Adhesion Considerations in Designing Dielectric Materials for Advanced Packaging Applications

Michaela Connell, Stephanie Dilocker, Ognian Dimov, Sanjay Malik

Fujifilm Electronic Materials U.S.A., Inc., North Kingstown, RI,USA

Outline

- *Background: Materials' Requirements for Advanced Packaging Applications*
- *Impact of Polymer Functional Group on Adhesion*
- *Role of Adhesion Promoter*
- *Reliability Studies*
- *Resolution*
- *Summary*

FUJIFILM

Dielectric Material Requirements for Advanced Packaging

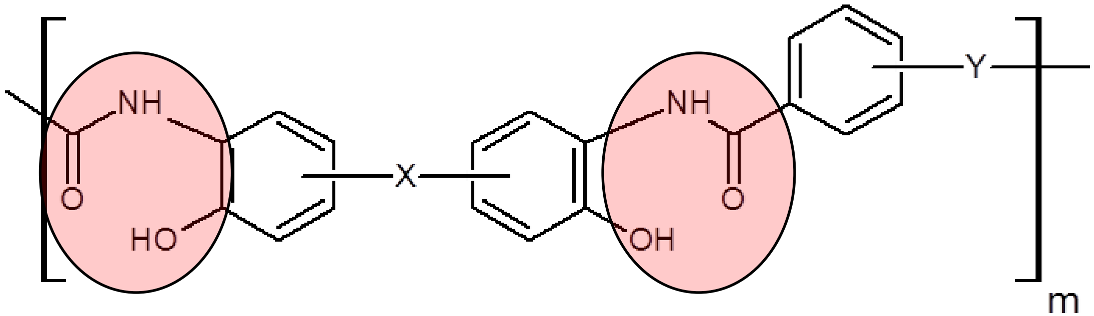
- *Low Thermal Shrinkage*
- *Low Temperature Cure*

Low residual stress and warpage control

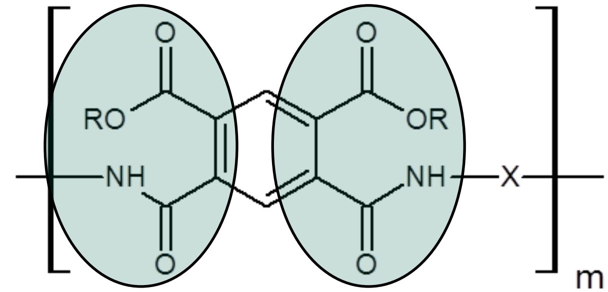
- *Good Thermal, Mechanical, and Overall Film Properties*
- *Rheological Properties – to improve planarization*
- *Multiple Patterning Options – improved resolution to ensure scalability*

