

Avatrel® Stress Buffer Coatings:

Low Stress Passivation and Redistribution Applications



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Outline

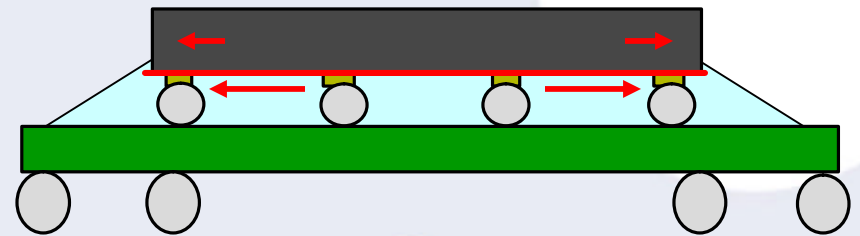
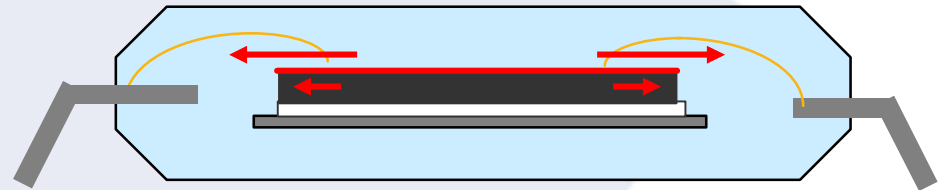
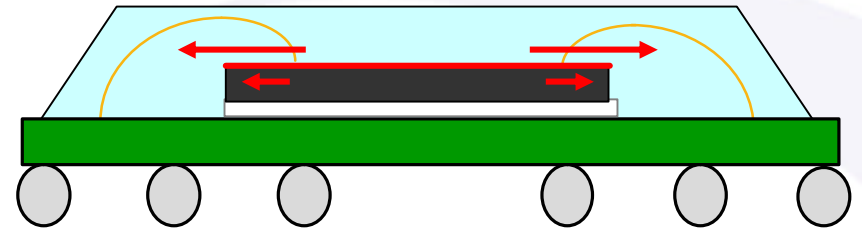
- Motivation
 - Simple Coatings
 - FEM Verification of Concept
 - Modulus vs. CTE
- Avatrel
 - Properties
 - Processing
- Materials Integration and Reliability - Flip Chip Packages
 - Thermal Cycling
 - Pressure Cooker Test
- New Generations
- Summary

Low Stress Motivation

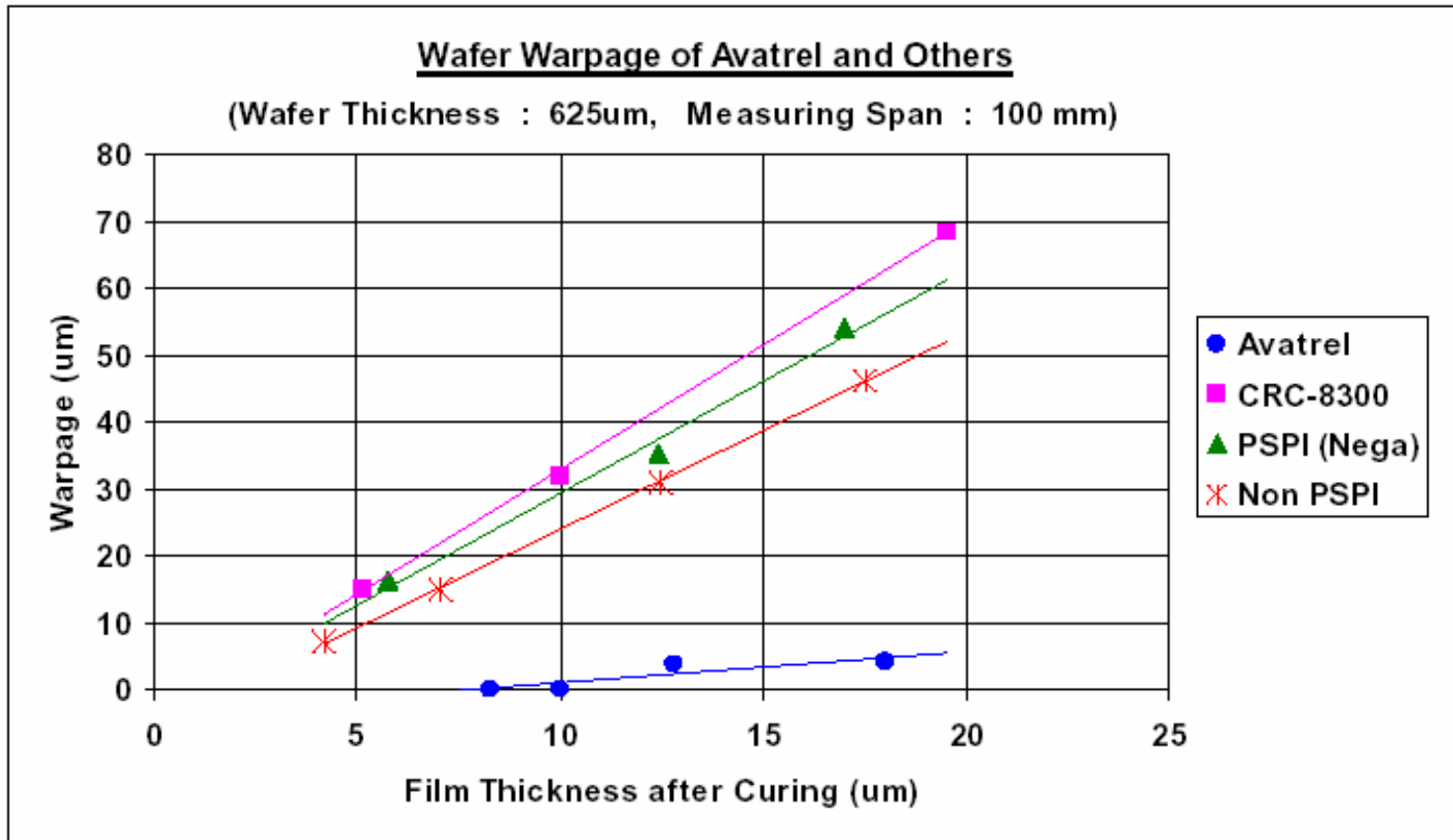
- Die are getting larger and more fragile (low k)
- Reduction of Stress is important to maintain reliability
- Reduce material shrinkage
- Reduce thermal stress
 - Reduce Modulus, $E(T)$ and/or CTE, $\alpha(T)$

