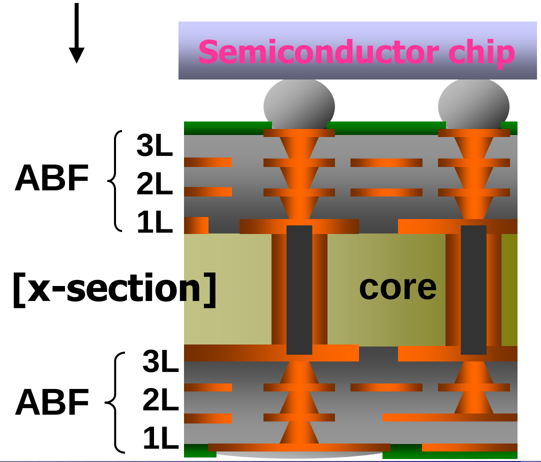


7. Dry Film patterning (exposure and development)
8. Electro Cu plating
9. Removal of Dry Film Pater formation by SAP (Semi-Additive Process)
10. Flash etching & annealing (Full-cure)

Repeat for multilayered BU

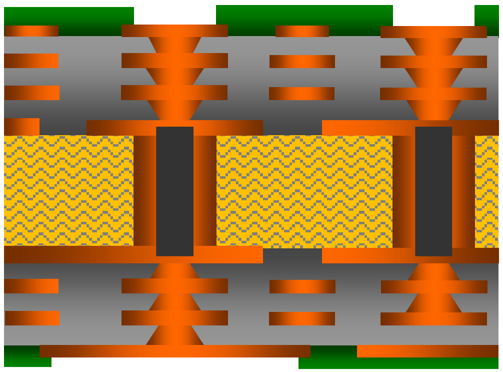


[package]

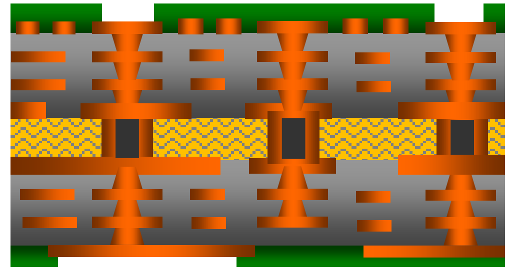


Next build-up material in demand

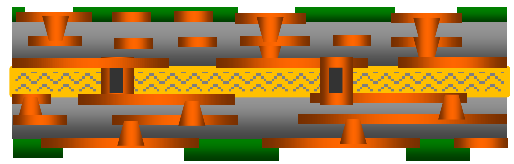
Current PKG structure



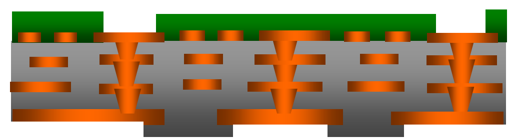
BGA



CSP



Coreless package



- Downsizing
  - Use thinner core
- High function
- High reliability

Demand for build-up material

- *Fine line & space (high adhesion strength with low roughness)*
- *Fine via pitch*
- *Low warpage during cure and reflow*
  - *Low CTE,*
- *High insulation reliability*
  (Layer to Layer, and circuit to circuit)

Next build-up material in demand

High functionalization of high-end equipment → High Frequency signal → **High transmission loss**
- Consumption of electronic signals

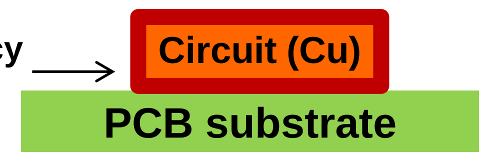
Transmission loss (α)
= Conductor loss(α_c) + Dielectric loss(α_d)

$\alpha_c \propto \varepsilon \times R_s(f)$

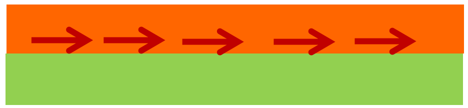
$\alpha_d \propto \sqrt{\varepsilon} \times f \times \tan\delta$

$R_s(f)$: Conductor surface resistance (frequency)
ε : Dielectric constant
$\tan\delta$: Dielectric loss tangent

High frequency signal →



Roughened surface
Low transmission because of high resistance at the interface of Cu and resin

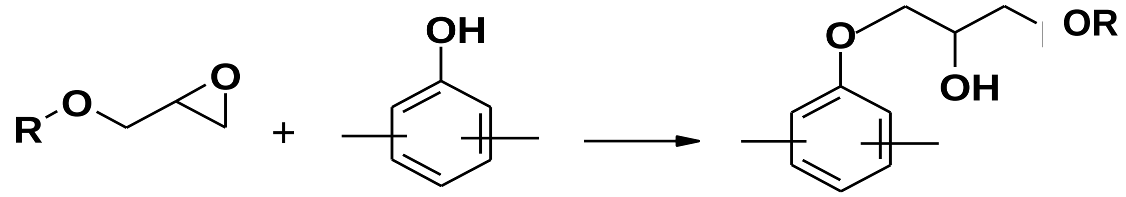


Smooth surface
High transmission because of low resistance at the interface.