Good adhesion to multiple substrates is key for enhanced reliability

Adhesion Considerations in Typical Organic Dielectric Materials

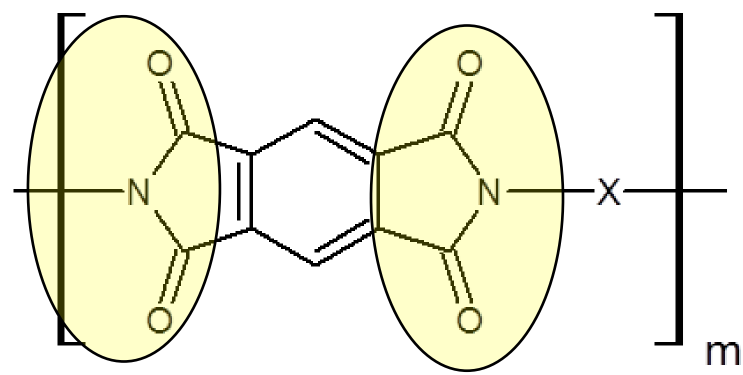


Polybenzoxazole (PBO) Precursor



Polyamic acid/ester (PI) Precursor

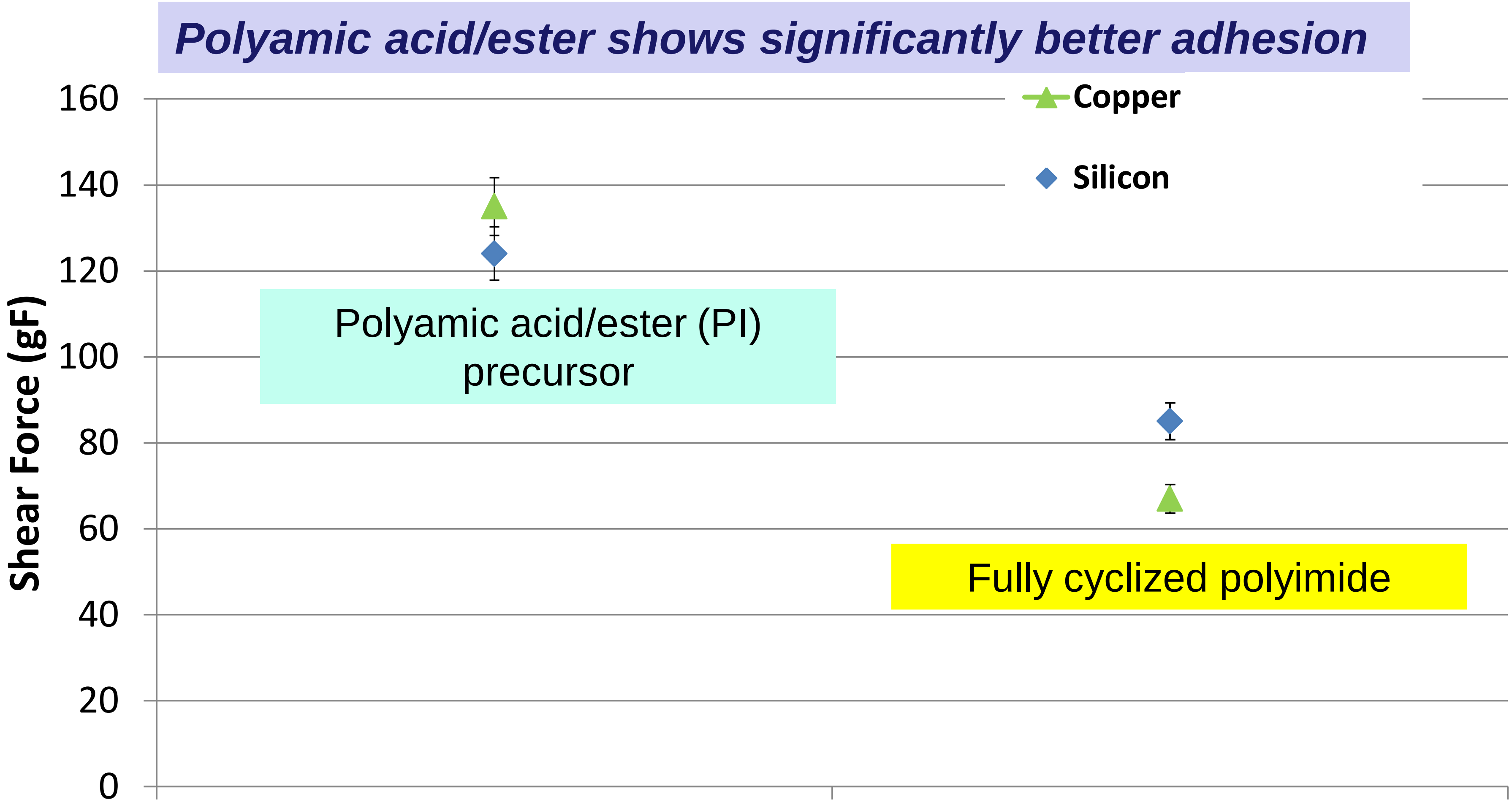
Highly polar functional groups of PBO precursor and Polyamic acid/ester (PI precursor) useful for anchoring to enhance adhesion with substrate



Fully Cyclized Polyimide

Adhesive properties of fully cyclized polyimide?

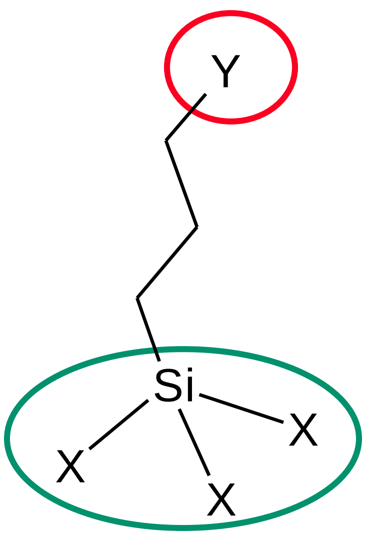
Impact of Polymer Functionality on Adhesion



Can an adhesion promoter be used to improve adhesion of the fully cyclized polyimide?

