Temporary Bonding of Electronic Devices

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A. Definitions

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- Total Thickness Variation (TTV)
- Bow
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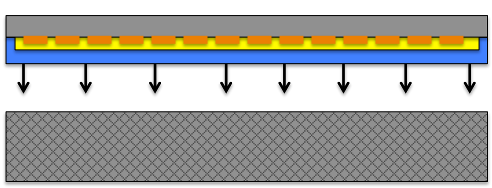
- Significant Contributor
- Bonded Stack
- Cost of Ownership (COO)

Coefficient Of Thermal Expansion (CTE)

- The fractional change in length or area or volume per unit change in temperature at a given constant temperature, typically presented as ppm/°C

Carrier & Wafer Temp Bond



Item	Thickness	Modulus	CTE
Wafer (Si)	~100um	High 130 GPa	Low 3.1ppm
Adhesive (silicone)	~10um	Low 0.2-7 MPa	High 300ppm
Carrier (Si or glass)	>700um	High 74 GPa	Low 3.1ppm

Mechanical Energy

- Hook's law: F=kΔx
  σ=Eε
- (F=force, k=elastic constant, Δx=change in length, σ=stress, ε=deformation=ΔL/Lo where Lo=initial length, E=young's modulus/modulus of elasticity)
- By integration, energy U is:
  $U=1/2k (\Delta x)^2$
  As such, the area under σ vs. ε curve is energy U [J] per unit of volume [m3]

Thermal Expansion

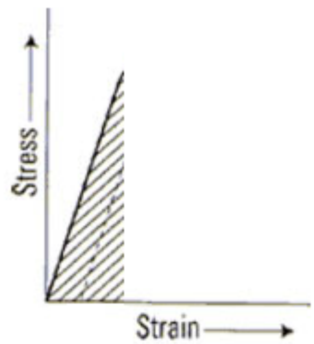
- **Silicone**. Let's assume that we subject the sample to a change in temperature of 200K. For simplicity, we can assume a silicon bar of 300mm length (thickness=width=1mm)
- $\Delta L=\alpha_L*\Delta T*L_o$
  [α=CTE, ΔT=change temp]
- ΔL=(300*1/K*10^-6)*200K*(0.3m)
- ΔL=1.08*10^-3 m

Deformation Energy

- How much energy represents this deformation of **Silicone**:
- ε=deformation=$\Delta L/Lo$
- $\varepsilon = 1.08 \cdot 10^{-3}/0.3 = 0.0036 = 0.36\%$
- $\sigma = E^* \varepsilon$
- $\sigma = 2GPa \cdot 0.0036mm/mm$
- $\sigma = 7.2MPa$

This change in temperature is equivalent to applying 7.2MPa to the material

- U/Vol=area under the curve=$1/2 \cdot \sigma \cdot \varepsilon$
- $U/Vol = 7.2MPa \cdot 0.0036mm/mm$
- $U/Vol = 13 \cdot 10^3\ J/m^3$
- $U = 13 \cdot 10^3\ J/m^3 \cdot 3 \cdot 10^{-7} m^3$
- $U = 3.89 \cdot 10^{-3}\ J$



How much does this energy represents to Silicon?

- Deform. Energy (assuming the same volume for Silicon sample)
- $U = 3.89 \cdot 10^{-3}\ J$
- $U = 13 \cdot 10^3\ J/m^3 \cdot 3 \cdot 10^{-7} m^3$
- $U/Vol = 13 \cdot 10^3\ J/m^3$
- $U/Vol = 1/2 \cdot \varepsilon \cdot \sigma$
- $U/Vol = 1/2 \cdot \varepsilon \cdot \varepsilon \cdot E$
- $U/Vol = 1/2 \cdot \varepsilon^2 E$
- $\varepsilon = (2 * 13 \cdot 10^3 J/m^3 / 130GPa)$^1/2
- $\varepsilon = 0.000446525$ mm/mm
- $\varepsilon = 0.045\%$

Conclusion: By using $13 \cdot 10^3\ J/m^3$ a linear deformation of **0.36%** was induced on Silicone. Using the same energy, a deformation of **0.045%** was induced in Silicon.

Therefore, per each unit of linear deformation that we have in the adhesive Silicone, we will have **1/806** of deformation in the Silicon carrier!!!!

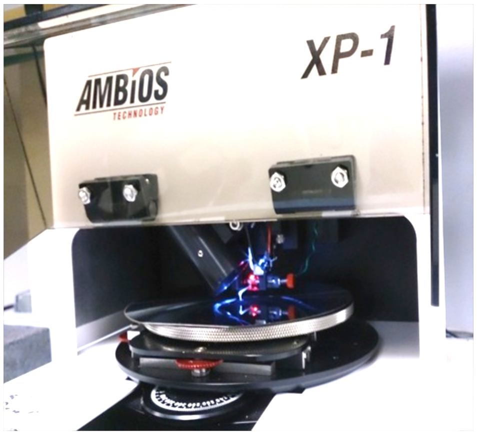
Thickness

- The distance through a substrate between corresponding points on the front and back surface. Thickness is expressed in microns or mils (thousandths of an inch).

Total Thickness Variation (TTV)

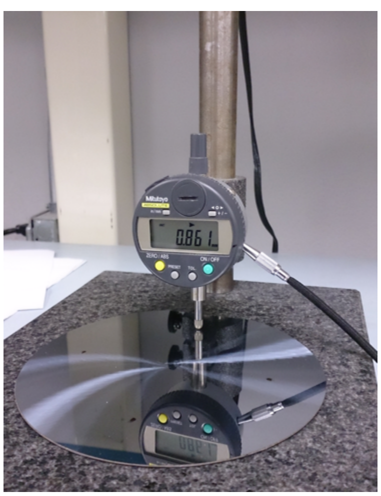
- The difference between the maximum and minimum values of thickness encountered during a scan pattern or series of point measurements. TTV is expressed in microns or mils (thousandths of an inch).
- The maximum variation in substrate thickness.

TTV

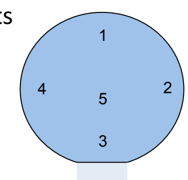


1. Surface Profilometer
   - Measure surface profile
   - Quantify roughness of a surface
   - Measure length: <3cm
   - Measurable height: 100µm

TTV



2. Drop Gauge
   - Thickness measurements are taken at 5 spots



   - TTV = Max thickness – Min thickness
   - Thickness of wafer = average of the measurements

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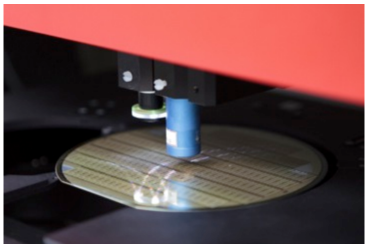
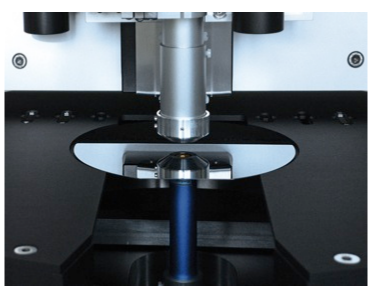
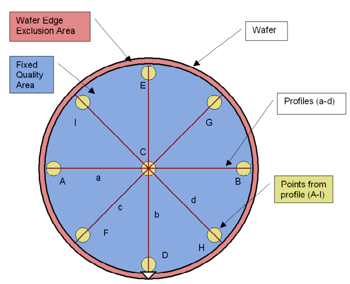
Semi Automated Metrology Tools



- substrates measured on the MicroProf®
- established metrology tool
- easy to use, highly reliable
- 2D profile and 3D raster scan measurements
- variable scan area selection
- chromatic white light sensors
- IR and film thickness sensors
- TSV depth measurements

FRT MicroProf® TTV
Measurements According to Semi Standards



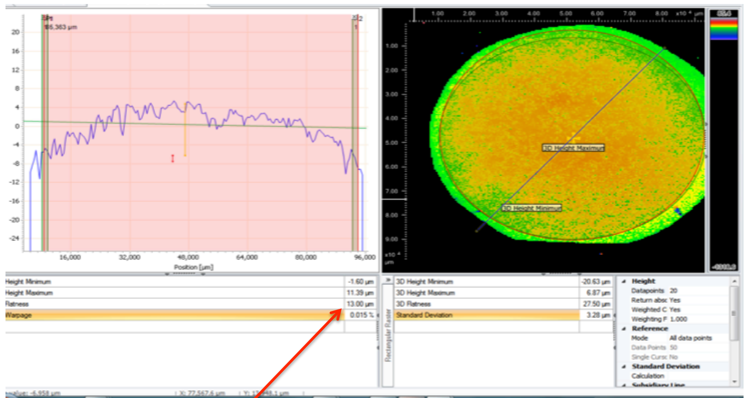


	MF1390	MF657	MF534	MF1530
Value	Warp	Warp, TTV	Bow	Flatness, Thickness, TTV
Methode	2-probe	2-probe	1-probe	2-probe
Flip wafer	Yes, wafer inversion method	No	Yes	No
Fixture	By mutual agreement	3-point reference plane	3-point	By mutual agreement

- fully Semi compliant
- sawn, ground, polished wafers
- material independent (Si, sapphire, glass,..)
- recipe driven Semi compliant software

Overview over relevant Semi standards

Wafer normalized, surface de-tilt



Max variation: 11.4um

Bow

- Deviation of the center point of the median surface of a free, unclamped substrate from the median surface to the reference plane, where the reference plane is defined by three corners of an equilateral triangle.
- Concavity, curvature, or deformation of the wafer centerline independent of any thickness variation present.

Warp

- The difference between the maximum and minimum distances of the median surface of a free, unclamped substrate and a reference plane.
- Deviation from a plane of a substrate containing both convex and concave regions.

Flatness

- The deviation of the front surface, expressed in total indicator reading (TIR) or maximum focal plane deviation (FPD), reletive to a specified reference plane when the back surface of the substrate is ideally flat
- Deviation from a plane of a substrate containing both convex and concave regions.

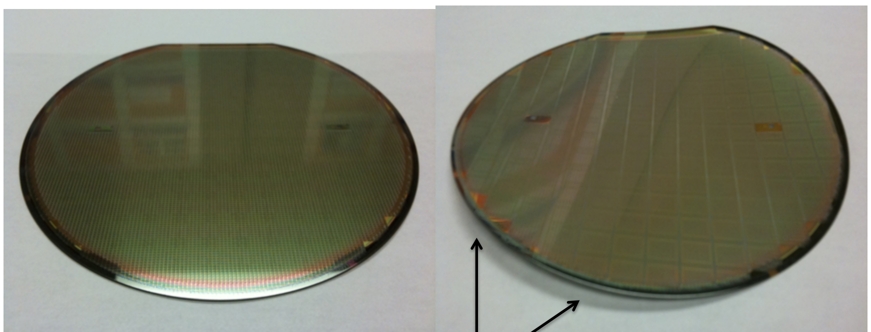
Total Indicator Reading (TIR): The span of readings, from maximum to minimum, for any dimension measured

Focal Plane Deviation (FPD): The largest of the absolute values of the deviations from a reference plane.

Bow/Warp Introduction

Bowing – observed internal stress, metal layers

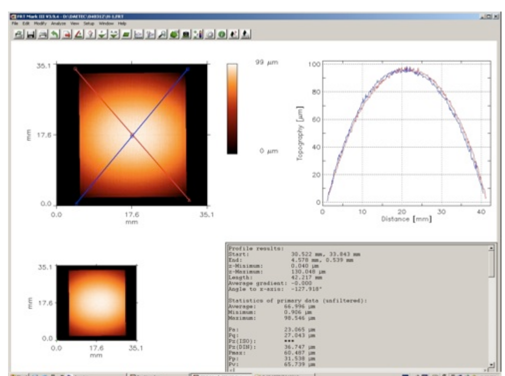
Full thickness ~ 700um **Thinned ~ 100um**



Wafer Bow

Interposer Initial Bow/Warp

- Bow, measured by optical profilometry
- Beginning bow varies from 100-120um
- Convex shape
- Must reduce to <40um



Significant Contributor

- Any metric in which changes cause significant variations to the final outcome of a technique or process.
- Main effect (e.g. CTE difference in thermal)

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Bonded Stack

- Bonded pair of a device substrate and a carrier substrate with an adhesive interface.