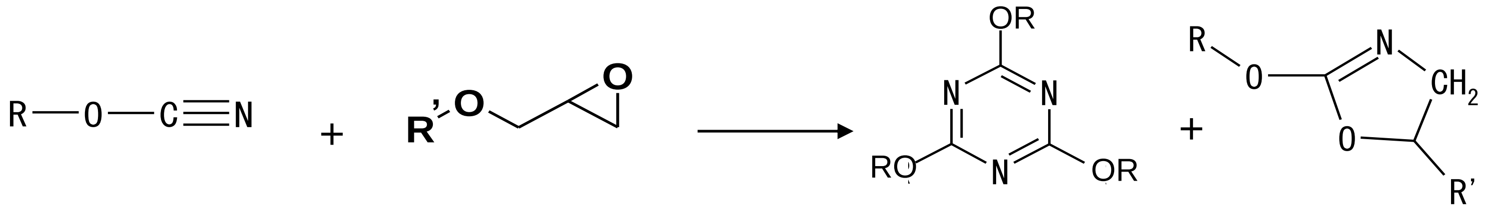
To reduce the transmission loss…

- *Low dielectric loss tangent (Df)*
- *Low dielectric constant (Dk)*
- *Low smooth surface at the interface between resin and conduct layer*
- *Good adhesion strength with smooth surface*
- *Thinner layer*

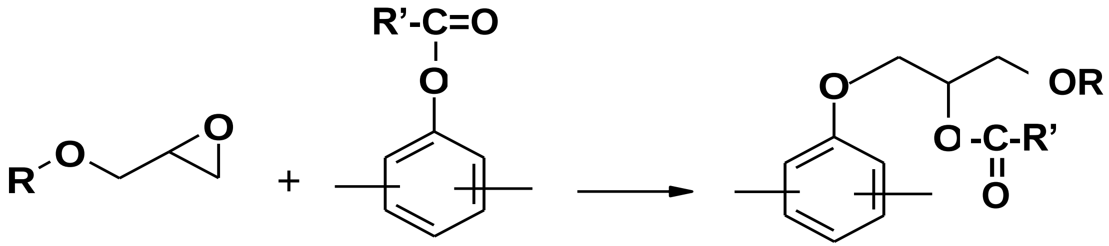
GX series (Epoxy & Phenol Hardener)



GZ series (Epoxy & Cyanate ester)

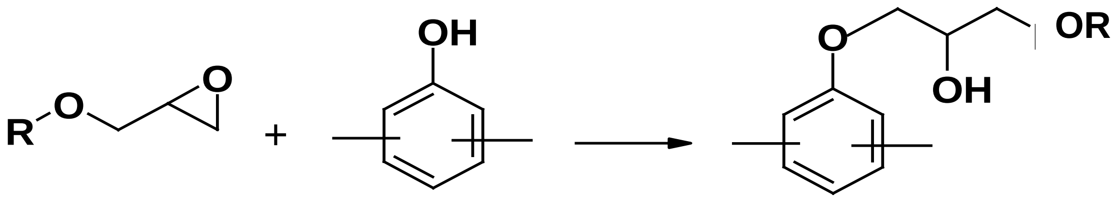


GY series (Epoxy & Phenolic Ester Hardener)



ABF-GX series: GX-T31

GX series (Epoxy & Phenol Hardener)

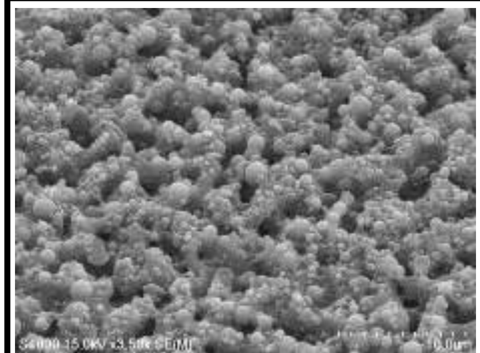
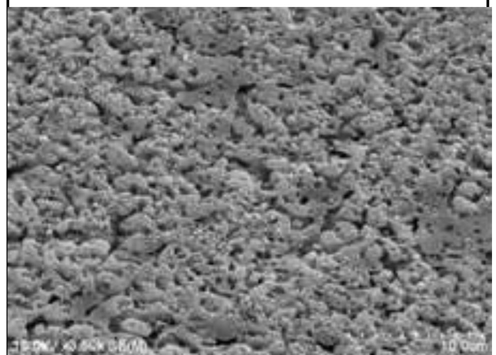
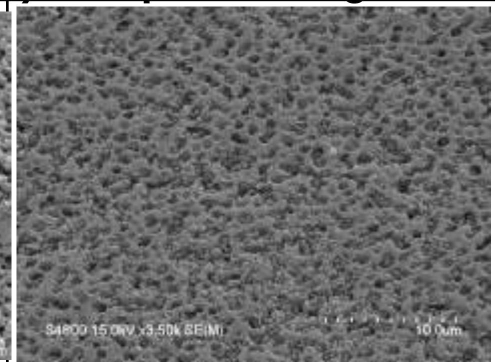


Test Condition		GX13	GX92	GX-T31
CTE x-y (ppm: 25-150degC) by tensile TMA		46	39	23
CTE x-y (ppm: 150-240degC) by tensile TMA		120	117	78
Tg (degC, by tensile TMA)		156	153	154
Tg (degC, DMA)		177	168	172
Young's modulus (GPa)	23 degC	4.0	5.0	7.5
Tensile strength (MPa)	23 degC	93	98	104
Elongation (%)	23 degC	5.0	5.6	2.4
Dielectric constant (Dk) (Cavity perturbation , 5.8GHz)		3.1	3.2	3.4
Dielectric loss constant (Df) (Cavity perturbation, 5.8GHz)		0.019	0.017	0.014
Water absorption 100degC,1h (wt%)		1.1	1.0	0.6
HAST L/S=15/15um (130degC, 85%, 3.3V)		200h<	200h<	200h<