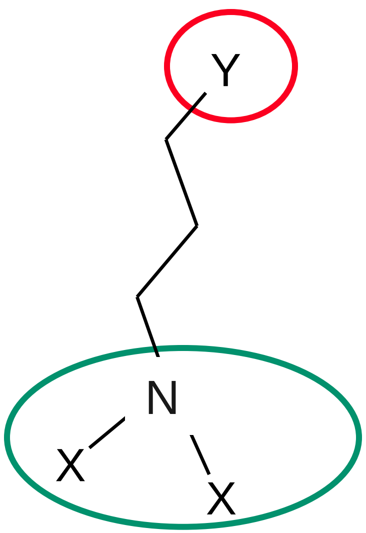
Improving Polymer Adhesion: Role of Adhesion Promoter

Polymer adhesion to substrates can be quite complex but typically occurs by chemical and/or physical interaction of adhesion promoter with both polymer and substrate.



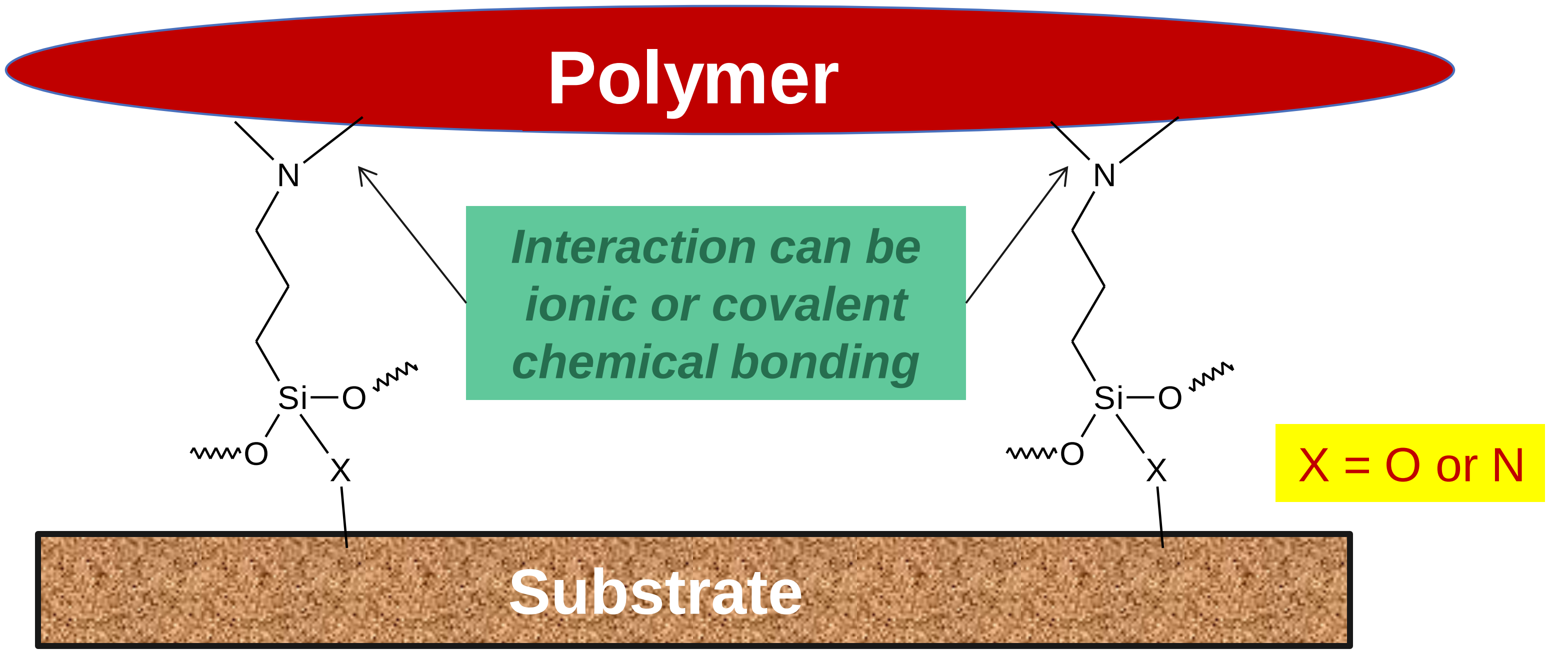
Polymer-reactive/interactive functional group