Thermal Stress (Simple View):

$$S = \int E(T) \times Da(T) dT$$

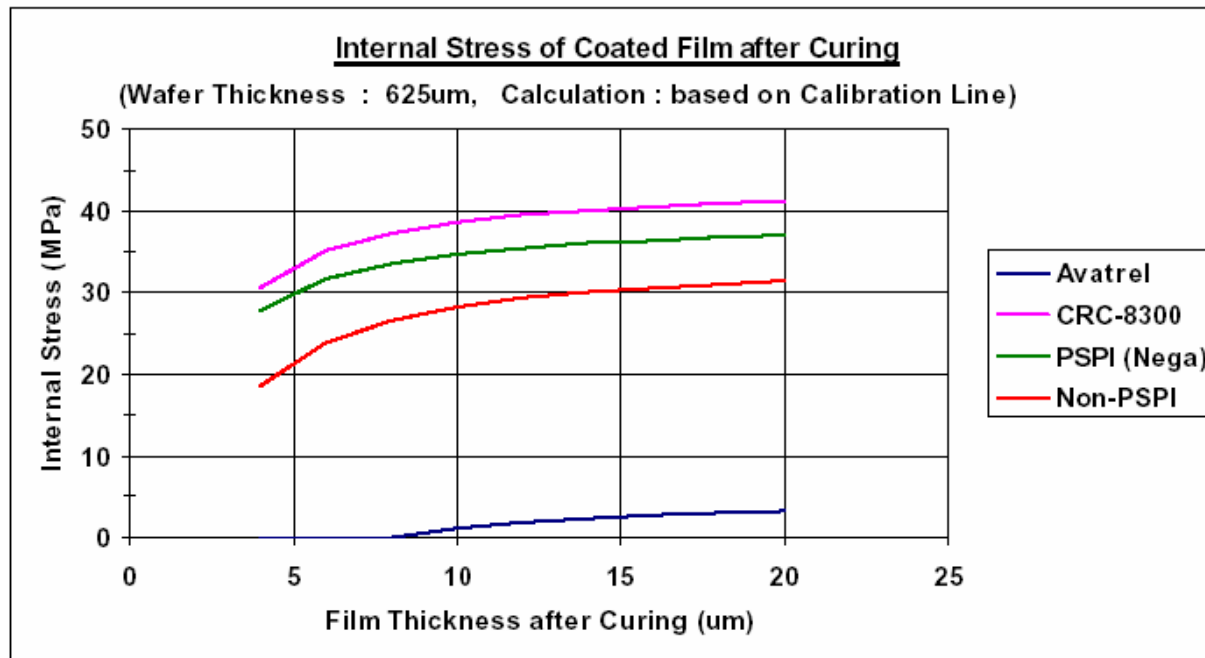


Wafer Warpage with Simple Coatings



Wafer: 8 inch Si Wafer
Thickness: 625 mm
Measuring span: 100 mm

Wafer Stress with Simple Coatings



Calculation of Stress

$$S = \frac{T^2 \cdot E}{6 \cdot R \cdot t \cdot (1 - \gamma)}$$

$$R = \frac{S^2 + 4 \cdot X^2}{8 \cdot X}$$

here :

S : Stress (kg/mm²)

T : Thickness of Wafer (mm)

E : Modulus of Silicon
(= 1.62 x 10⁴ kg/mm²)

R : Radius of Curvature

t : Film Thickness (mm)

γ : Poisson Ratio Silicon
(= 0.3)

S : Measuring Span
(= 100 mm)

X : Warpage (mm)