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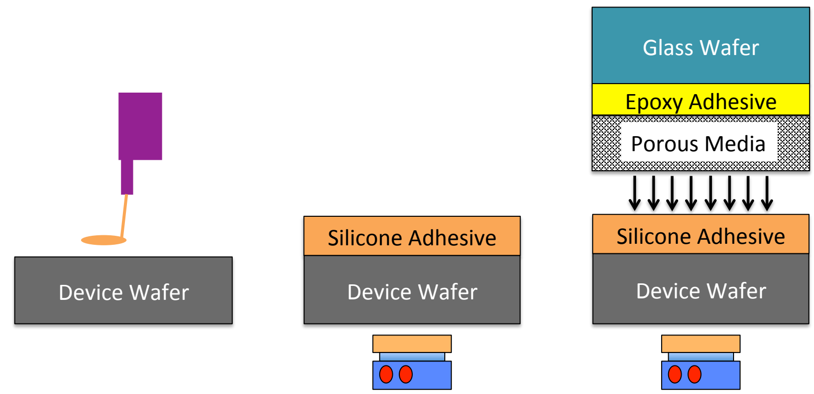
Forming a Bonded Stack



Spin Coat:
- 3500rpm (60sec)

Soft Bake:
- 50°C (5min)

Thermal Bond:
- Bond at 25PSI
- 50°C (30min)

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Cost of Ownership

- The full cost of embedding, operating, and decommissioning in a factory environment a process system needed to accommodate the required volume of a product material.

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COO Defined (SEMI E35)

$$COO = \frac{F\$+R\$+Y\$}{L \times T \times Y \times U} = \frac{Costs}{Product}$$

Item	Definition
F$	Fixed Costs
R$	Recurring Costs
Y$	Yield Cost (scrap)
L	Equipment Life
T	Throughput
Y	Composite Yield
U	Utilization

$$\frac{COO_2}{COO_1} = \frac{\text{New Process}}{\text{Existing Process}}$$

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COO Value Calculation Example

$$\frac{COO_2}{COO_1} = \frac{\text{New Process}}{\text{Existing Process}}$$

Item	Definition	COO_2 vs. COO_1	Explanation
F$	Fixed Costs	$F\$_1 = 5.1 \times R\$_1$ $F\$_2$ = -0- or $1.2 \times R\$_2$	Existing tool as Materials Use in-house wet bench (-0-) or new bench
R$	Recurring Costs	$R\$_2 = 0.75 \times R\$_1$	Materials Cost #2 (New) = 0.75 X #1 (Existing)
Y$	Yield Cost (scrap)	$Y\$_2 = Y\$_1 = 0$	No loss for each tech.
L	Equipment Life	$L_2 = L_1$	Same life
T	Throughput	$T_2 = 8.3 \times T_1$	New vs Existing = $8.3 \times T_1$
Y	Composite Yield	$Y_2 = Y_1$	Same yield
U	Utilization	$U_2 = U_1$	Same maintenance

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COO_2/COO_1 Comparison Results

Comparison of COO Technologies	Use in-house Wet Bench (Batch)	New Wet Bench (Batch)
COO_2/COO_1	1.5%	3.2%

Summary: The COO of the new technology is projected to be between 1.5 – 3.2% of the COO of the existing technology (using in-house wet bench or buy new)

PP of New and Existing Lines

Payback Period Method	Use Existing Wet Bench (Batch)	New Wet Bench (Batch)
Throughput considered	<1mo	~1mo.
Remove Throughput	4mos	10mos

B. Adhesion Theory (Definitions)

- Adherend (substrate)
- Adherate (coating or adhesive)
- Adhering system
- Adhint (adhesive joint)
- Heterohesion (different)
- Homohesion (self)

Homohesion (Ex.)

- Glass fusion
- Glass on glass – display manufacture
- Glass is a supercooled liquid. Under ideal conditions of cleanliness, glass contact causes fusion (ideal adhering system)

Adhesion Types

- Mechanical
- Adsorption
- Surface energy
- Electrostatic
- Diffusion
- Chemical
- Other (WBL, Viscoelastic, AB)

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Mechanical (Interlocking)

- Adhesion proportional to surface roughness
- Adhesion proportional to surface area (porosity or roughness)
- Adhesion proportional to amount of adherend used to interact with the surfaces
- Maximize by knowledge of adherend (substrate) surface condition prior to application
- Measure by surface roughness (profilometer)

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Drawbacks

- Roughness exceeds sufficient amount of adherend to make contact with such surface area
- Mechanics of bonding is not sufficient to allow adherend to make contact with surface area (i.e. insufficient pressure)

Adsorption

- Adherend (substrate) is porous
- Examples: wood, paper, porous metals or ceramics, and certain permeable polymers
- Adherate (adhesive) is applied as a casting, is absorbed and fixed into the surface

Surface Energy

- Basic requirement:
  - SE (adherate) < SE (adherend)
  - Coatings preferred to be low surface energy
  - Substrates preferred to be high surface energy
  - Items can be maximized by surfactants (adherate/ coating) & surface treatment (adherend/ substrate)
  - Measure by contact angle & surface tension

Chemical Adhesion

- Covalent bonding between adherate (adhesive) and adherend (substrate)
- Coupling agents (primers) are common
- Chemical reaction with the adherend
- Coupling agent is commonly very thin
- Coupling agent becomes the adherend
- Coupling agent exhibits chemical/mechanical adhesion with the adherate (photoresist)

Electrostatic Adhesion

- Static electricity – polarization is established between two adherends using embedded electrodes in one surface
- Common with dielectric materials where electrical charges can be generated
- Electrostatic gripping devices

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Diffusion Adhesive

- Common with thermoplastics
- Method includes thermal and chemical
  - Plastic to plastic bonding (i.e. lucite & TCA), where TCA is the temporary coupling agent
  - TCA facilitates co-mingling of adherate with adherend
- Common with application of paint (adherate) to plastic (adherend) forms

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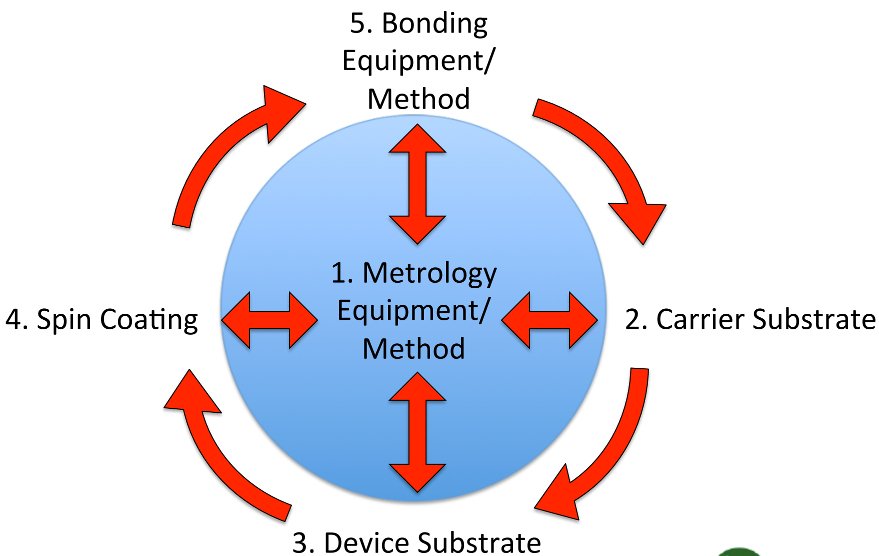
Temporary Bonding



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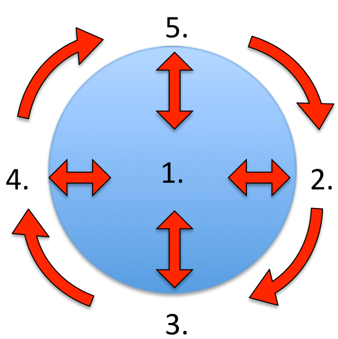
5 Components of Temporary Bonding:



1. **Metrology Equipment/Method**
   a. Has the equipment been tested? Are internal standards available? Is there a Standard Operating Procedure that can be replicated at any laboratory?
2. **Carrier Substrate;**
   a. Is the substrate flat (TTV)? Is the substrate clean? Begin with a transparent substrate?
3. **Device Substrate:**
   a. Is the substrate flat/clean? What metals are present? What kind of topography is present? What is the initial substrate thickness? What is the final substrate thickness?
4. **Spin Coating:**
   a. What material is being used? What kind of bond does this material permit? How reproducible is the coating? What environmental concerns need to be addressed?
5. **Bonding Equipment/Method:**
   a. What defects can the bond process hide? How large is the process window for bonding? Has this equipment been tested and qualified?

NOTE: All Steps are dependent on Metrology Equipment/ Method.

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Temporary Bonding Is Easy!

2 x Perfectly Flat Substrate (TTV= 0.0Å)

Adhesive Coating →

Perfectly Flat Adhesive (TTV= 0.0Å)

Perfectly Flat Bonding Press (TTV= 0.0Å Closed)

Heat Pressure Vacuum →

Perfectly Bonded Substrates! (TTV= 0.0Å)

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Reality Check

Description	Reality
2 x Perfectly Flat Substrate (TTV= 0.0Å)	Typical Wafer TTV <5µm Wafers Available TTV <1µm
Perfectly Flat Adhesive (TTV= 0.0Å)	Typical Coating TTV <5µm Optimized Coating TTV <2µm
Perfectly Flat Bonding Press (TTV= 0.0Å Closed)	Typical Bonder TTV <2µm High End Bonder TTV <0.5µm

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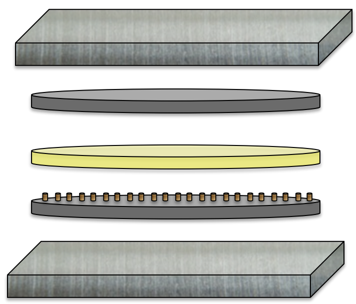
Look At Each Layer Independently

- To develop a temporary bonding process, it is useful to look at each layer in the Bonded Stack as a separate entity.



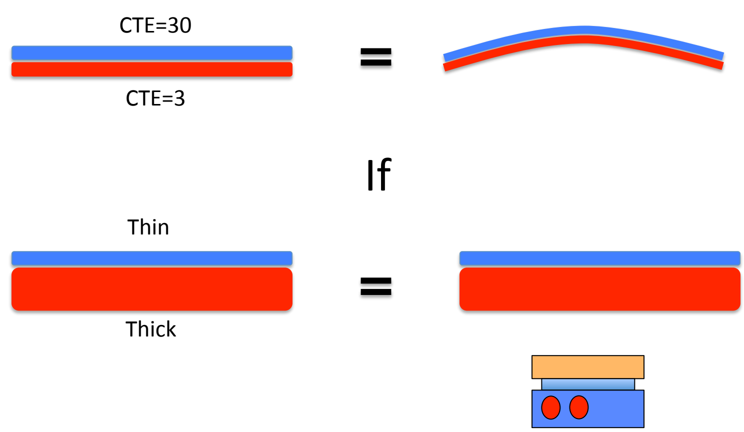
C. Key Properties and Measurement

- CTE
- Thermal Resistance
- Chemical Resistance
- Geometry (TTV, Bow, Warp, Size)