Substrate-reactive/interactive functional group



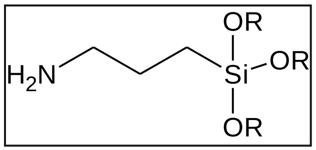
Mechanism of Adhesion

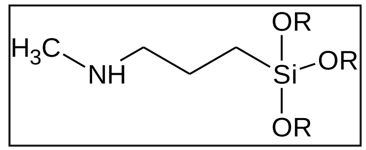
- *Adhesion promoter connects polymer to substrate through chemical bonds with reactive groups on alternate ends of adhesion promoter.*

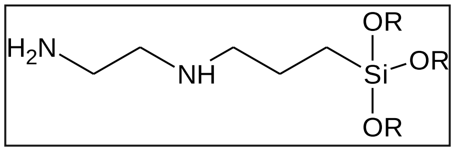


Adhesion Promoter Examples

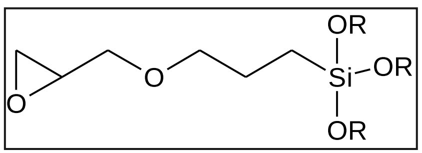
Type 1

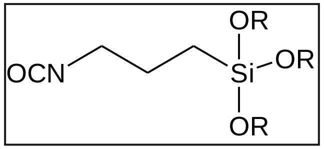


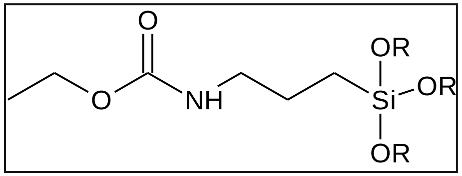


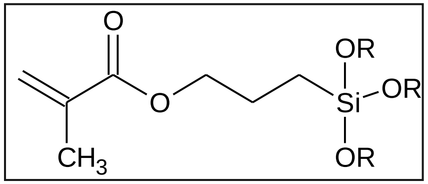


Type 2

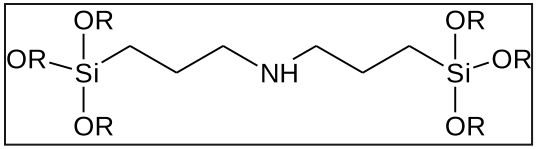