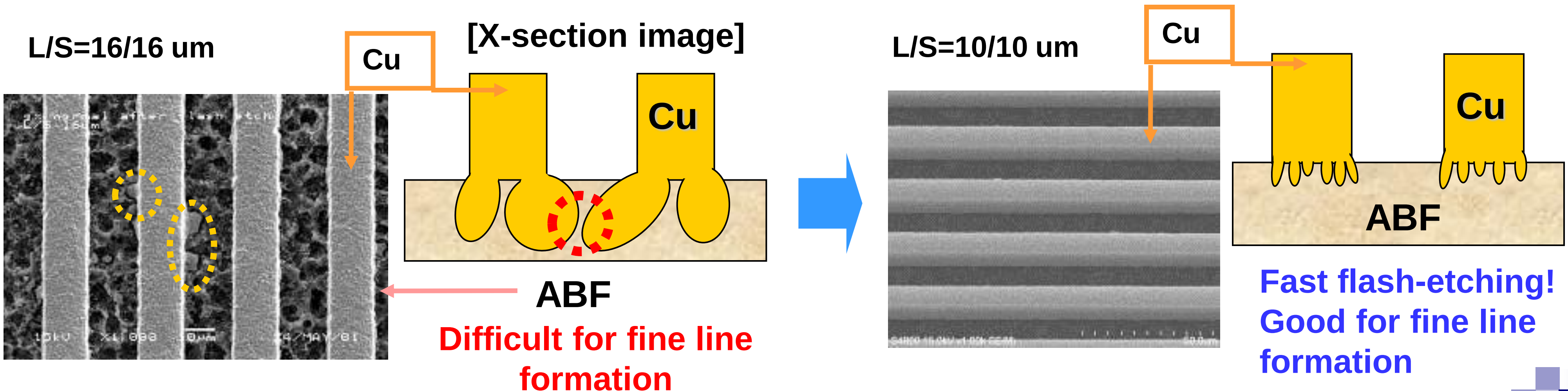
GX13:180deg.Cx90min curing, Others:190deg.Cx90min

- ***Lower CTE***
- ***Higher Young's Modulus***
- ***Lower Df***
- ***Lower water absorption***
- ***Good insulation reliability***

Smooth Surface for Fine Line Formation

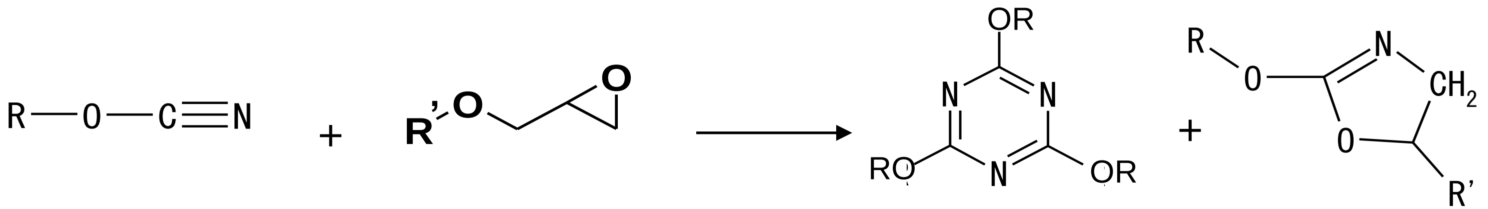
GX13	GX92	GX-T31
SEM of Resin Surface after Desmear (x3500) / Cu peel strength		
		
0.7-0.8kgf/cm	0.65-0.75kgf/cm	0.6-0.7kgf/cm

The key of fine line formation is to lower profile (smooth surface) with keeping high peel strength.



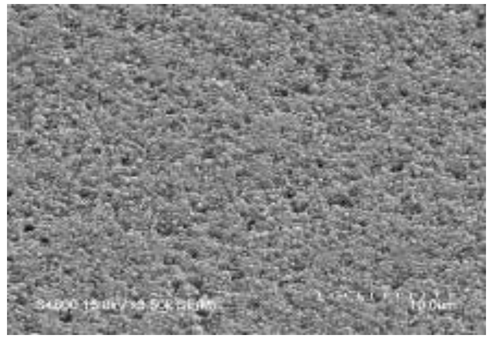
ABF-GZ series : GZ-41

GZ series (Cyanate ester & Epoxy)



Test Condition		GZ22	GZ41
CTE x-y (ppm: 25-150degC) (tensile TMA)		31	20
CTE x-y (ppm: 150-240degC) (tensile TMA)		82	67
Tg (degC, tensile TMA)		165	176
Tg (degC, DMA)		192	198
Young's modulus (GPa)	23 degC	6.4	9.0
Tensile strength (MPa)	23 degC	116	120
Elongation (%)	23 degC	3.2	1.7
Dielectric constant (Dk) (Cavity perturbation , 5.8GHz)		3.2	3.3
Dielectric loss constant (Df) (Cavity perturbation, 5.8GHz)		0.011	0.0074
Water absorption 100degC,1h (wt%)		0.6	0.5
HAST L/S=15/15um (130degC, 85%, 3.3V)		>200h	>200h