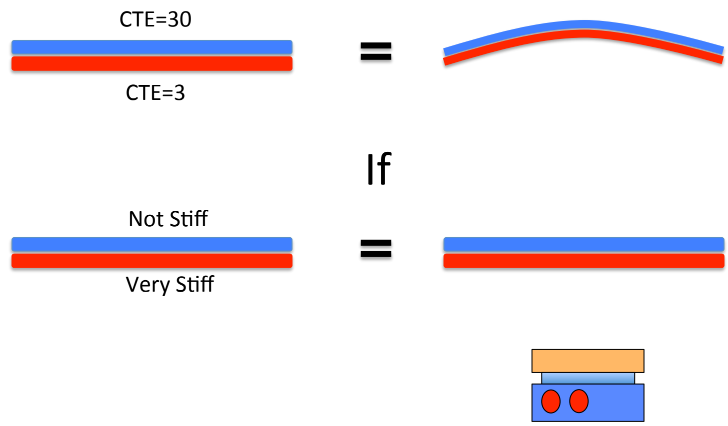
CTE Mismatch

- CTE is typically provided by materials suppliers.
- Stresses, observed as work unit deformation occurs due to a collusion of effects working in concert:
  - Adhesive/Carrier CTE Relationship
  - Adhesive Strain
  - Adhesive Tensile
  - Adhesive Thickness
  - Adhesion Force
  - Carrier Stiffness
  - Carrier Thickness

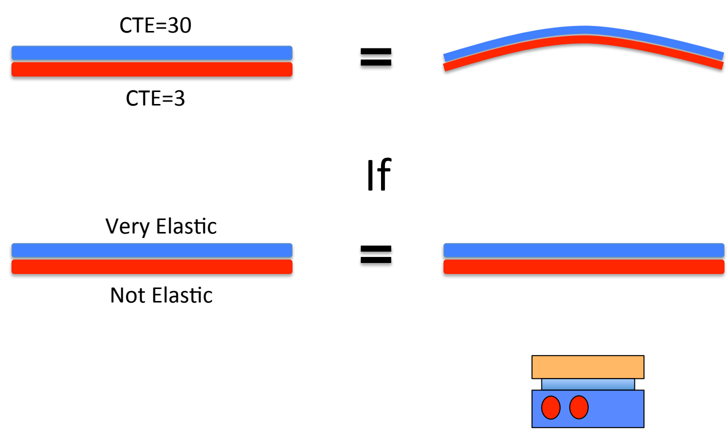
CTE and Thickness

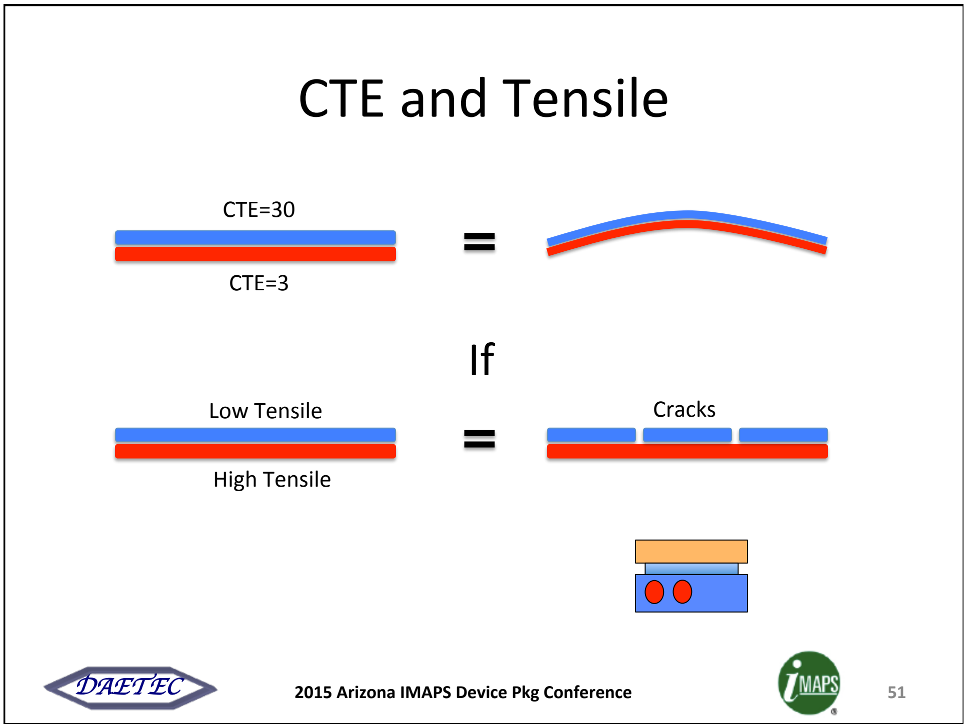


CTE and Stiffness



CTE and Strain (Elasticity)




CTE and Tensile
CTE=30
CTE=3
If
Low Tensile
High Tensile
Cracks
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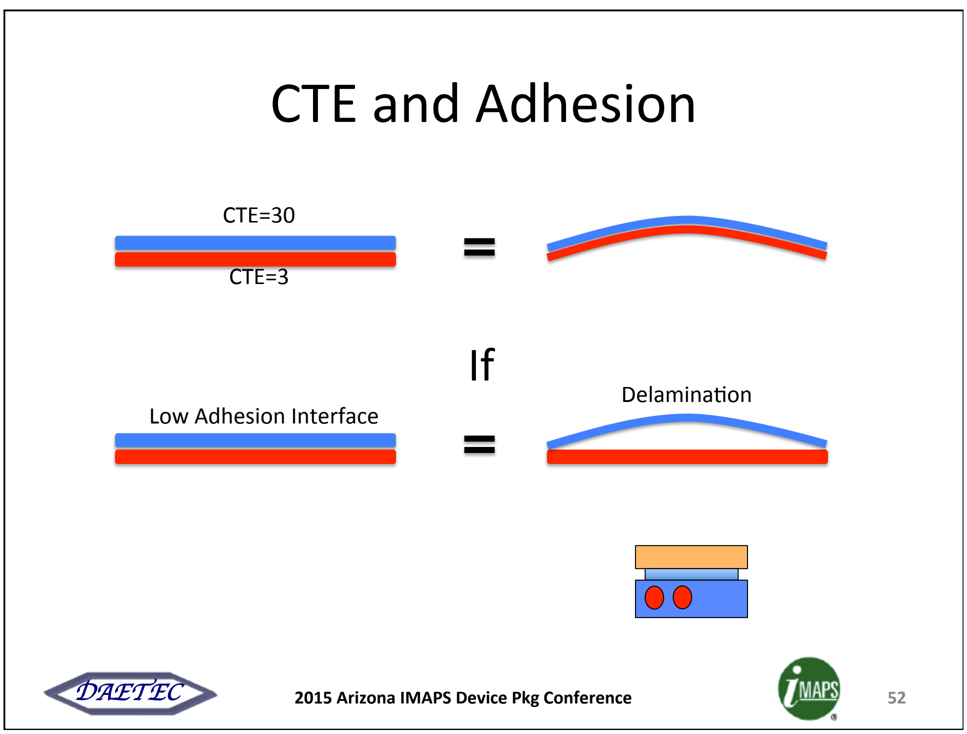
CTE and Adhesion
CTE=30
CTE=3
If
Low Adhesion Interface
Delamination
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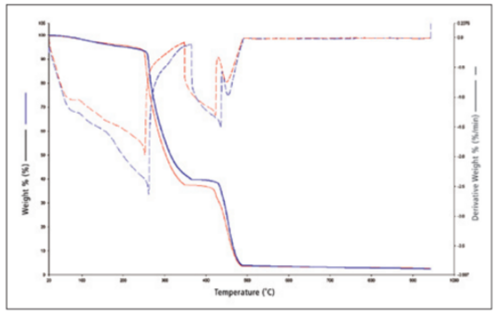
Thermal Resistance

- Thermogravimetric Analysis (TGA) is the most commonly used metric to qualify thermal stability of adhesive materials.
- Vacuum pump down time at temperature.



Chemical Resistance

- Various methods, gravimetric recommended

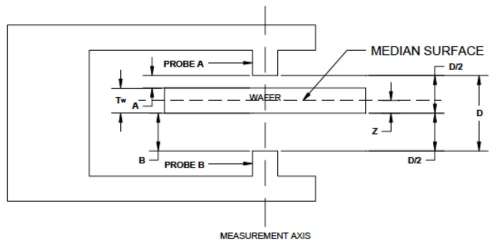
Paraffin	A	A	A	A	A			A		B	B	A	A		A	B	A	A	B		A		A	A		A	A					A
Pentane	A	C	C		A		B	A		B	B				A	D	A	A	D				A	A		A	A		B	D	D	A
Perchloroethylene[2]	B	A	A		A			C		B	B	A			A	D	A		D		D	A	A	A		A	C	D	D	D	D	A
Petrolatum	A		A		B			B		C	C				A	D	A	A	B				A	A		A	A		B	A	D	A
Phenol 10%	B	A	A		A		B	C		B	D		A	C	A			D				A				B	D		C	D	C	C
Phenol (Carbolic Acid)	B	A	A	A	B	C	A	B	D	D	D	A	A	C	A	C	D	D		D	B	A	A	D	A	A	D		D	D	D	B
Phosphoric Acid (40% Solution)		B	A	A	D	A	A	D	D	D			A	B	A	A	D	D	C	B	A	A	B	C	D	A	D		D	B	C	A
Phosphoric Acid (40% - 100% Solution)		C	B	B	D	B	A	D	D	D			A	B	A	A	D	D	D	C	A	A	B	D	D	A	D		D	B	C	C
Phosphoric Acid (Crude)		D	C	C	D	C	A	D	D	D	D	A			A		D	D	D	C		A	C	D		A	D		D	B		A
Phosphoric Anhydride (Dry or Moist)		A	A						D				D	D	A								A			D	D		D		A	
Phosphoric Anhydride (Molten)		A	A		D			D	D				D		A			A		D						D	C		D		D	A
Photographic (Developer)		C	A	C	C	A	A			D			A			A	C			B	A		A	A		A	A		A			A
Phthalic Anhydride	B	A	B		B		A	B		C	C				A			A								A	C					
Picric Acid	B	A	A		C		A	D	D	D	D		A	A	A			A		A						A	A	D	A		A	A
Plating Solutions																																
Antimony Plating 130° F			A			A	A						A		A	A		D			A			A		A	A	D	A			B
Arsenic Plating 110° F			A			A	A						A		A	A		A			A			C		A	A	D	A			B
Brass Plating																																
Regular Brass Bath 100° F			A			A	A						A		A	A		A			A			C		A	A	D	A			B
High Speed Brass Bath 110° F			A			A	A						A		A	A		A			A			D		A	A	D	A			B
Bronze Plating																																
Copper Cadmium Bronze Bath R.T.			A			A	A						A		A	A		A			A			C		A	A	D	A			B
Copper-Tin Bronze Bath 160° F			A			A	A						D		A	A		A			A			D		A	A	D	B			C
Copper-Zinc Bronze Bath 100° F			A			A	A						A		A	A		A			A			C		A	A		A			B
Cadmium Plating																																
Cyanide Bath 90° F			A			A	A						A		A	A		A			A			C		A	A		A			B

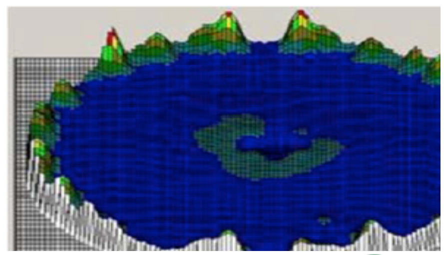
A — No effect — Excellent
B — Minor effect — Good
C — Moderate effect — Fair
D — Severe effect — Not recommended

1. P.V.C. — Satisfactory to 72° F.
2. Polypropylene — Satisfactory to 72° F.
3. Polypropylene — Satisfactory to 120° F.
4. Buna-N — Satisfactory for "O" Rings
5. Polyacetal — Satisfactory to 72° F.
6. Ceramag — Satisfactory to 72° F.