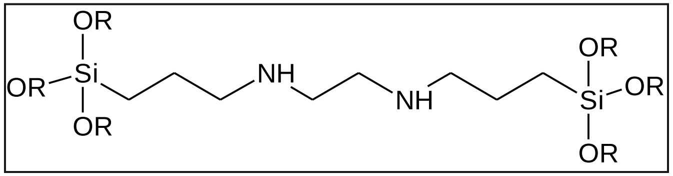


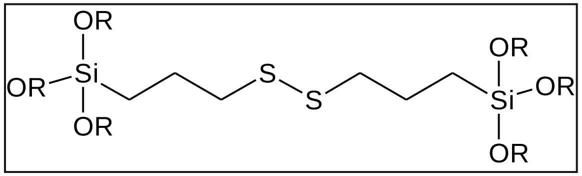




Type 3

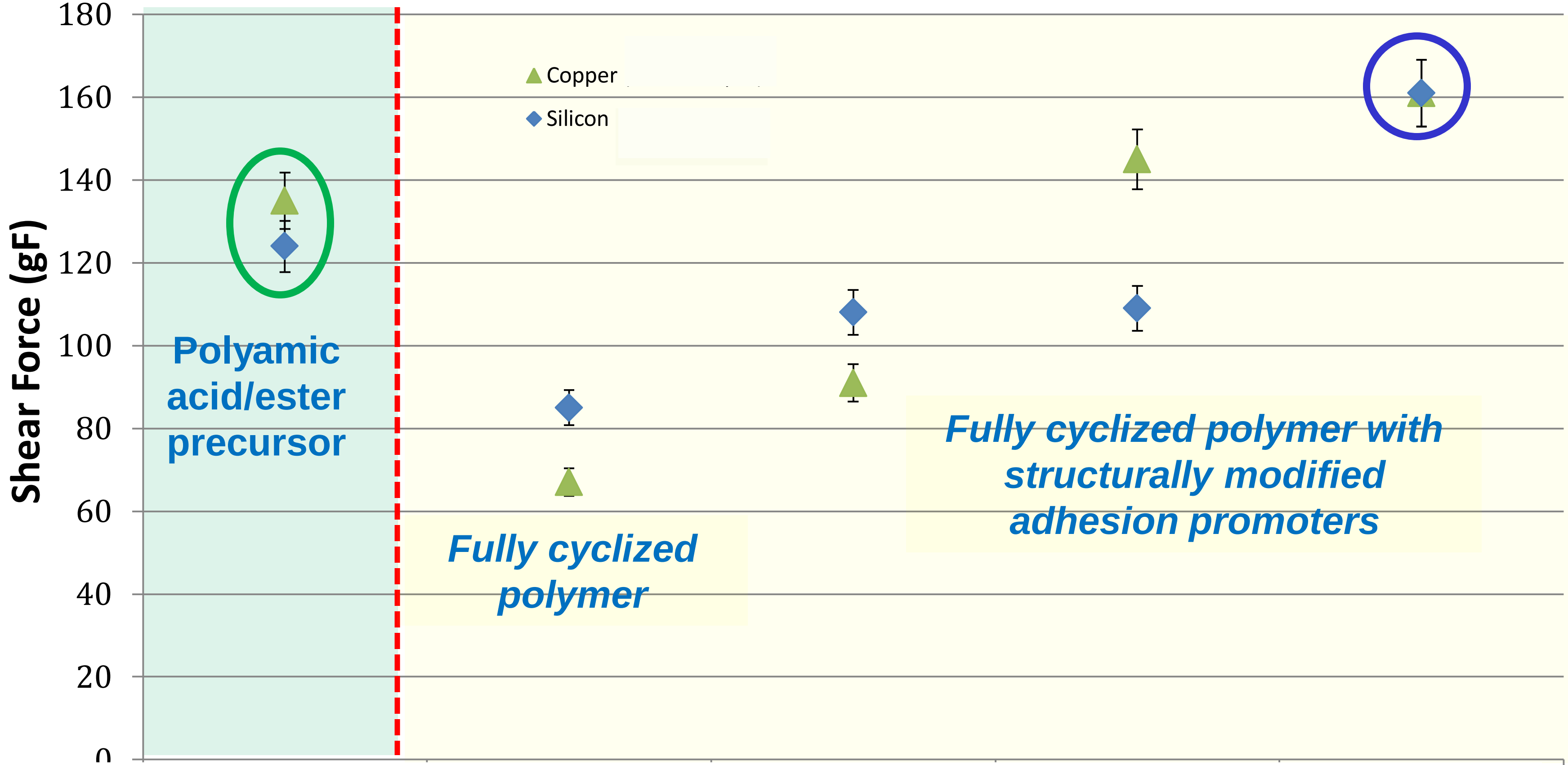






FUJIFILM Electronic Materials

Improving Polymer Adhesion via Adhesion Promoter



Improved adhesion could be achieved using structurally modified adhesion promoters

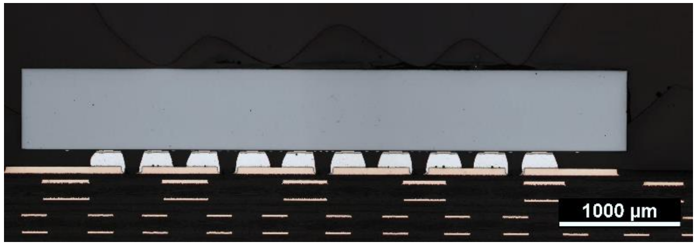
Impact of improved adhesion on reliability

FUJIFILM

Board Level Reliability Data: Summary

- **Drop Test**

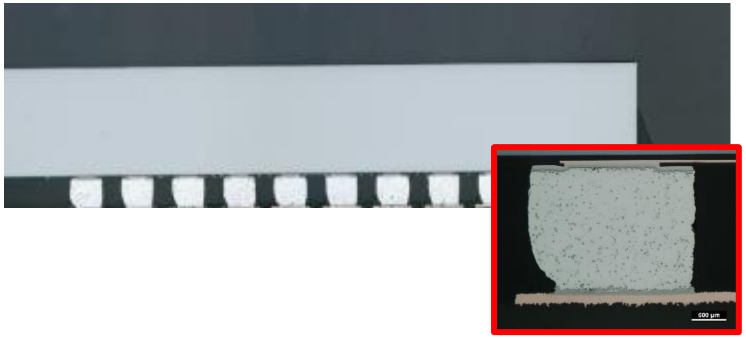
Under Fill	Chip Size
	5X5 mm^2
No	10/10 Chips (100%)
Yes	10/10 Chips (100%)