SEM of Resin Surface after Desmear

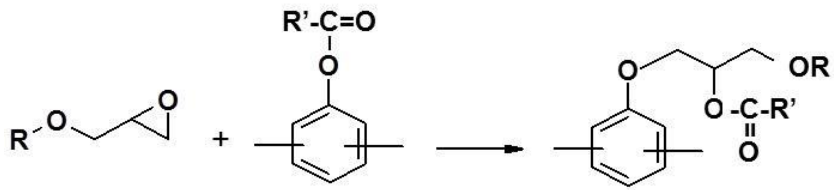


x3500

GZ41: Peel strength 0.55kgf/cm

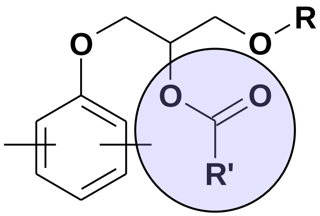
ABF-GY-series: GY11

GY series (Epoxy & Phenolic Ester Hardener)



Test Condition		GZ41	GY11
CTE x-y (ppm: 25-150degC) (tensile TMA)		20	26
CTE x-y (ppm: 150-240degC) (tensile TMA)		67	81
Tg (degC, tensile TMA)		176	155
Tg (degC, DMA)		198	165
Young's modulus (GPa)	23 degC	9.0	8.9
Tensile strength (MPa)	23 degC	120	115
Elongation (%)	23 degC	1.7	3.2
Dielectric constant (Dk) (Cavity perturbation , 5.8GHz)		3.3	3.2
Dielectric loss constant (Df) (Cavity perturbation, 5.8GHz)		0.0074	0.0042
Water absorption 100degC,1h (wt%)		0.5	0.2
HAST L/S=15/15um (130degC, 85%, 3.3V)		>200h	>200h

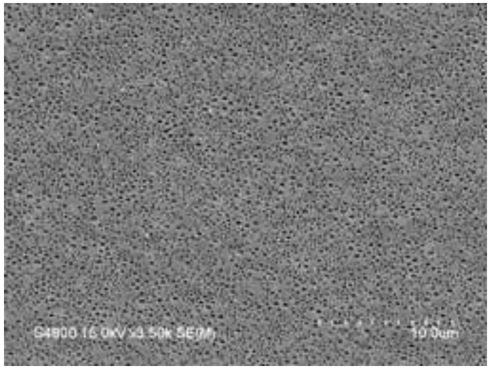
190deg.Cx90min Curing



Lower Polarization

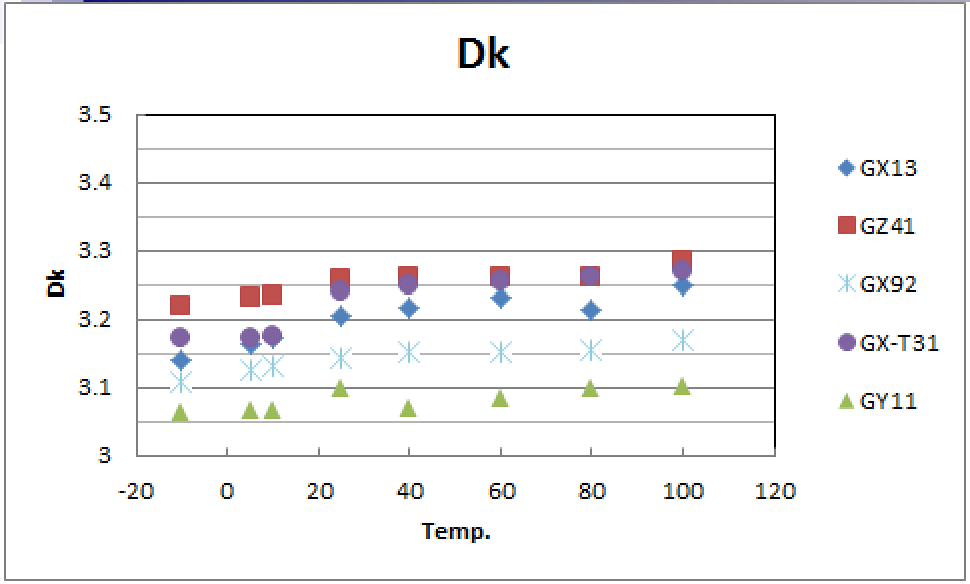
[SEM of Resin Surface after Desmear]