$$1 \text{ kg/mm}^2 = 9.807 \text{ MPa}$$

A More Detailed View Using Finite Element Modeling

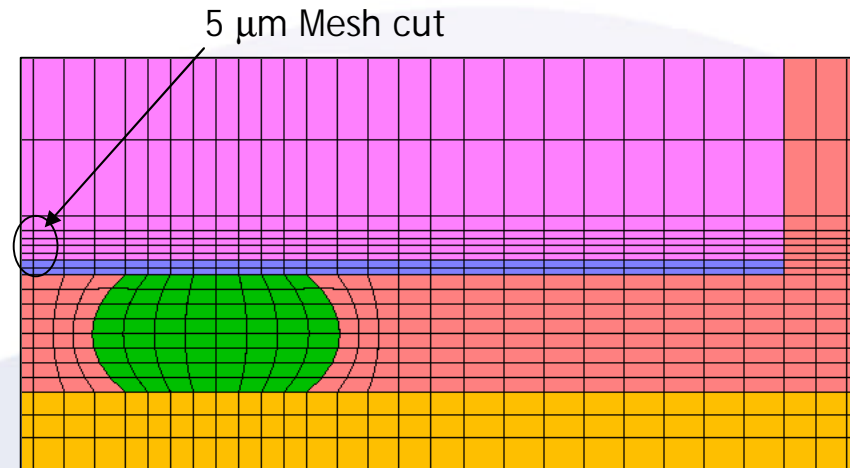
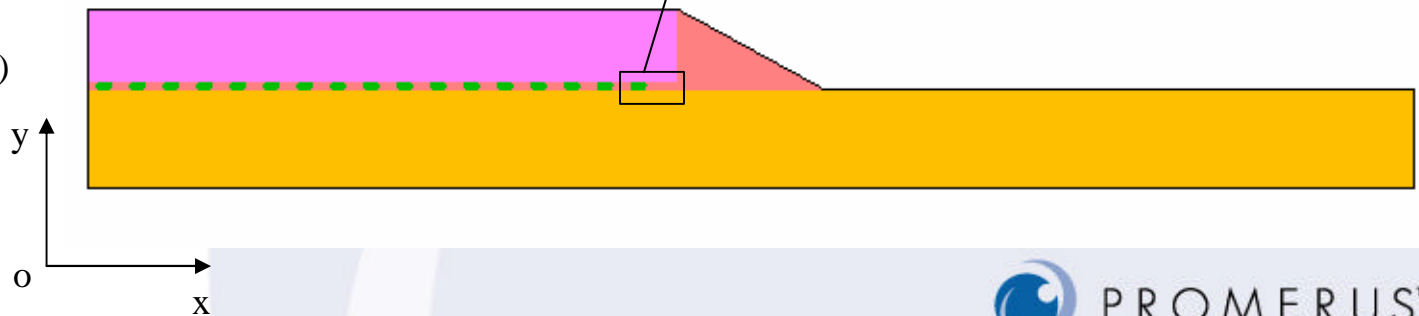
The distortion element of 4 nodal point (#11)

Nodal point : 9007

Element : 8649

Thermal stress analysis from 125 to -55degC

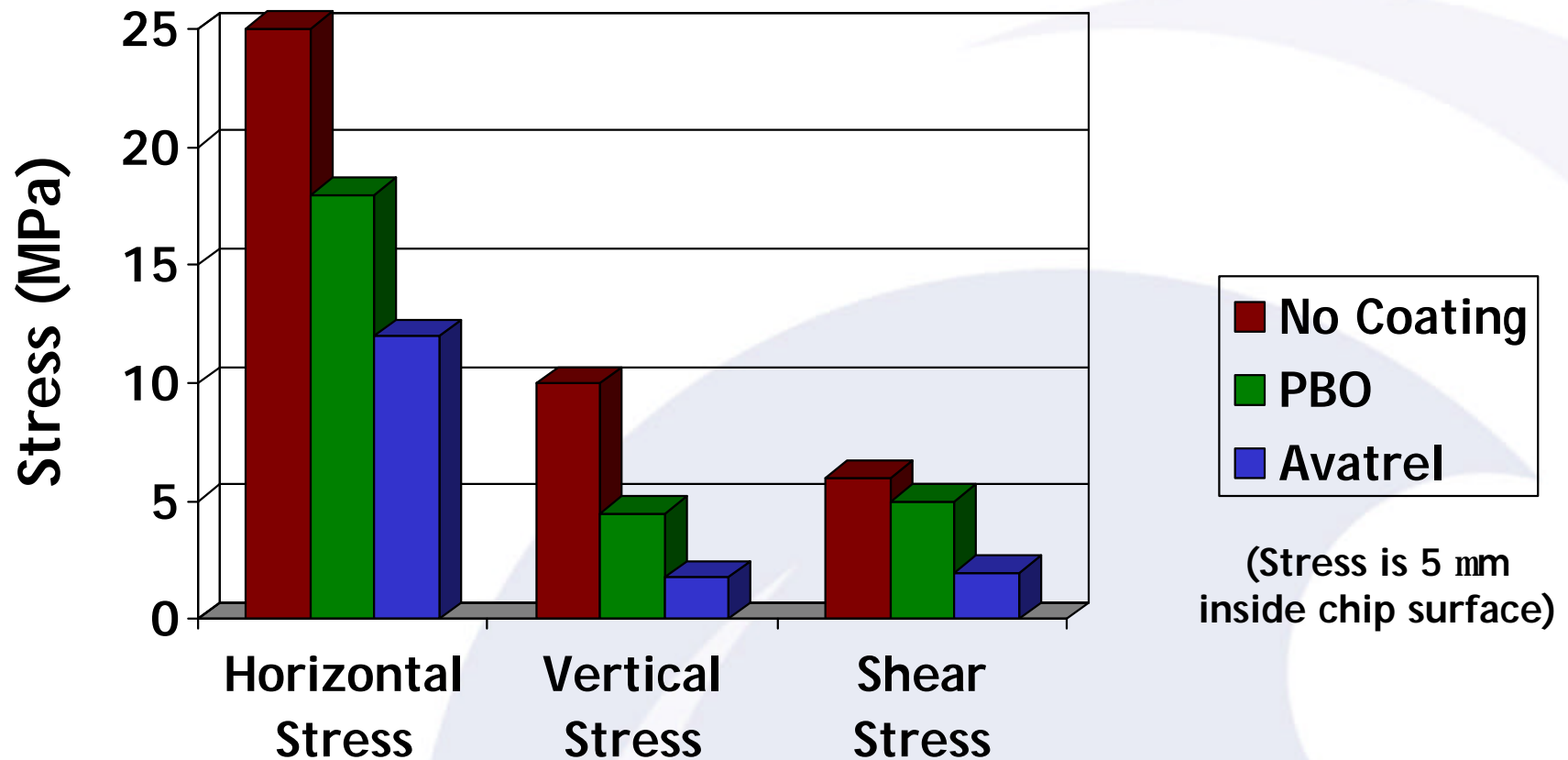
Chip
Underfill (SB: CRP-4152R5)
BT substrate
Bump
Buffer Material
(Avatrel and PBO)