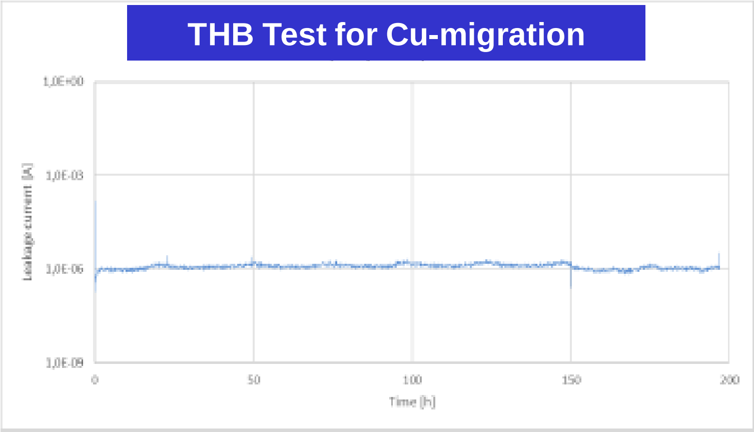
No electrical failure detected. No open daisy chain structure or voiding in solder bumps observed in cross section

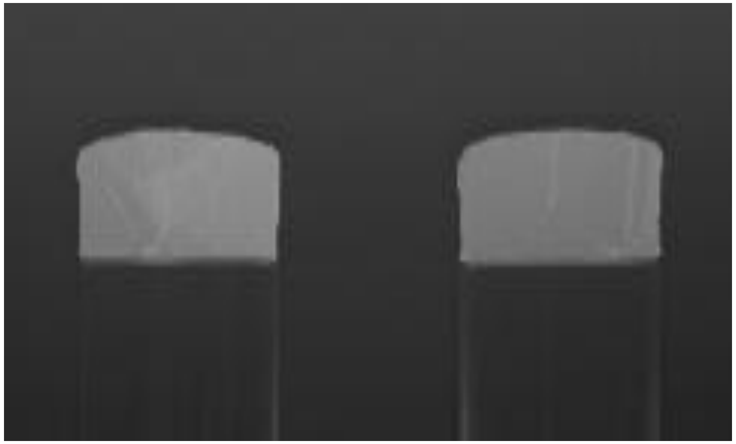
- **TCT ([-55 °C / +125 °C)**

Under Fill	Chip Size
	5X5 mm^2
Yes	10/10 Chips (100%) 500 cycle



THB Inline Leakage Current Measurement (after 196 hours of Storage)