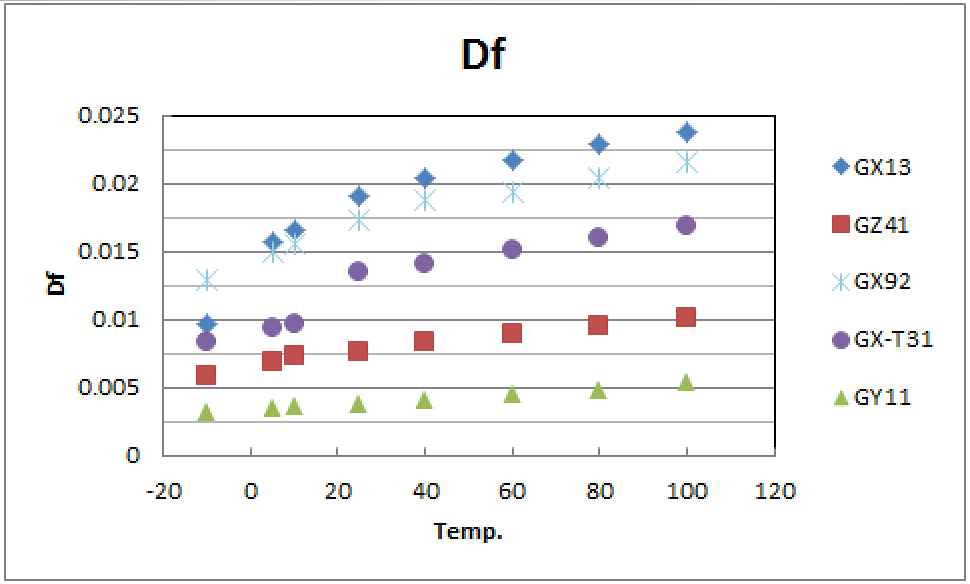
GY11: Peel 0.54kgf/cm



x3500

Temp. dependency on Dk & Df (@10GHz) of ABF(40um)





ABF	Temp./degC	-10	5	10	25 (r.t.)	40	60	80	100
GX13	Dk	3.14	3.16	3.17	3.21	3.22	3.23	3.21	3.25
	Df	0.0096	0.0158	0.0166	0.0190	0.0204	0.0217	0.0230	0.0238
GZ41	Dk	3.22	3.23	3.24	3.26	3.26	3.26	3.26	3.28
	Df	0.0059	0.0069	0.0072	0.0076	0.0083	0.0090	0.0095	0.0102
GX92	Dk	3.11	3.13	3.13	3.14	3.15	3.15	3.16	3.17
	Df	0.0129	0.0150	0.0155	0.0173	0.0187	0.0194	0.0204	0.0216
GX-T31	Dk	3.17	3.17	3.18	3.24	3.25	3.25	3.26	3.27
	Df	0.0083	0.0094	0.0097	0.0135	0.0141	0.0151	0.0159	0.0169
GY11	Dk	3.06	3.07	3.07	3.10	3.07	3.08	3.10	3.10
	Df	0.0032	0.0035	0.0036	0.0039	0.0040	0.0045	0.0048	0.0054

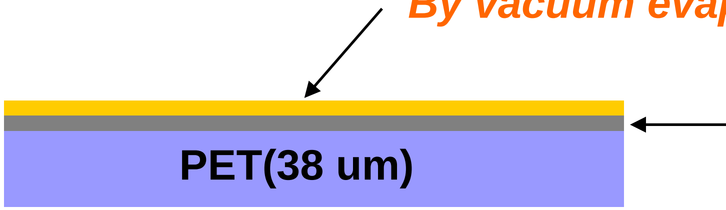
ABF with very thin Cu transfer film (ABF-RCC)

High Adhesion without Anchor Effect

Very *Thin Cu Transfer Film* with ABF

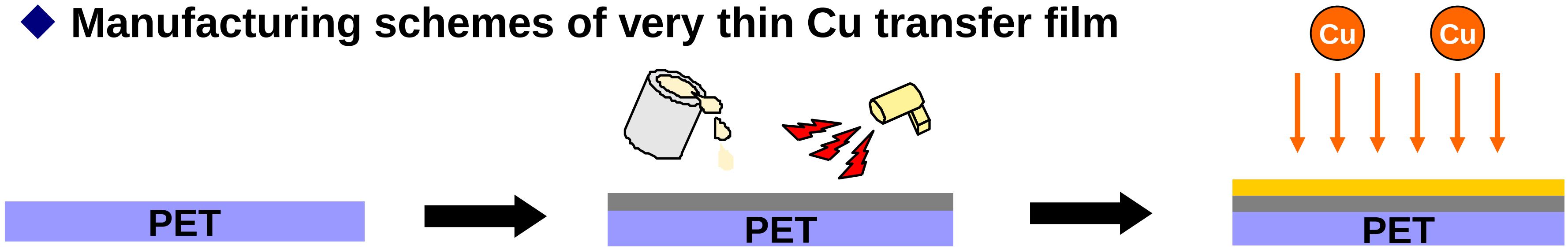
◆ Construction

Thin Cu (0.1～2 um)
By vacuum evaporation or sputtering



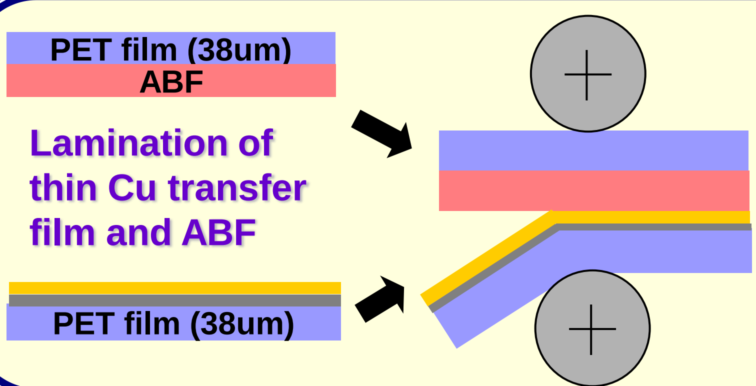
Alkaline-soluble resin Layer
(release layer, 1 um)
Key point for the uniform Cu transfer