Material Properties

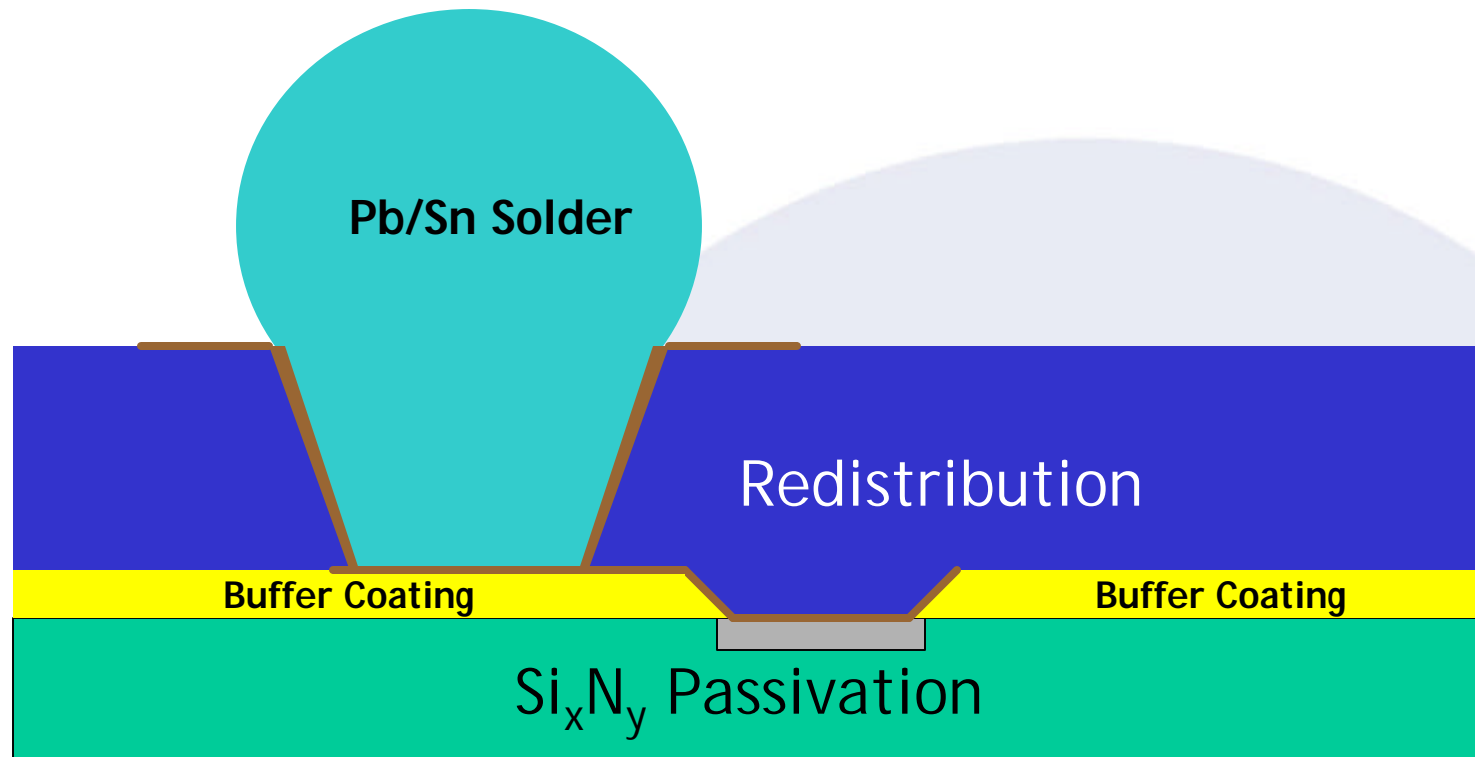
Item	Tg	Modulus	CTE	Poisson's ratio
Unit	°C	kgf/mm ²	ppm/°C	
Chip	-	16800	3.0	0.34
Underfill	80	E1: 820 E2: 3.1	α 1: 32 α 2: 102	0.30
BT substrate	-	x, z: 1990 y: 870	x, z: 17.6 y: 64.1	0.39
Bump	-	-40°C: 2120 25°C: 1620 80°C: 1320 125°C: 1120	29.2	0.35
PBO (CRC) 10 μ m thick	330	300	50	0.30
Avatrel 10 μ m thick	200	40	150	0.30

FEM Findings...