Geometry: TTV

- Calibrate
- Measurement
  - Grid
  - Points
  - Surface[7]
- Characterization





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Bow

- Note the median surface center point
- TTV variations removed by calculation
- Positive value = convex
- Negative value= concave

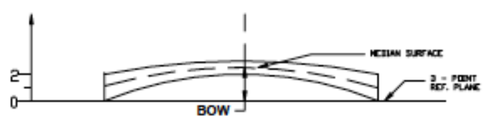
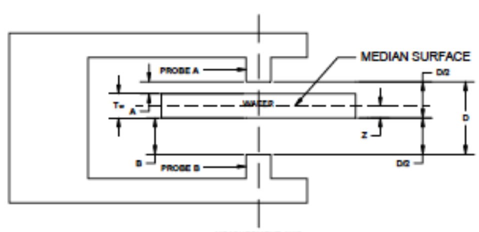


Figure 3



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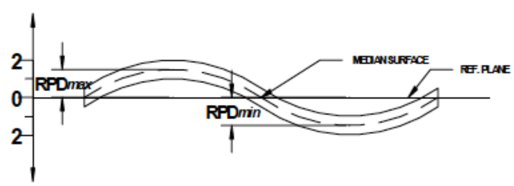
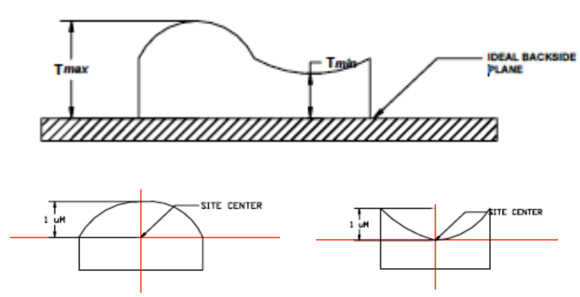
Warp

- More detailed than bow, but references the entire median plane
- TTV variations removed
- Distance from the reference plane (RPD)



Geometry vs Forces

- Pressure required to flatten substrate
- Surface Area
- TTV, CTE are "fixed"

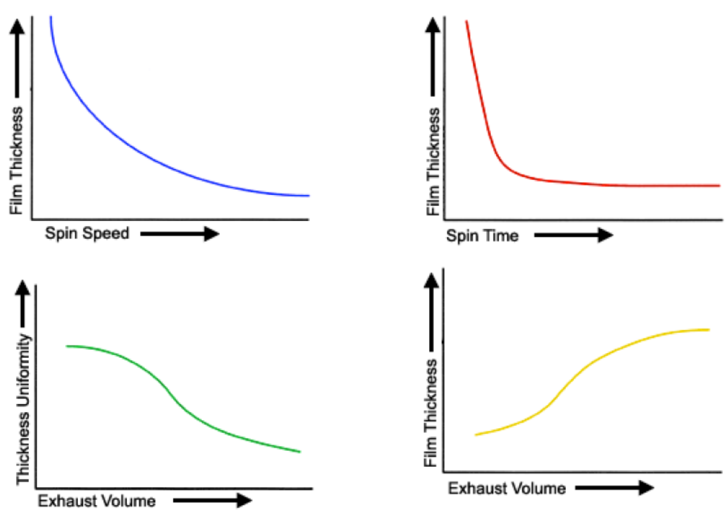


D. Applied Concepts: Spin Coating

- Generate an in-house spin-speed curve for the material.
- Re-create this curve periodically, this simple test should indicate the stability of the R&D lab to coating variations.
- Optimized spin coating
  - Devoid of particles
  - No bubbles
  - Flat
  - Lowest possible adhesive usage
  - Fastest possible cure
  - Covers all topography with a "safety zone"

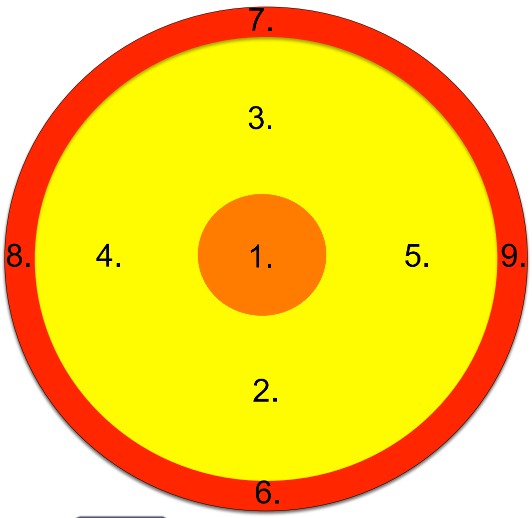
Spin Coating

General Process Trends Visualized



Spin Coating

5 and 9 Point Metrology



- 5 Point metrology is able to identify many effects with the substrate.
- 9 Point metrology is needed for temporary bonding to quantify the edge bead.

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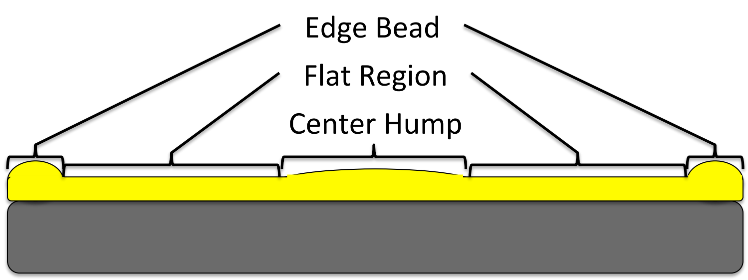
Spin Coating

Non-Optimized Spin Coating Profile



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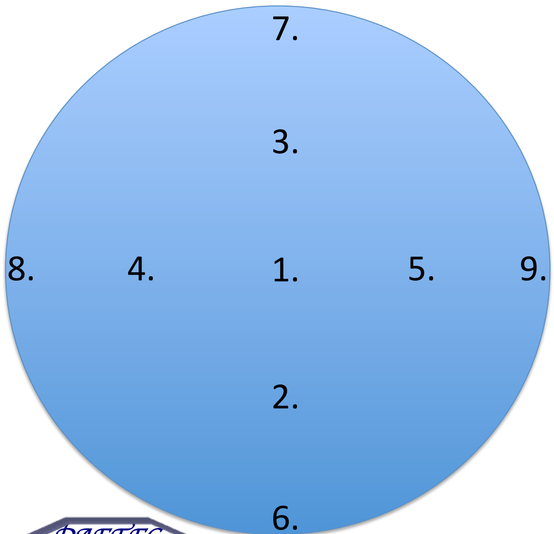
Spin Coating

5[a] and 9[b] Point Metrology



1. Center
2. ≈Radius/2
3. ≈Radius/2
4. ≈Radius/2
5. ≈Radius/2
6. On edge bead
7. On edge bead
8. On edge bead
9. On edge bead

a. SEMI standard method
b. Daetec standard method

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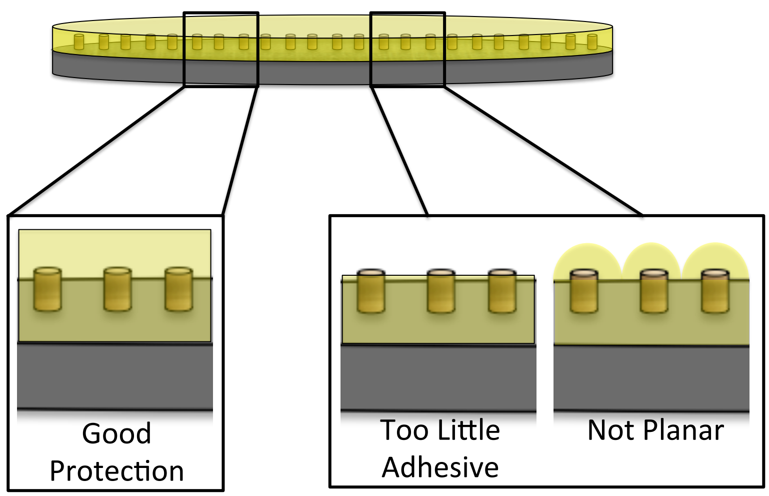
Spin Coating

Topography Considerations



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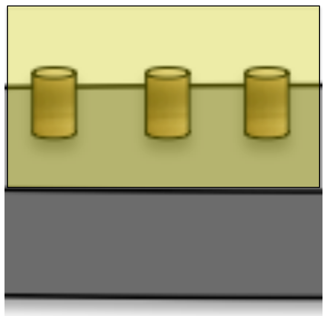
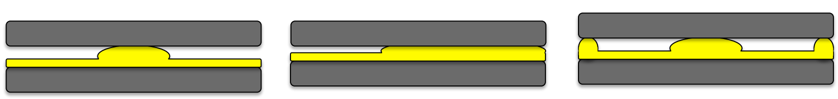
Spin Coating

Overcoat "Safety Zone" For Topography Protection



Spin Coating

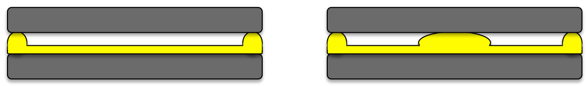
Center Hump Is Too Tall



- Bonded region may be only in the center, sloped, or center and edge bead.
- The center hump can be eliminated by changing the spin process:
  - Increase lag time after dispense.
  - Dynamic dispense.
  - Slow acceleration to maximum spin-speed.

Spin Coating

Edge Bead Is Too Tall

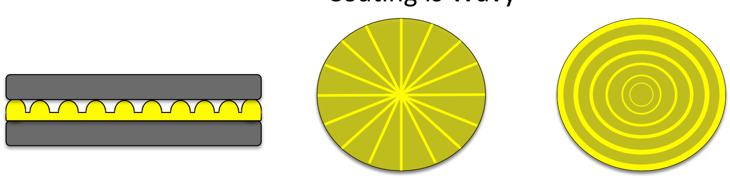


- Bonded region may be only on the edge bead, or on the center and edge bead.
- The edge bead can be eliminated by changing the spin process:
  - At the end of the spin process, a brief, high-speed spin to "throw off" the edge bead.*
  - At the end of the spin process, a brief, slow-speed spin with a solvent stream to "spray off" the edge bead.*
  - "Cut off" the edge bead with a razor blade after cure.*

*Commercially available equipment is available to automate these processes.

Spin Coating

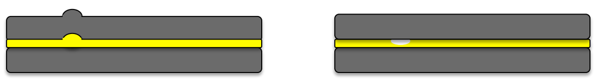
Coating Is Wavy



- A wavy surface can appear as grid like pattern of voids, radial spokes, or concentric circle.
- Wavy coatings can be eliminated by:
  - Increase lag time after dispense.
  - Dynamic dispense.
  - Slow acceleration to maximum spin-speed.
  - Decrease exhaust rate.
  - Low temperature soft bake (70-90°C).

Spin Coating

Irregular Tall/Short Region

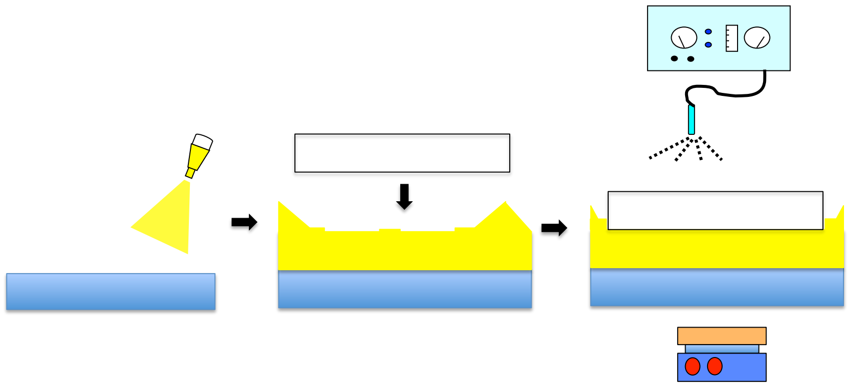


- Irregular surface with no noticeable pattern, is usually due to bubbles, particles, or non-uniform viscosity.
- Irregular surfaces can be eliminated by:
  – Point of use filtration
  – Particle management in the lab
  – Degas sample prior to coating
  – Check dispensing nozzle for burrs and contamination

Adhesive Types

Parameter	100% Solids	Pressure Sensitive Adhesive (Tape)	Thermal Bonding
Bond Temp.	Room Temperature	Room Temperature	> Melting Point of Adhesive
Adhesive Treatment	Removal of Excessive Adhesive	Outgas at Process Temp.	Outgas at Process Temp.
TTV Control	Easy	Difficult	Easy
Bond Strength	Strong	Good	Good
Bubbles Removal	Apply Vacuum while bonding	Difficult	Apply Vacuum while bonding
Bond Pressure	Low	Low	High
Disadvantage	No Outgas Step	Hard to control TTV	High Temperature Bonding