◆ Manufacturing schemes of very thin Cu transfer film



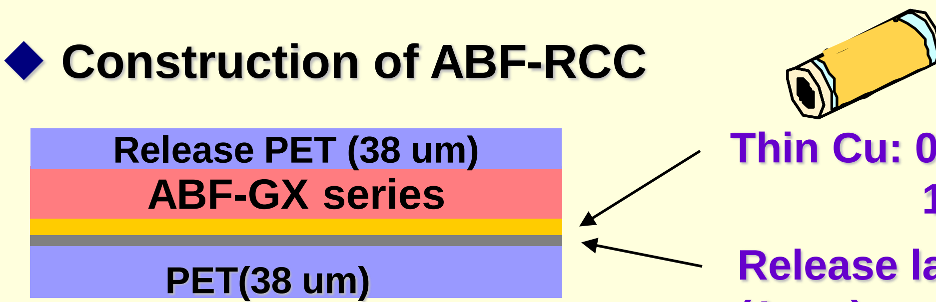
Coating & Drying of alkaline-soluble resin

Cu Deposit by vacuum evaporation or sputtering



Lamination of thin Cu transfer film and ABF

◆ Construction of ABF-RCC

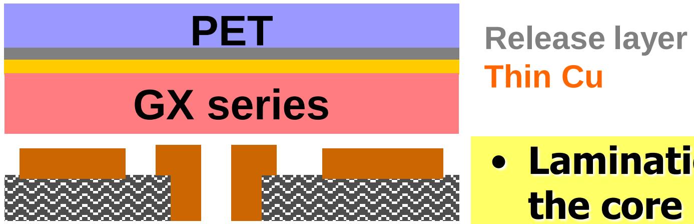


Thin Cu: 0.25
1 um

Release layer
(1 um)

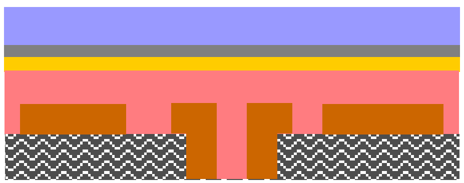
Process using ABF-RCC

*) *One side of the core is shown by space restrictions*

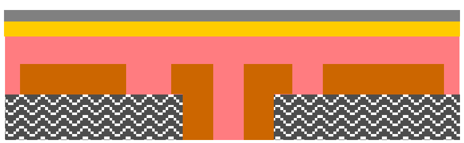


Core pattern

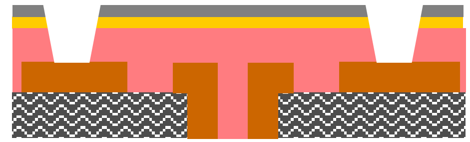
- **Lamination ABF-RCC on the core board**
  Vacuum lamination or ***Vacuum hot press***
- **Curing (100deg.Cx30min & 180deg.Cx30min)**



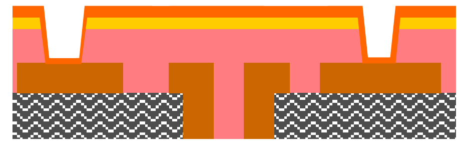
- **Removal of PET**



- **Direct Laser drilling**

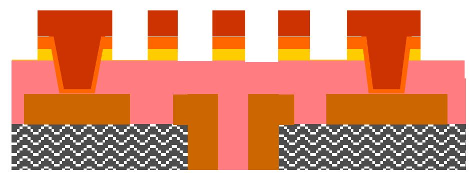


- **Desmear**
- **E-less Cu plating**



Thin Cu prevents desmear solution from roughening the resin surface.

- **Patterning (Semi-additive or Fine-subtractive)**



- ***Thin Cu prevents desmear solution from roughening the resin surface.***
  - **No damage of the resin surface by desmear**
- ***High adhesion to thin Cu without anchor effect***
  - **Ultimately low roughness and high adhesion**
- ***Easy fine line formation***

ABF GX series for thin Cu transfer film

Test Condition		GX92	GX-T31	GX-E4	GX-E5
CTE x-y (ppm: 30-80degC) (tensile TMA)		26	13	8	7
CTE x-y (ppm: 25-150degC) (tensile TMA)		39	23	12	10
CTE x-y (ppm: 150-240degC) (tensile TMA)		117	78	34	29
Tg (degC, tensile TMA)		153	154	156	196
Tg (degC, DMA)		168	172	180	212
Young's modulus (GPa)	23 degC	5.0	7.5	13	17.0
Tensile strength (MPa)	23 degC	98	104	98	106
Elongation (%)	23 degC	5.6	2.4	0.8	0.8
Dielectric constant (Cavity perturbation , 5.8GHz)		3.2	3.4	3.4	3.3
Loss tangent (Cavity perturbation, 5.8GHz)		0.017	0.014	0.0093	0.0073
Water absorption 100degC,1h (wt%)		1.0	0.6	0.4	0.4
Comment		-	Low CTE	Low CTE	Low CTE High Tg