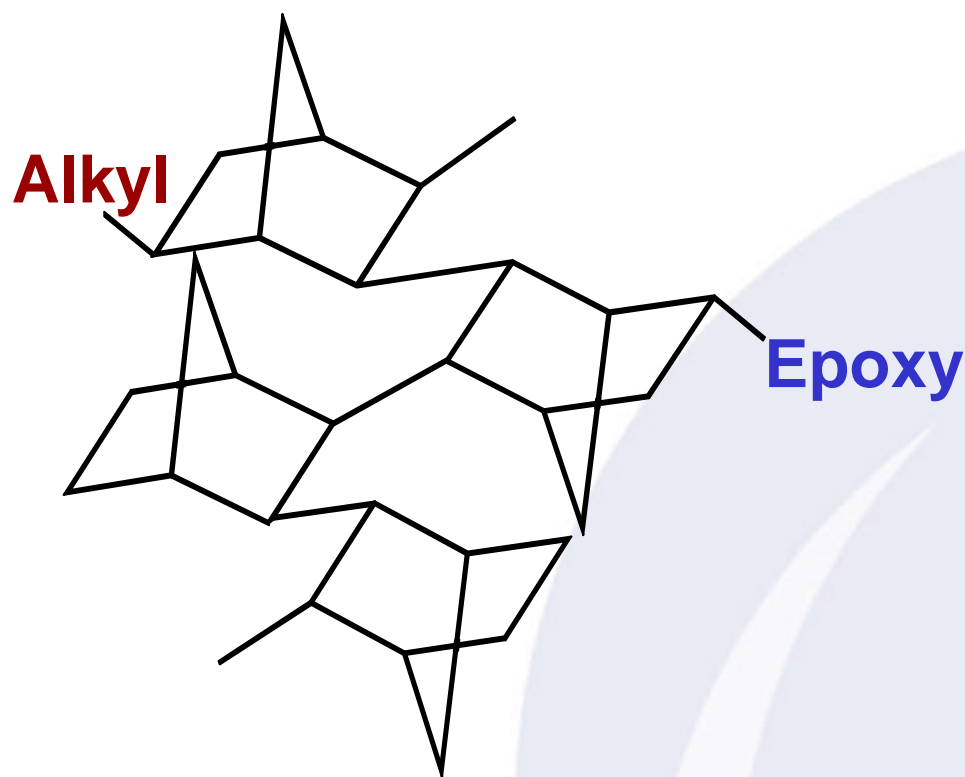


Reducing Modulus has a greater impact than reducing CTE

Wafer Level Packaging



Synergies Between Two Chemistries



Polynorbornene

- Low Dielectric Constant
- Low Moisture Absorption
- Isotropic Properties
- High T_g From Backbone
- Transparency
- **Alkyl** - Tune Modulus/Stress

Epoxy

- Adhesion
- Photosensitive
- Accepted Chemistry

Typical Properties

■ Photodefinition

- Negative Tone, Solvent Develop
- Up to 50 μm thick
- 1:1 Aspect Ratio
- 250-500 mJ/cm^2

■ Adhesion

- Pressure Cooker (196 hours) on Si, SiON , Si_xN_y , SiO_2 , PI, Al & Cu
No delamination and passes tape test

■ Top Layer Metal

- Cr/Cu & Ti/Cu
90° Peel = 4 lb/in

■ JEDEC Solder Reflow*

- Level 2A - PASS
(60°C/60% RH, 120 hours, 260°C reflow 3x)
- Level 3 - PASS
(30°C/60% RH, 192 hours, 260°C reflow 3x)

* 8 mm on 0.32 mm SiN wafer, 160°C cure, SB-epoxy molding compound, 208 L QFP with Cu L/F, scanning acoustic microscope inspection

■ Electrical

- Dielectric Constant
2.50 @ 1 MHz
- Dissipation Factor
0.009 @ 1 MHz

■ Thermo-Mechanical

- $T_g = 220^\circ\text{C}$ (TMA)
- Modulus, 0.5 GPa
- ETB, 20%
- Stress, 0-5 MPa

■ Moisture

- 0.14% (100% RH, 24 hrs, RT)

Processing

1. Plasma Pre-Treatment ($O_2:Ar$) at 300 mTorr and 300 Watts for 30 seconds
2. Dehydration bake before coating is optional
 - 4 minutes at 250°C is effective
3. Spin Coat Avatrel on wafer with a spread spin of 800 rpm for 8 seconds and Final Spin for 30 seconds to obtain final film thickness
4. Soft Bake at 120°C for 5 minutes
5. I-Line UV Exposure with Adjusted Depth of Focus
6. Post Exposure Bake at 100°C for 4 minutes
7. Spray Develop for 30 seconds with limonene, Rinse with IPA for 10 seconds 5 second overlap and Spin Dry
8. **Cure at 160°C for 60 minutes**

Typical process, but low T final cure

Formulation & Process Optimization: Overlapping process space for Al and Silicon Nitride

Peeling on Al

Good on Al

Good on PE SiN

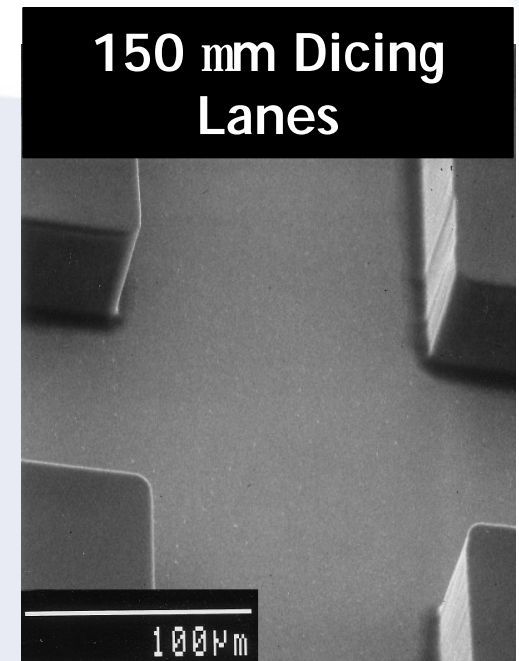
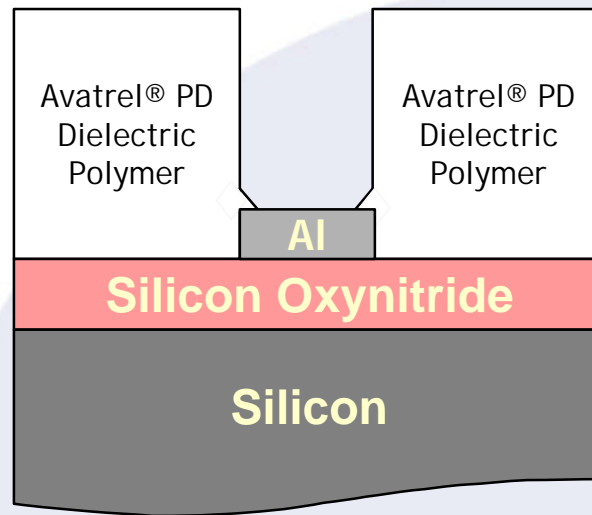
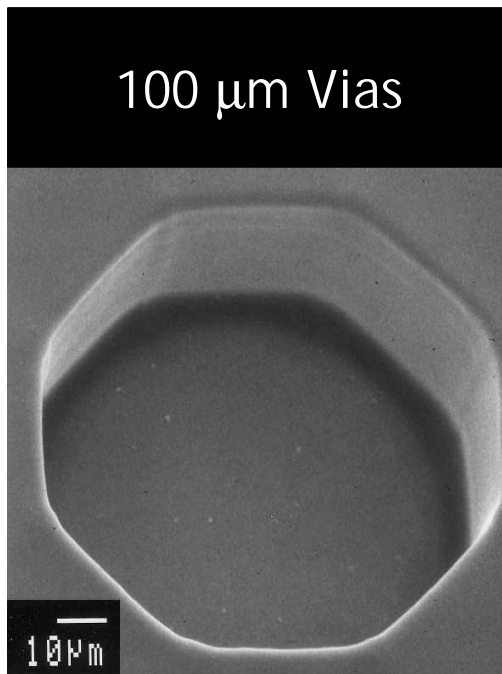
Good on both