Voltage: 5V

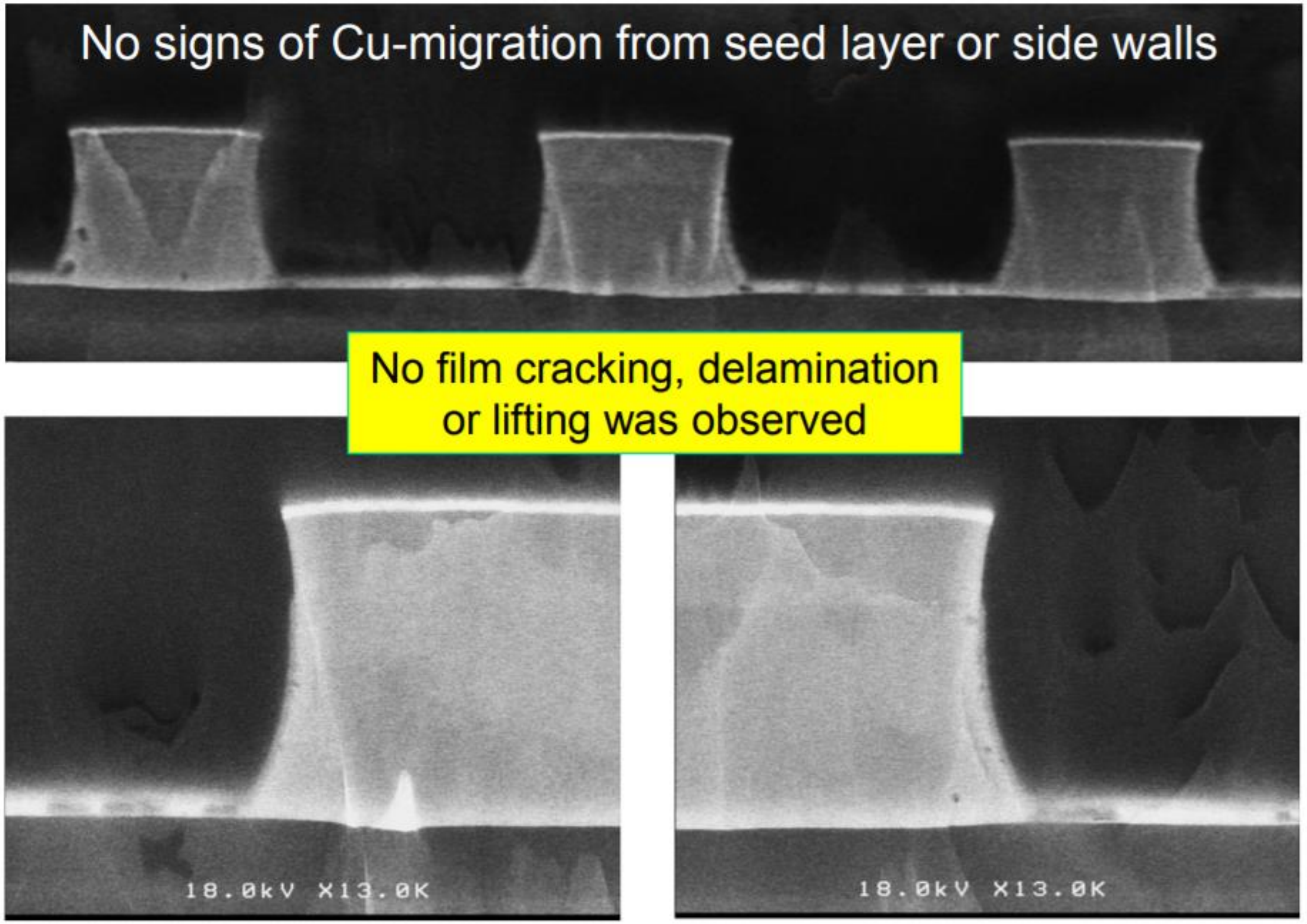
10 um L/S 5um high

Interdigital electrode area 2 x 14.65 mm

Temperature: 85˚C/ RH:85%

- *Material was processable on copper inter-dielectric electrodes*
- *without any copper attack or corrosion*
- *Sample showed no corrosion of the copper after the biased storage. No evidence of dendrite*
- *Leakage current was stable during the storage of 196 hours*

Cross Sectional SEM Analysis after 1000 Hours of HTS (150°C)



FUJIFILM

Dielectric Material Requirements for Advanced Packaging

- ❑ *Low Thermal Shrinkage*
- ❑ *Low Temperature Cure*

Low residual stress and warpage control

- ❑ *Good Thermal, Mechanical and Overall Film Properties*
- ❑ *Rheological Properties – to improve planarization*
- ❑ *Multiple Patterning Options – improved resolution to ensure scalability*

Good adhesion to multiple substrates is key for enhanced reliability

Overall Film Properties (Cured at 170°C/2 hrs.)

CTE (50 ~ 125˚C)	60 ppm/˚C
Young Modulus (room temperature)	3.3 GPa
Poisson ratio	0.4
Residual Stress, MPa	13
Elongation-to-break	60%
Tg (DMA by storage modulus)	247˚C
Thermal stability	2% weight loss: 315˚C 5% weight loss: 390˚C
Thermal Shrinkage (Post 170˚C cure)	<5%
Moisture uptake (80%RH/80˚C)	0.97%
Dielectric constant/Dielectric loss (1-20 GHz)	2.8/0.02
Leakage current (Before and after 250 hrs. THB)	< 1.0E-06Å
Peel strength	1.3KgF/cm (Before HAST) 0.6KgF/cm (after 500 hours HAST)