GX-E4, E5

- ***Low CTE***
- ***Low dielectric loss tangent***
- ***High Tg (E5)***

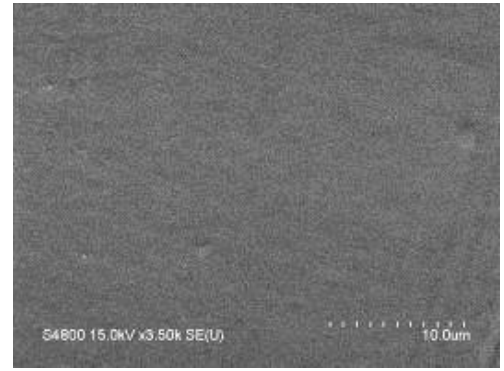
Cu Adhesion of GX-E4, E5 with *Thin Cu Transfer Film*

Pre-cure
- GX-E4: 100degCx30min + 180degCx30min
- GX-E5: 100degCx30min + 170degCx30min

Full-cure: 190degCx60min

Properties		GX-E4	GX-E5
Peel strength for Seed process (kgf/cm)	After Full-cure	0.70	0.65
	After HAST 100h	0.50	0.45
	Reliability for 10 times reflow tests	No blister	No blister

SEM image of resin surface after Cu etching

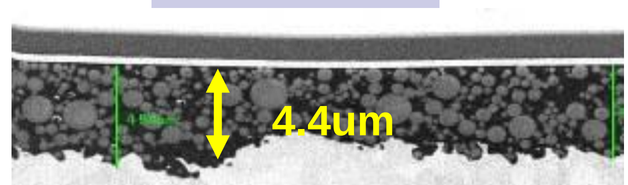


(Peak temp. 262degC)

GX-E4: Thin Film HAST Reliability (130degC, 85%RH, 3.3V DC)

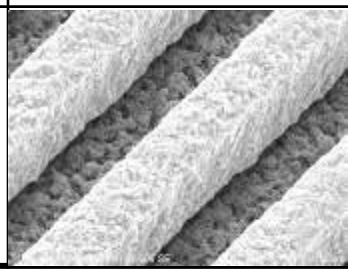
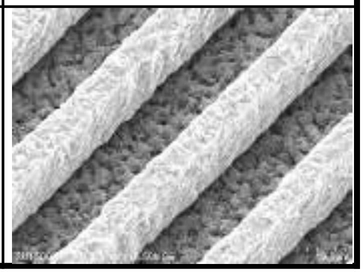
	0h	50h	100h	150h	200h
1	6.53E+09	1.24E+10	1.49E+10	1.66E+10	5.01 E+08
2	9.15E+10	2.53E+11	1.22E+11	9.46E+10	7.80E+10
3	2.99E+11	1.70E+11	6.68E+10	1.99E+10	5.51 E+11
4	1.58E+11	4.09E+11	1.05E+11	4.88E+10	7.94E+09
5	5.73E+11	1.49E+11	5.71 E+11	1.02E+11	3.91 E+11
6	5.68E+11	3.05E+11	5.53E+11	2.53E+11	9.46E+10

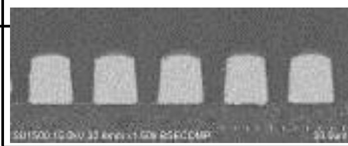
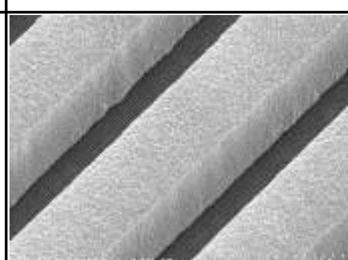
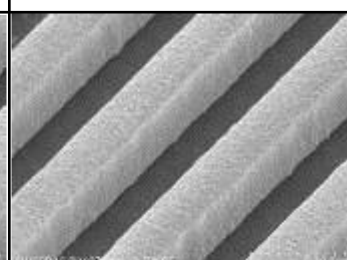
X-sectional view

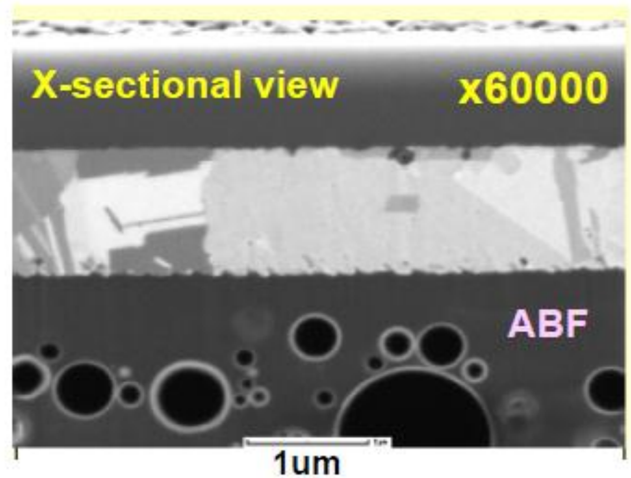


- **No desmear damage led good insulation reliability.**

Fine Line Formation & Surface Comparison / GX92

Desmear SAP DFR Pitch (L/S)	16(6/10)	12um (5/7)
X-section / x1500		
Cu L/S (um)	9.2/7.0	3.3/8.9
Cu height (um)	13.0	8.4
Over view / x3.5k		

Thin Cu Process DFR Pitch (L/S)	16(6/10)	12um (5/7)
X-section / x1.5k		
Cu L/S (um)	10.0/6.3	5.0/6.8
Cu height (um)	12.2	9.9
Over view / x3500		



Very flat surface makes easy to make fine L/S!