Imaging of 2195P

		365nm UV Exposure Dose (mJ/cm ²)																	
10 um Via		50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900
Depth Of Focus (% Film Thickness)	11																		
	22																		
	33																		
	44																		
	56																		
	67																		
	78																		
	89																		
	100																		

Imaging of Avatrel, 50 mm

Test Package



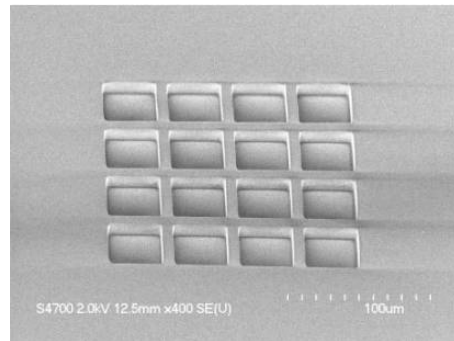
Imaging of Avatrel, 10 mm



Prebake: 120°C/5min
Exposure dose: 400mJ/cm²
PEB: 100°C/4min

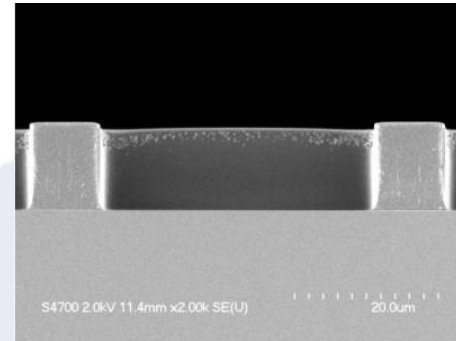
Curing: 160°C/60min in N₂
Observation pattern: 40um via hole

Bird's-eye View



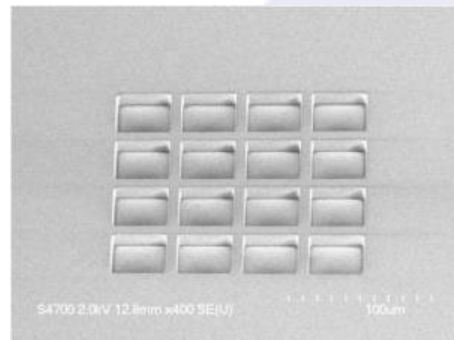
After
developing

Cross section

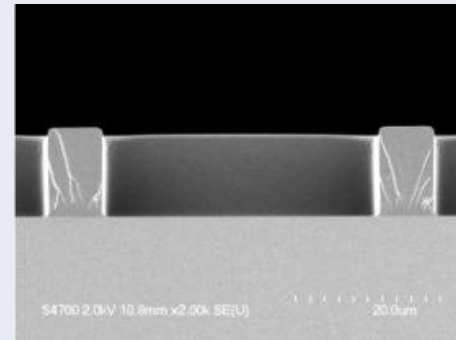


10 micron film

After curing



Magnification : x400

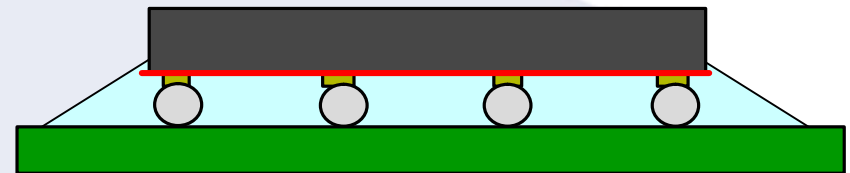


Magnification : x2000

Reliability Testing of Avatrel



- Sample Preparation
 - Silicon wafer coated with Avatrel or Non-photosensitive Polyimide, 5 μm thick
 - Substrate: FR5 with solder resist
 - Underfill: standard grade (CRP-4152R5) or new, low stress grade (CRP-X4498)
 - Post-cure 150°C, 120 minutes
- Treatment
 - JEDEC Level III
 - Baking: 150°C / 24 hours
 - Humidity: 30°C / 60%RH / 192 hours
 - Reflow: 240°C IR reflow 3 times
- Reliability Testing
 - Thermal Cycling (T/C): 125°C/30min \leftrightarrow -55°C/30 min (no interval), 200 cycles
 - Pressure Cooker Test (PCT): 125°C/100%RH/2.3 atm, 96 hours
- Evaluation by Scanning Acoustic Microscopy