100% Solids



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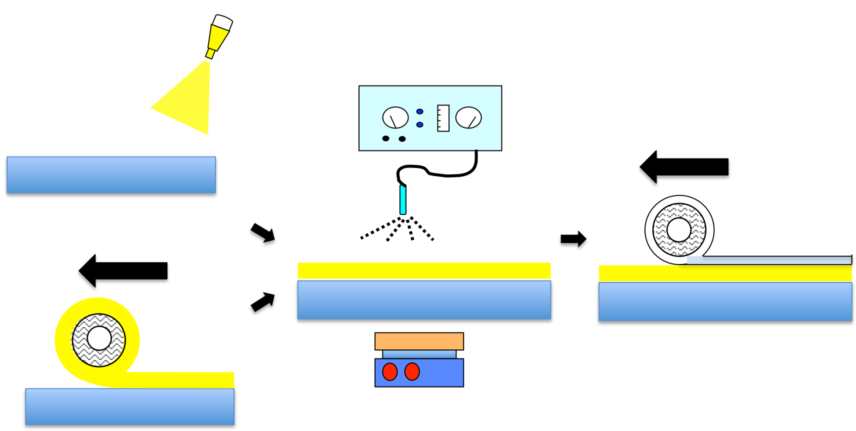
Pressure Sensitive Adhesive (Tape)



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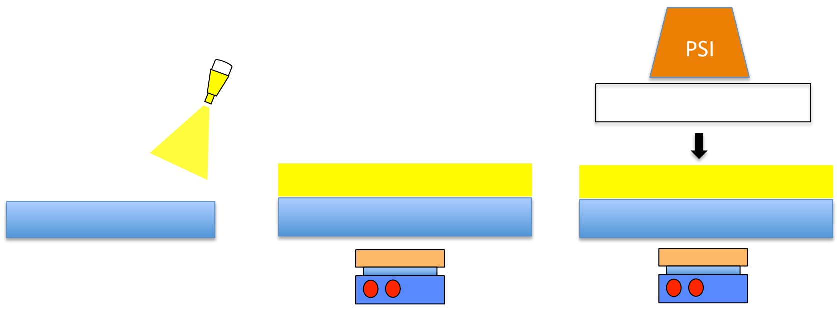
Thermal Bonding



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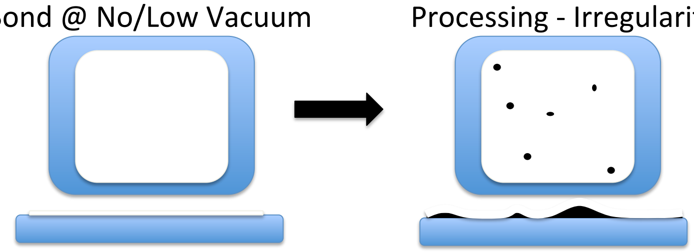
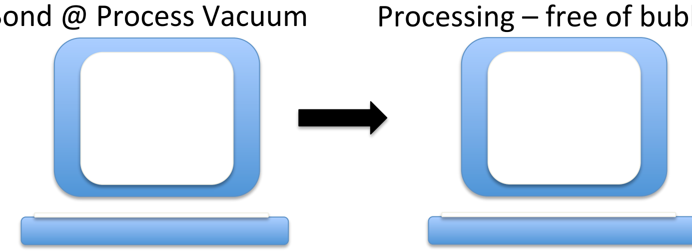
Vacuum

Bond @ No/Low Vacuum Processing - Irregularities



Bond @ Process Vacuum Processing – free of bubbles



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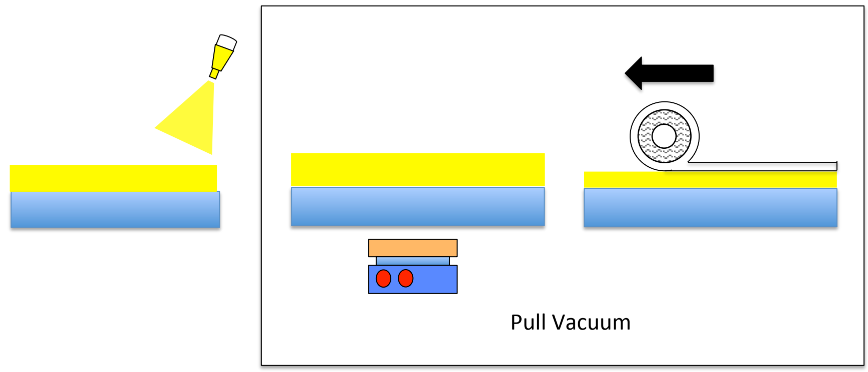
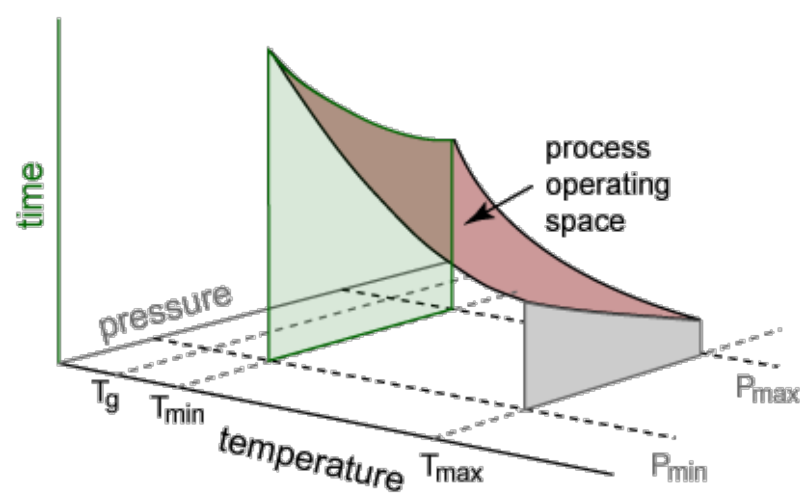
Elimination of Voids



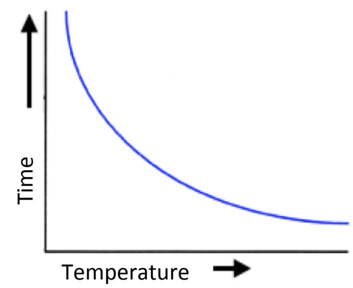
Bonding



Bonding

Time/Temperature Relationship

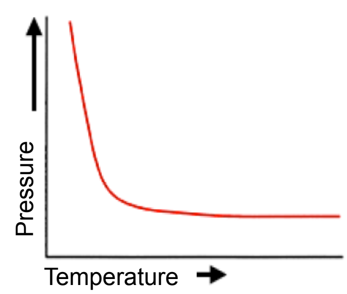
- Temperature α $Time^{-1}$
- An “optimized” system will result in the highest possible yields.
- A low temperature, short time bond would be the ideal cost situation.
- During testing, begin at high temperatures, long time, and work down.



Bonding

Pressure/Temperature Relationship

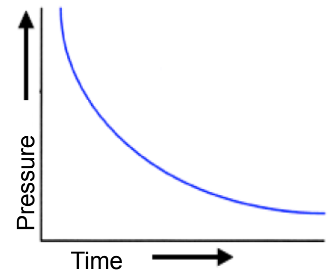
- Temperature α $Pressure^{-1}$
- A low temperature, low pressure bond would be the ideal cost situation.
- During testing, begin at high pressure, high temperature, and work down.



Bonding

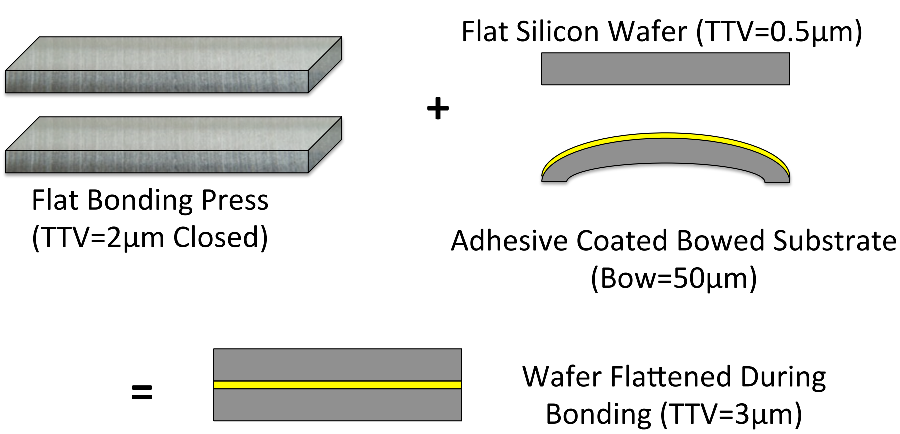
Pressure/Time Relationship

- Time α $Pressure^{-1}$
- A short time low pressure bond would be the ideal cost situation.
- During testing, begin at long time, high pressure, and work down.



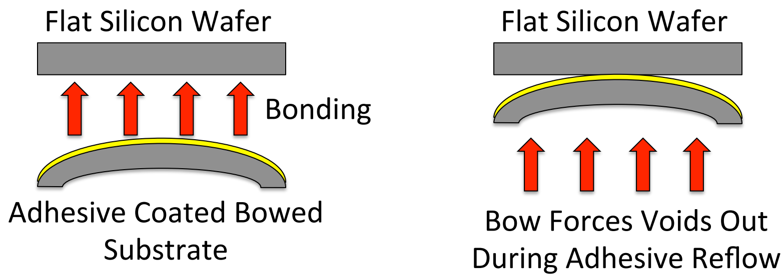
Bonding

Bow



Bonding

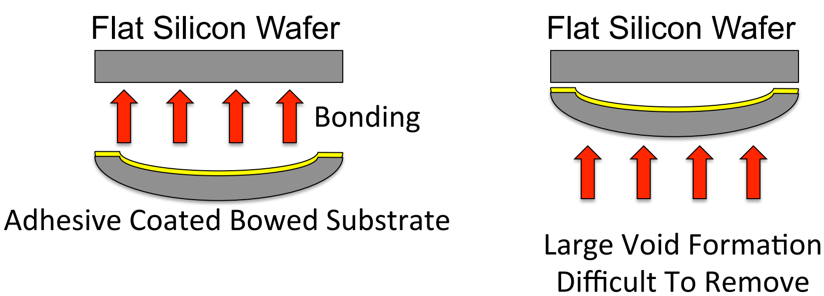
Why is Convex Bow Easy to Bond?



- This configuration can actually make a void free bond easier to obtain.

Bonding

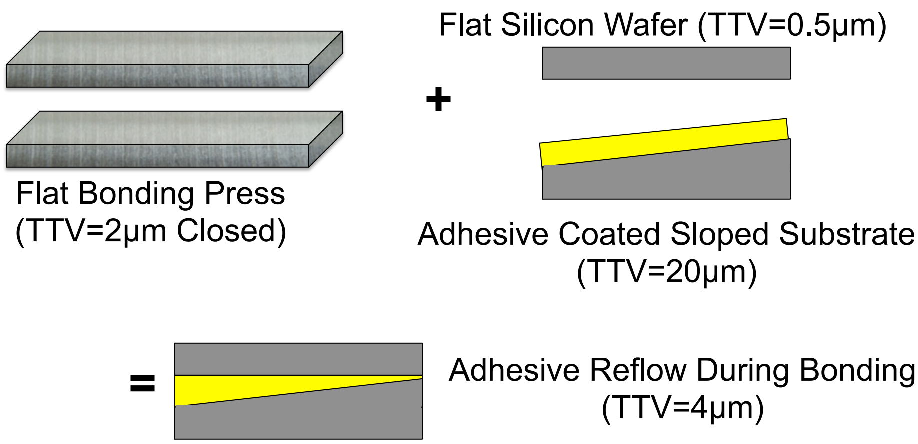
Why is Concave Bow Difficult to Bond?