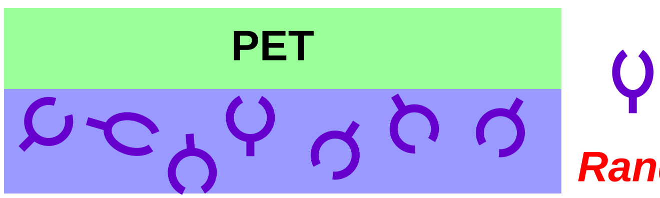
No desmear damage leads the better insulation reliability.

Mechanism of high adhesion strength

[Cure with thin Cu transfer film]

Thin Cu works for self-assembly of specific bonds on the resin surface and as a protective layer against desmear.

Coordination compounds
= aromatic, elements with lone-pair



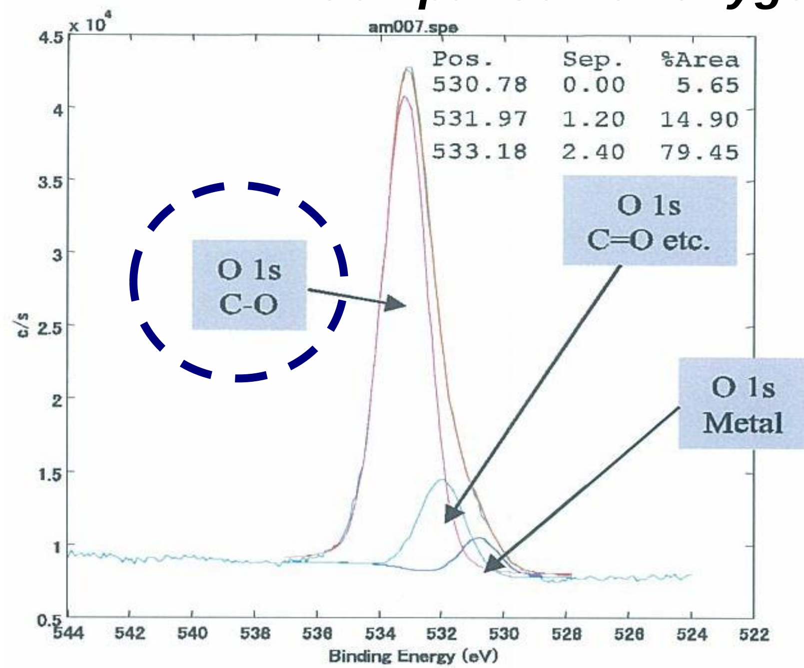
Randomly arranged.

[normal cure]

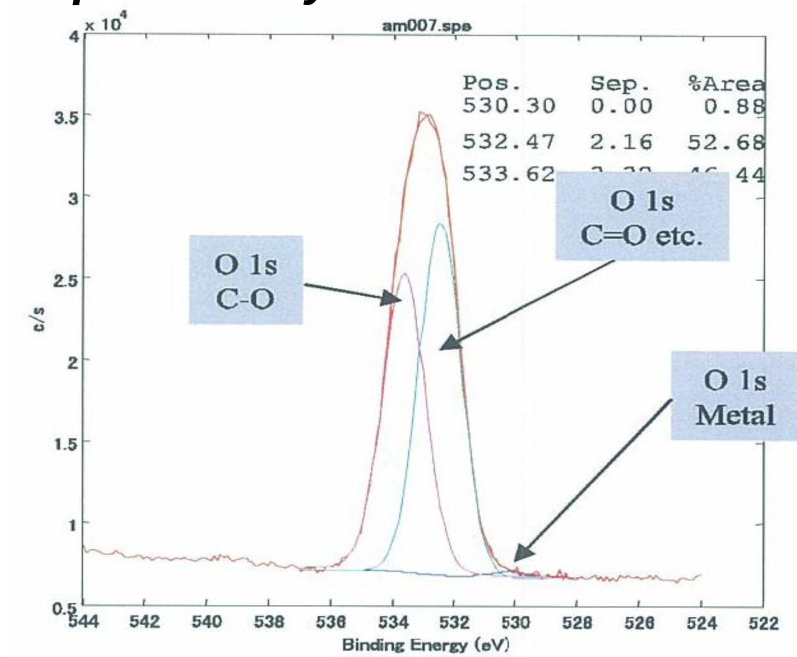
- **Some specific chemical groups in the resin composition are enriched at the thin Cu side during curing and they bind Cu to produce coordinate bond and covalent bond. Hence, the self-assembly of these chemical bonds on the surface leads the high adhesion strength.**
- → ***High peel strength without an anchor effect!***

O1s XPS analysis on resin surface after cure w/ or w/o Cu

Comparison of Oxygen-narrow spectrum by XPS



w/ thin copper



w/o thin copper

Proportion of each Oxygen-bond

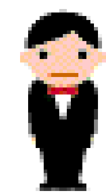
Condition	unit	C-O	C=O etc.	O-Metal
Cure without thin copper	atomic %	46.44	52.68	0.88
Cure with thin copper		79.45	14.9	5.65

- **C-O bond such as ether or ester alcohol on the resin surface cured with thin copper were observed more than that cured without copper.**

Summary

- Build-up material for high speed transmission PKG
  - Low Df
    - GX-T31, GZ41 and GY11
  - Smooth interface between Cu and resin and low CTE
    - ABF with thin Cu transfer film, GX-E4, E5

Thank you !



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