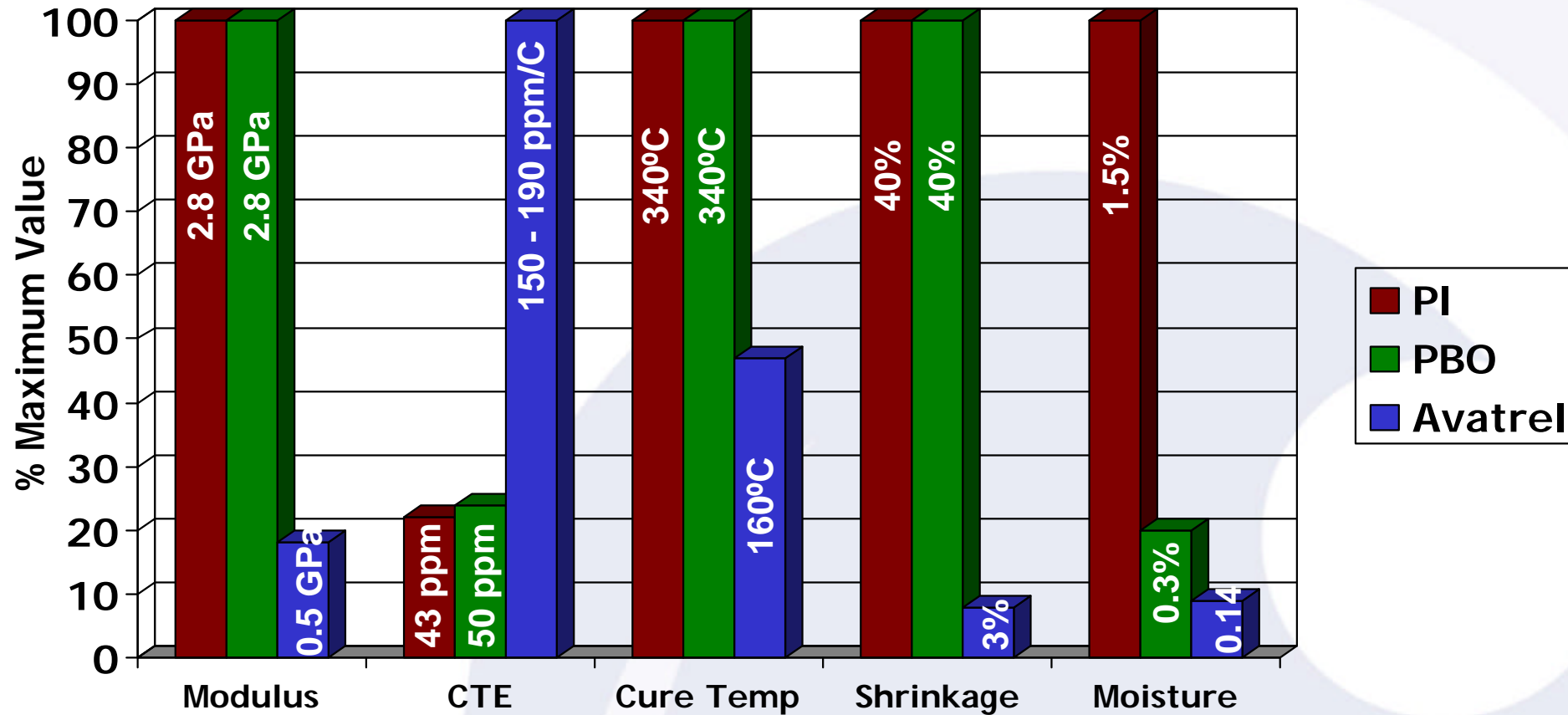


Reliability Testing of Avatrel 2195P

		Avatrel	Non-photo PI
Conventional Underfill (CRP-4152R5)	T/C Test	100% Pass	100% Pass
	PCT	100% Pass	100% Pass
Low Modulus & Low Moisture Underfill (CRP-X4498)	T/C Test	100% Pass	100% Pass
	PCT	100% Pass	100% Fail

Avatrel is compatible with standard and new, high reliability underfill materials