FUJIFILM

Dielectric Material Requirements for Advanced Packaging

- *Low Thermal Shrinkage*
- *Low Temperature Cure*

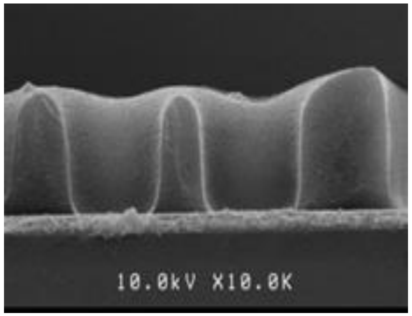
Low residual stress and warpage control

- *Good Thermal, Mechanical and Overall Film Properties*
- *Rheological Properties – to improve planarization*
- *Multiple Patterning Options – improved resolution to ensure scalability*

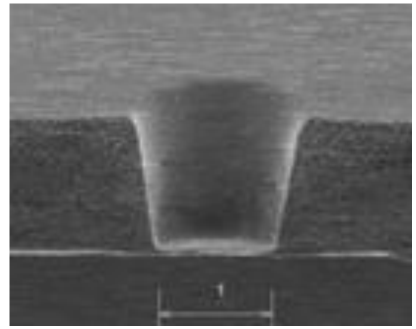
Good adhesion to multiple substrates is key for enhanced reliability

Resolution Capability

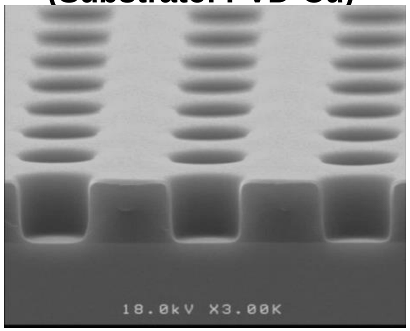
1.9 µm Vias in 5µm Film
E=150 mJ/cm² (0.18 NA i-Line)
(Substrate: PVD-Cu)

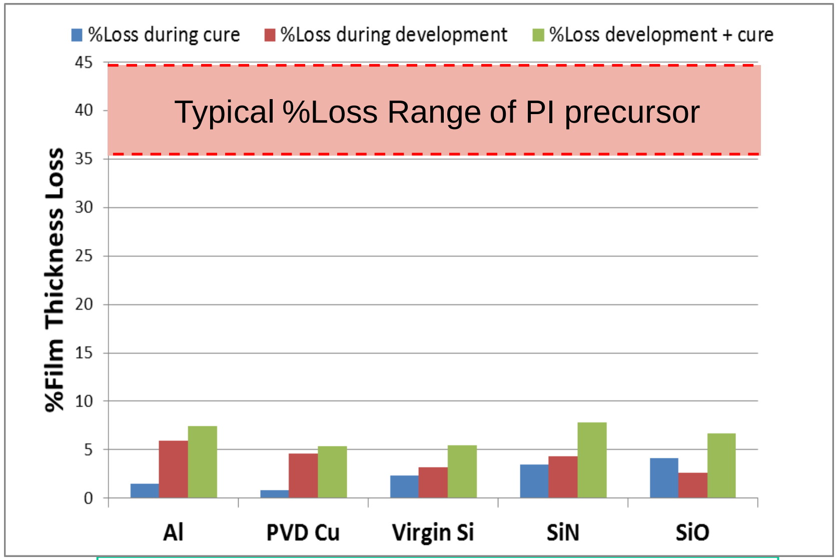


5 µm via in 12 µm Film
400 mJ/cm² (0.45 NA i-line)
(Substrate: PVD-Cu)



5 µm via in 8µm Film
200 mJ/cm² (LDI exposure)
(Substrate: PVD-Cu)





Total film Loss due to development and cure processes combined is ~ 6-8%.

Typical Process Conditions

Substrate Preparation: Varys with substrate type

Spin coat: 1000 rpm to 4000 rpm (to cover film thickness range of 5 to 20 µm

Soft bake: 90˚C/180 seconds

Develop & Rinse: 2 puddles (40 to 90 seconds each) in cyclopentanone, followed by 2 puddles (20 to 45 seconds each) in PGMEA

Post Exposure Bake: None

Cure: 170˚C for 2 hours in nitrogen or air

Summary

- *Fully cyclized polyimide demonstrated low thermal shrinkage and low residual stress*
- *High resolution is demonstrated under i-line and LDI conditions*
- *Significant improvement in adhesion could be achieved by formulating with appropriate adhesion promoter*
- *Optimized film passed all reliability properties*