- Just by changing the orientation of the bow, bonding becomes much more difficult.
- This challenge can be overcome by applying pressure without applying heat (wafer can flatten before tack is developed)

Bonding

Sloped Substrates



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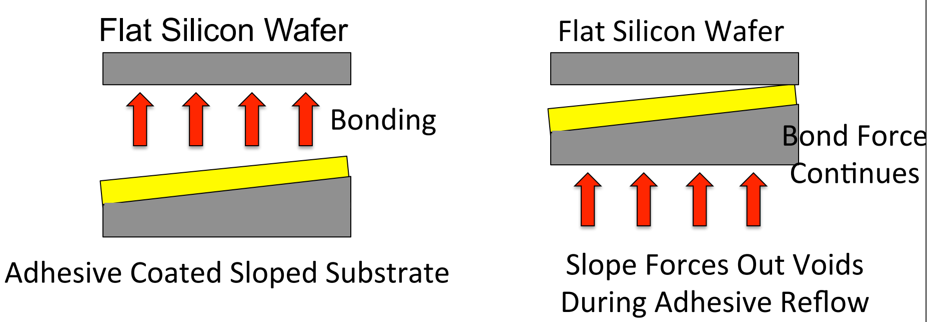
Bonding

Why is Sloped Easy to Bond?



- This configuration can actually make a void free bond easier to obtain.

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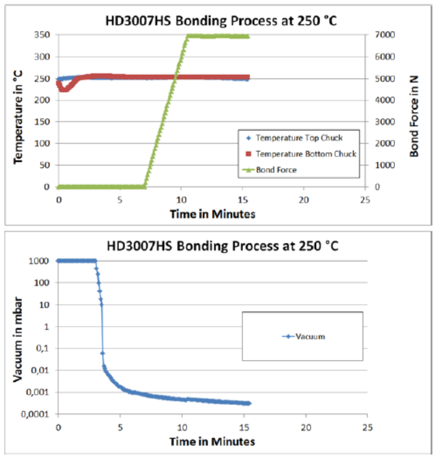
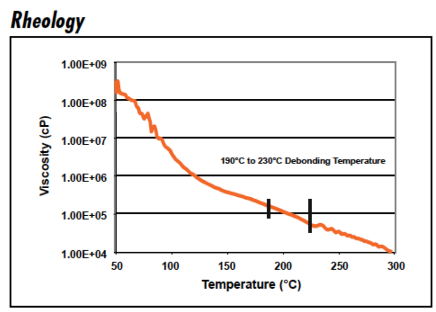
Bonding

Examples



- Image courtesy of DuPont

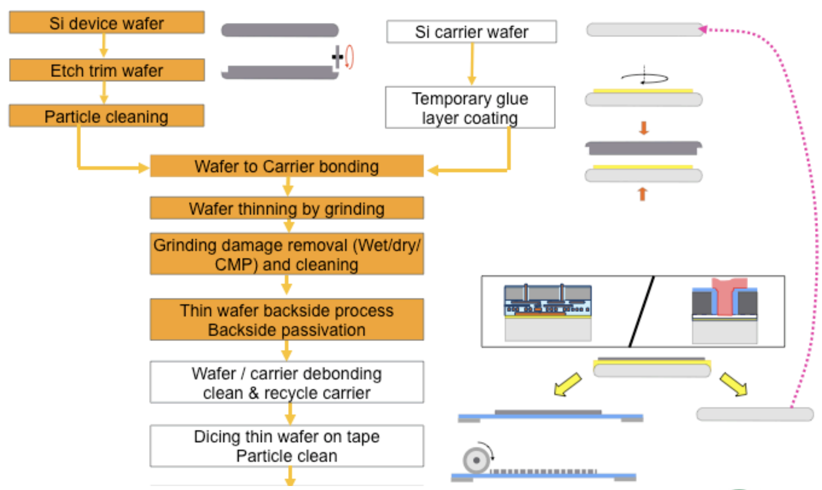


- Image courtesy of Brewer Science

2. Wafers

A. Process Overview
B. Carriers
C. Commercialized Technologies
D. Case Studies

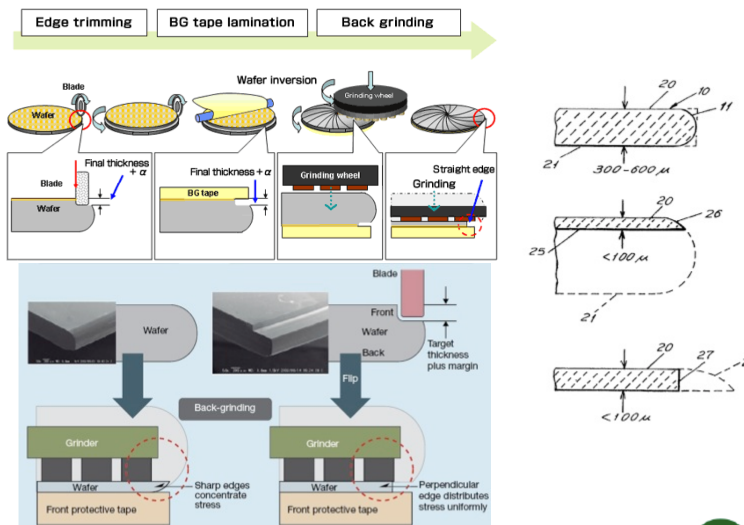
A. Process Overview

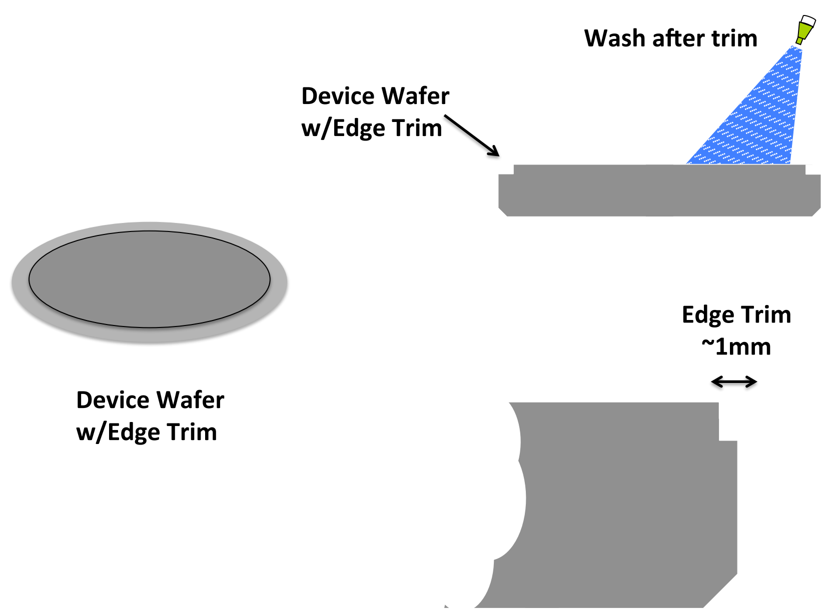


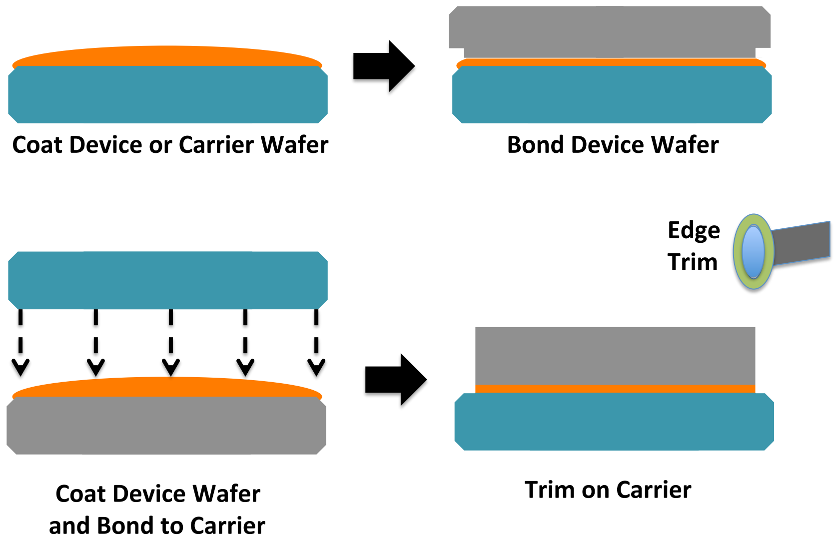
Thinning Trends

- Wafer thinning offers many benefits
- Temporary bonding continues to be a key challenge
- Wafer thickness is expected to drop over time

Edge Trim


Edge trimming
BG tape lamination
Back grinding
Wafer inversion
Blade
Wafer
Grinding wheel
Final thickness + α
BG tape
Straight edge
Grinding
Front
Back
Target thickness plus margin
Flip
Back-grinding
Grinder
Front protective tape
Sharp edges concentrate stress
Perpendicular edge distributes stress uniformly
300-600 μ
<100 μ


Wash after trim
Device Wafer
w/Edge Trim
Device Wafer
w/Edge Trim
Edge Trim
~1mm



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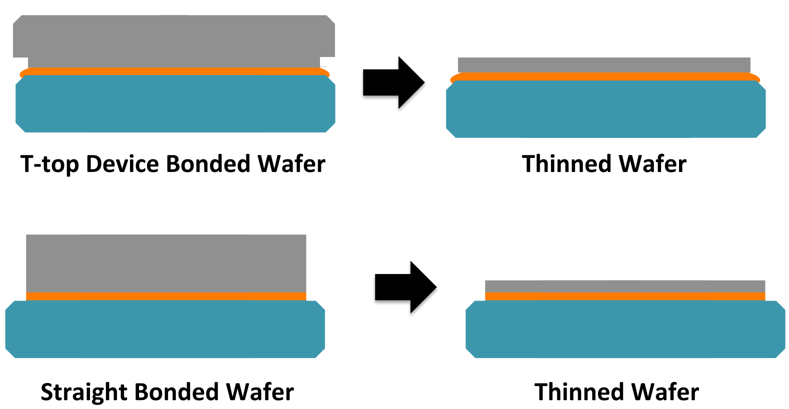
Final Thinning



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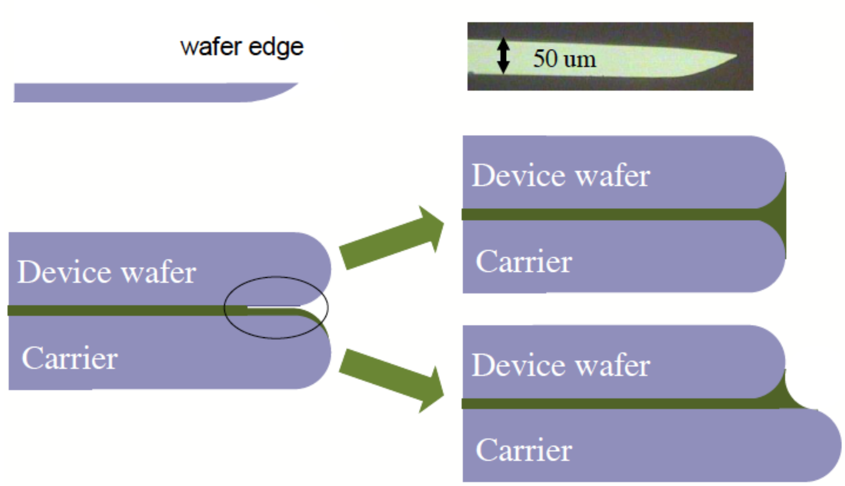
Oversize Carriers



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Bond Types

- 100% Solids Wet Bond
  - Pro: Fast, low pressure/time/temperature bonding, easy to remove voids, covers large topography
  - Con: No post bake prior to bond, squeeze out
- Thermoplastic Bond
  - Pro: Well qualified, significant control of bonding
  - Con: High temperature/time/pressure bonding
- Pressure Sensitive Adhesive
  - Pro: Fast cure, low pressure/time/temperature bonding, TTV easy to control
  - Con: Difficult to remove voids, lower adhesion force