Major Factors Affecting Reliability

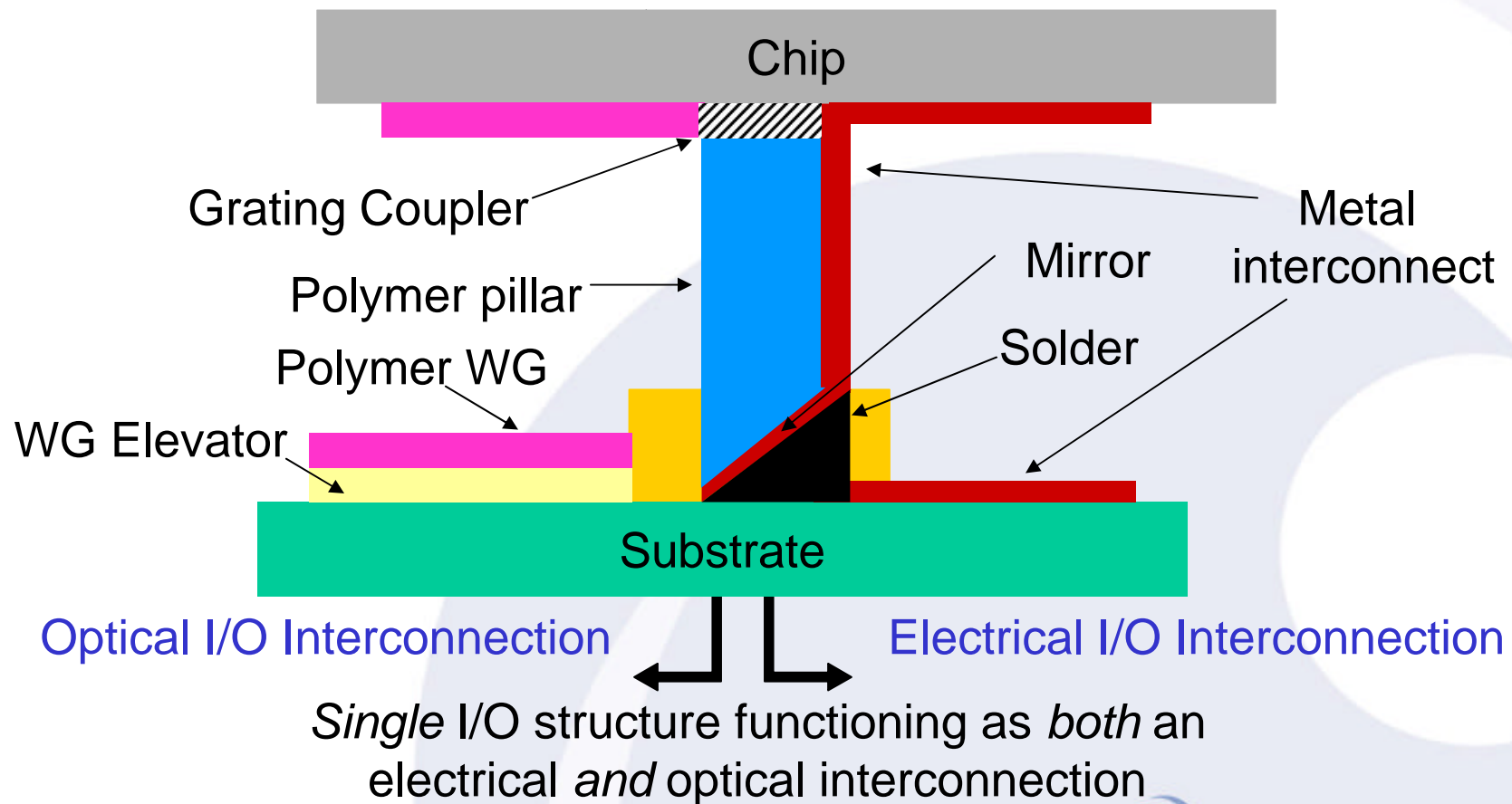


Avatrel Development Activities

- Sloped Sidewalls to facilitate conformal metalization and bumping processes
- Increased elongation and higher strength versions under evaluation
- Aqueous Base developable versions are underway

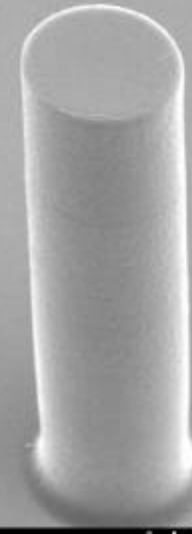
GT - "Polymer Pillars"

Highly Compliant, Low Stress Approach



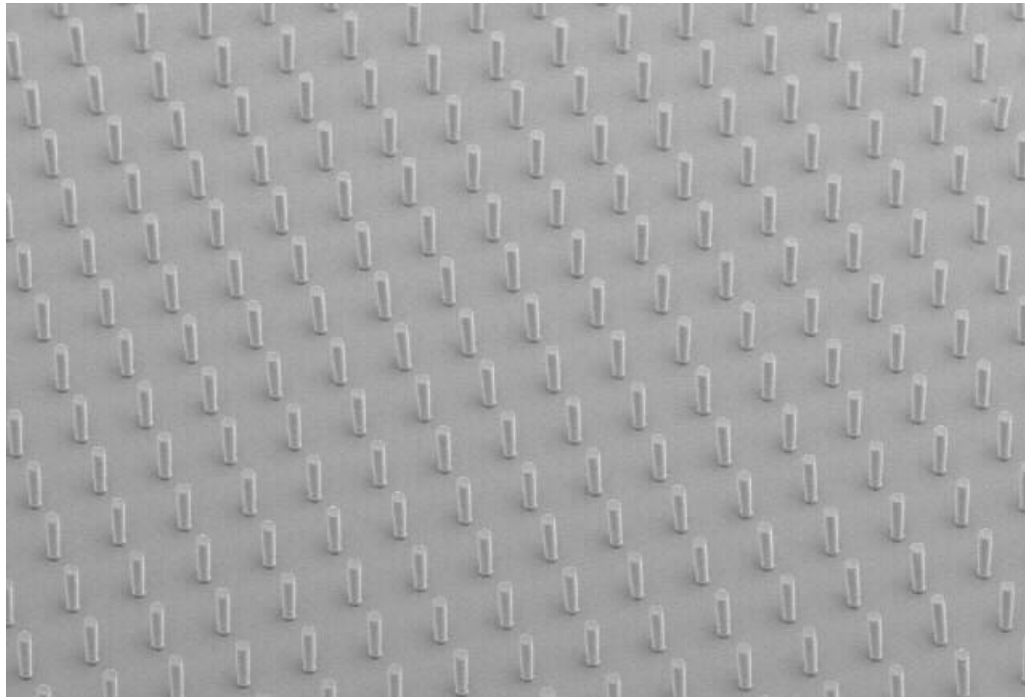
Avatrel Pillars...

63 x 325 mm



24-Oct-03

WD55.4mm 15.0kV x400 100um



24-Oct-03

WD53.3mm 15.0kV x25 2mm

Avatrel Summary

- Low Stress Materials focusing on stress buffer layers and redistribution
- Early results indicate significantly improved reliability is possible
- 160°C final cure temperature is compatible with back end wafer processing and post bump process steps
- Exceptionally low cure shrinkage
- Very good mechanical properties
- Very good photo definition in 5 to 50 μm thick films
- Good adhesion to all substrates
- Very low moisture absorption
- Highly tailorable - new versions are in development