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B. Carriers

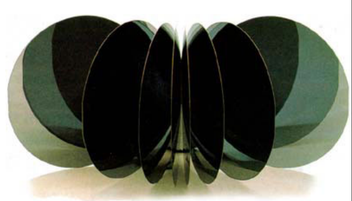
- Silicon
- Glass
- Sapphire
- Tape

Carriers

Silicon

Property	Value
CTE, linear	2.6 ppm/°C
Hardness	7 Mohs
Shear Modulus	64.1 Gpa
Young's Modulus	129-186.5 Gpa

- Standard Carrier
- Preferred for most applications

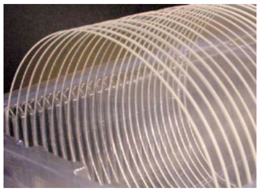


Carriers

Glass

Property	Value
CTE, linear	3.1 ppm/°C
Hardness	5 Mohs
Shear Modulus	30.1 Gpa
Young's Modulus	73.6 Gpa

- Transparency is the key feature
- Structurally weak compared to other substrates



Carriers

Quartz

Property	Value
CTE, linear	0.55 ppm/°C
Hardness	7 Mohs
Shear Modulus	31 Gpa
Young's Modulus	72 Gpa

- Transparency is the key feature
- Structurally weak compared to other substrates

Carriers
Sapphire

Property	Value
CTE, linear	5.9-9 ppm/°C
Hardness	9 Mohs
Shear Modulus	145 Gpa
Young's Modulus	345 Gpa

- Structural integrity is the key feature
- High cost, # of recycles must be high

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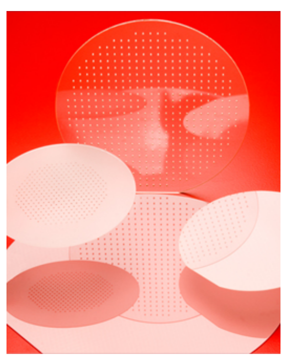
Carriers
Perforated



- Almost exclusively sapphire
- Developed for chemical release

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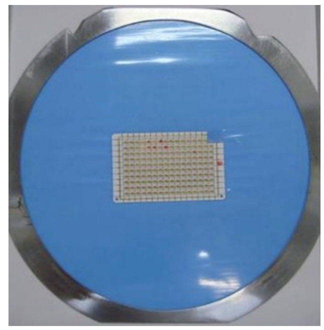
Carriers

Tape



- Ok for minimal post processing
- Minimal tooling required

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C. Commercialized Technologies

- Overview
- Process Flows
- Pro/con

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Overview

	Mechanical Peel	Laser assisted debonding	Thermal slide	Chemical release (as available today)
	The carrier wafer is peeled off using a vacuum roller making use of a plexyglass protecting sheet	Laser breaks the molecular bonds in the adhesive or release layer at the interface to the glass carrier	Viscosity of the adhesive is reduced at elevated temperature which enables to slide off the thin wafer	A solvent penetrates through a porous carrier and dissolves the adhesive between carrier & device wafer
Debonding eq. cost	2,5 mio$	> 2,5 mio$	Med	> 2,5 mio$
Carrier Type	Silicon, Glass	Glass, Sapphire	Silicon	Perf. Sapphire
Carrier cost	Low	Low	Low	Very high
Carrier availability	Up to 12"	Up to 12"	Up to 12"	Up to 6-8"
Stress	Low	Mid	High/Fail	None
TTV	Good	Good	Good	Poor (shadows)
CTE match	100%	Acceptable	100%	Acceptable
Throughput	High (20-30 wph)	High	Low (15-25 wph)	Low (15 wph)

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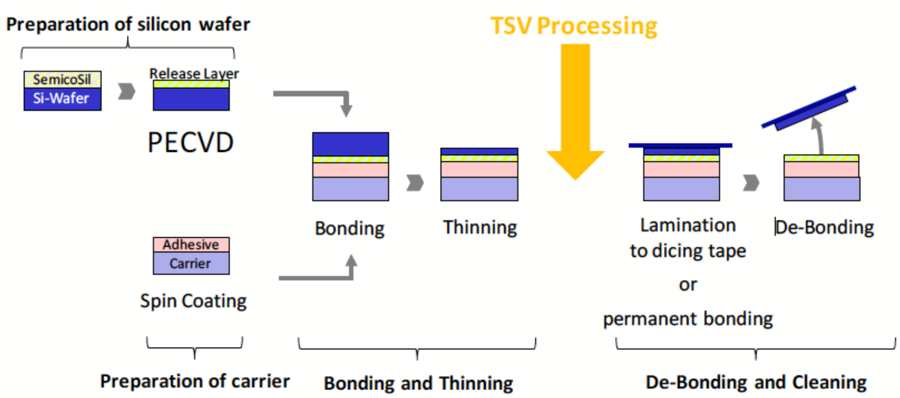
Process Flows

Peelable Glue



- Images courtesy of Thin Material AG

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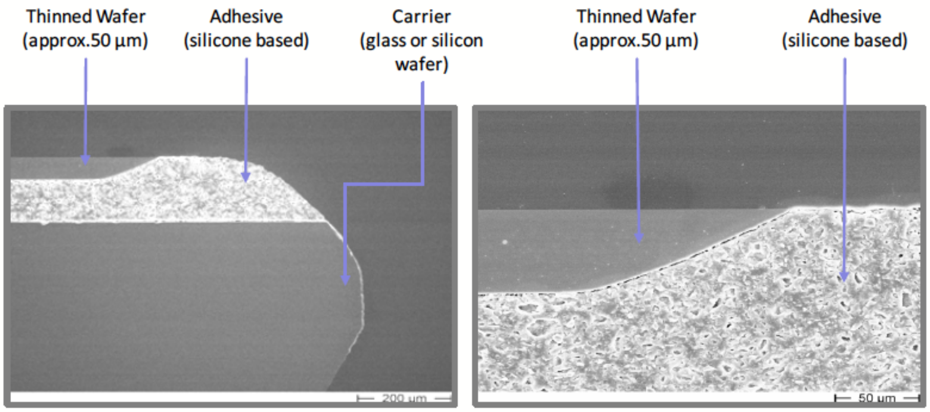
Process Flows

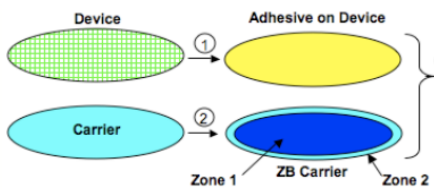
Peelable Glue

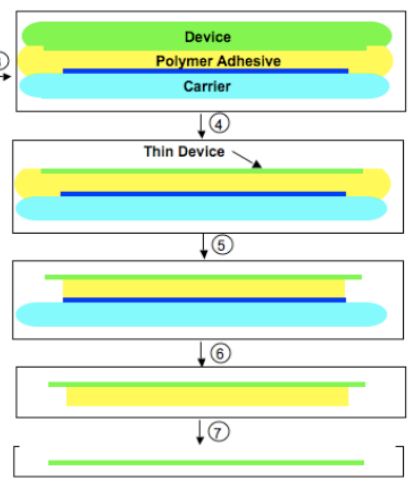


- Images courtesy of Thin Material AG

Process Flows

Peelable Carrier





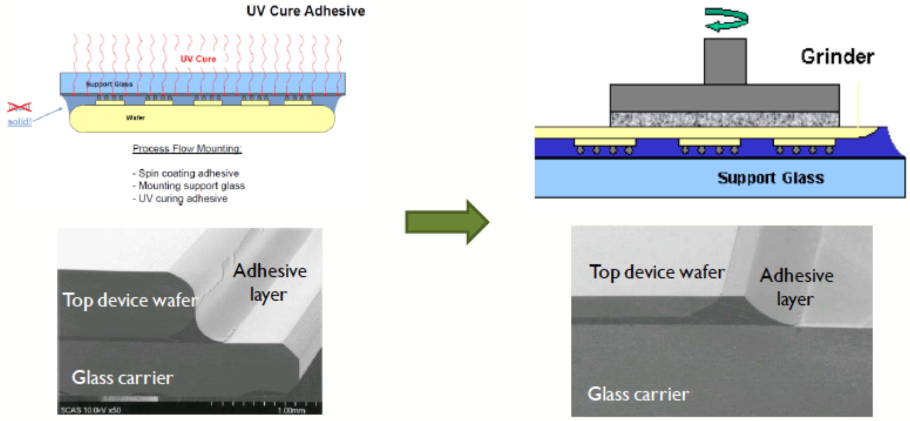
Basic Process Flow:
1. Coat polymer adhesive on Device
2. Fabricate Zone 1 of Carrier→ Release Zone
3. Bond face to face
4. User processes, thin, pattern, etc.
5. Remove adhesive from Zone 2 (Stiction Zone)
6. Peel Carrier from adhesive left in Zone 1
7. Clean adhesive from Device

NOTE: Edge trimmed device is shown in figures

- Images courtesy of Brewer Science

Process Flows

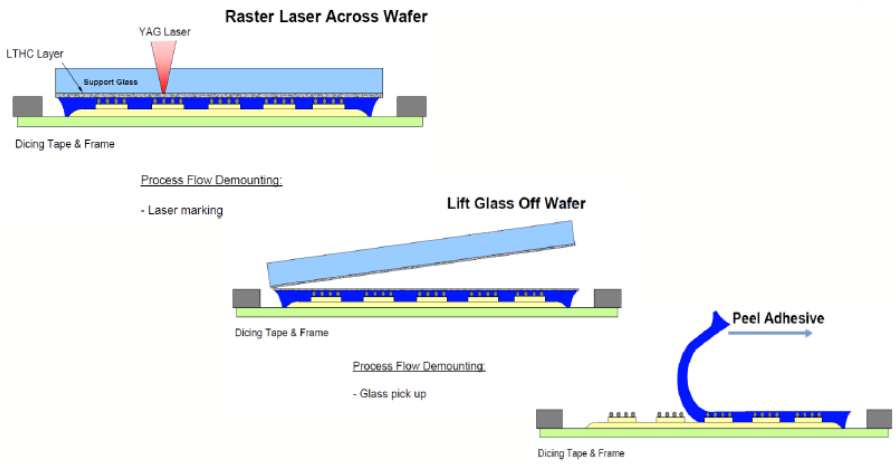
Laser Abladable Glues



- Images courtesy of 3M

Process Flows

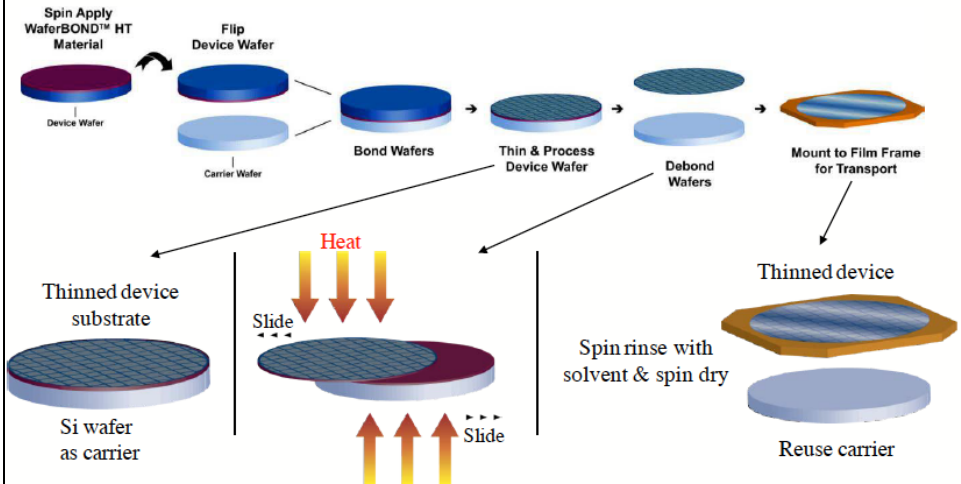
Laser Abladable Glues



- Images courtesy of 3M

Process Flows

Thermoplastic Release



- Images courtesy of Brewer Science

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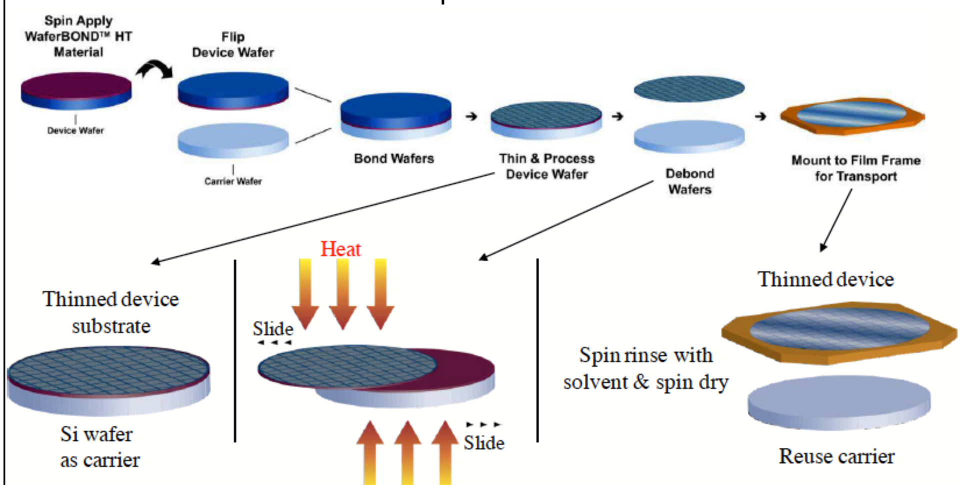
Process Flows

Thermoplastic Release



- Images courtesy of Brewer Science

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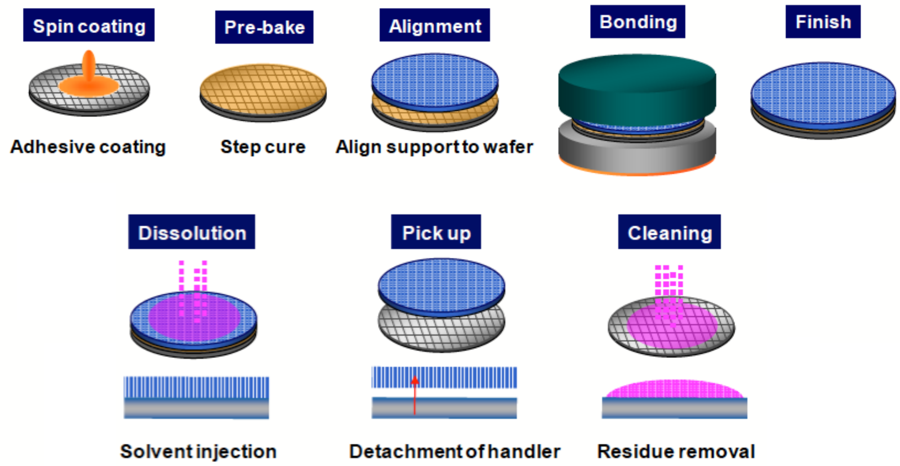
Process Flows

Chemical Release



- Images courtesy of TOK

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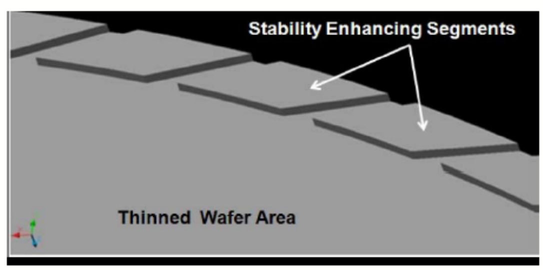
Process Flows

Ring Support



- Images courtesy of DISCO and Doublecheck Semiconductors

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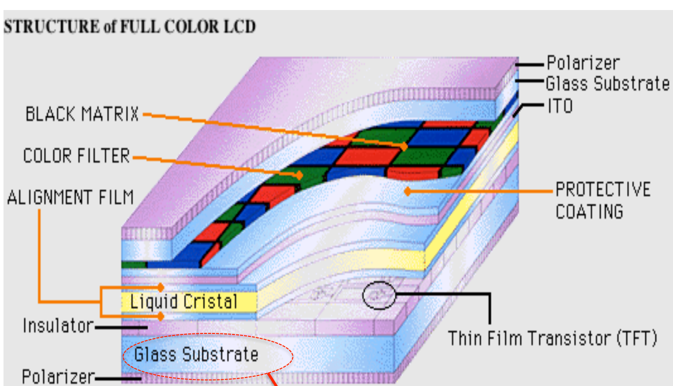
Pro/con

		BSI	BSI (Zonebond)	3M	TMAT	Dupont	BSI, Dupont, TOK
Process	Bond type	Thermo-compression 10-40µ	Thermo-compression 10-40µ	Wet bond 20-200µ	Wet bond 20-200µ	Thermo-compression 10-40µ	Any
Process	Debond type	Slide + CRT	Peel	Laser + peel	Peel	Laser + CRT	CRT
Process	Tooling needed	Thermoslide tool	Peel tool Edge removal tool	Laser tool Peel tool	Peel tool	Eximer laser Perforated carrier	Capture cassette
Process	Post processing	Cleans, tape isolation	Cleans, tape isolation	Cleans, tape isolation	Cleans, tape isolation	Cleans, tape isolation	None
Key challenges	Temperature	200° C max.	250° C max.	250° C max.	300° C max.	450° C max.	Adhesive
Key challenges	Complete cleans	No	Yes	No	No	No	Yes
Key challenges	Geom. damage	Some	No	Some	No	No	No
Key challenges	Additional steps	Release layer Edge removal	Precursor coat, plasma treat	LTHC coat & multi stage debond	Coat Precursor	None	None
Key challenges	Process cost	Mid	Mid	High	Mid	High	High (carrier)
Key challenges	Process speed	Mid	Slow	Fast	Fast	Very slow	Batch
Key challenges	Additional challenges	None	Edge clean before debond	Transparent carrier needed	None	Very long bond cycle	Dimpling 6" max.
Benefits	Key benefits	▪ Standard ▪ Simple	▪ Room t° debond ▪ Geometry safe	▪ Thicker coating ▪ Room t° debond	▪ Thick coating ▪ Room t° debond	▪ High t processes	▪ High yield ▪ Known process ▪ Min. tooling

- Table reflects the experience of Daetec LLC. and should be considered an opinion only

3. Displays



Replacement w/thin, flexible substrates

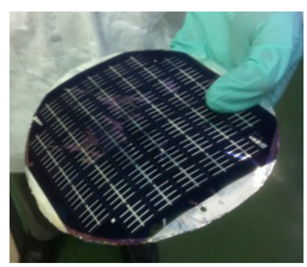
Transparent Display



US Patent: US 8314902 B2

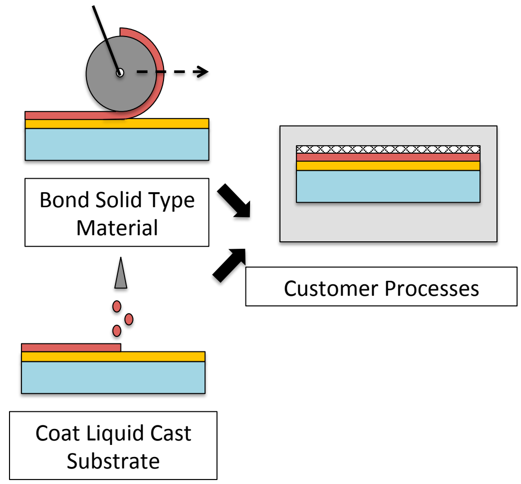
Multitude of Flexible Displays





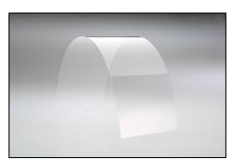
Flexible Display

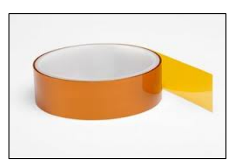
- Solid substrate
  - PET
  - PEN
  - PI
  - Metal + dielectric
  - Composite
- Castable Liquids
  - PI
  - Other



Solid Substrates

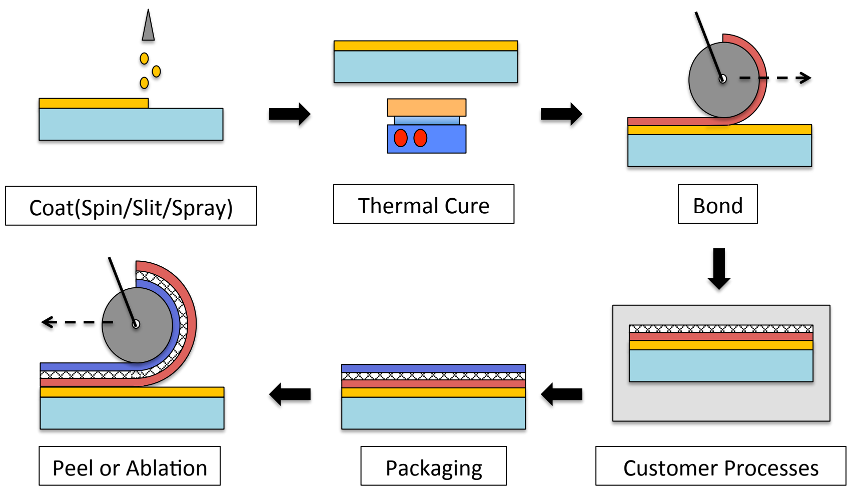
- Bond Types:
  - 100% Solid Wet Bond
  - Pressure Sensitive Adhesive
- Debond Types:
  - Peel



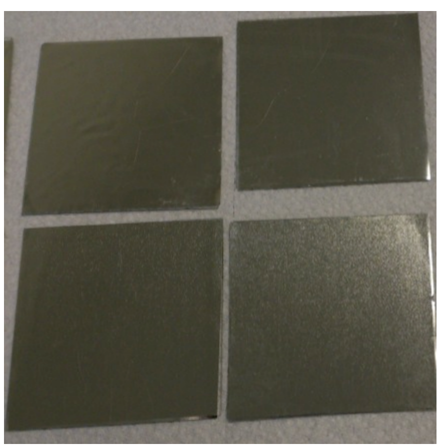


Solid Substrates

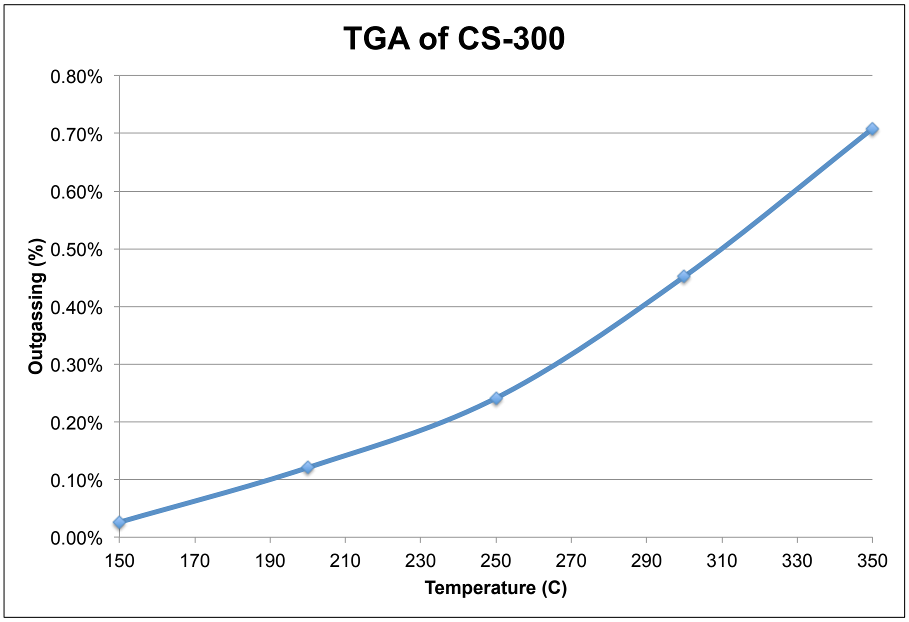
Process Flow



Metal Foil



- Foil Bonded to adhesive according to curing program
- Post baking at 350C for 15 minutes



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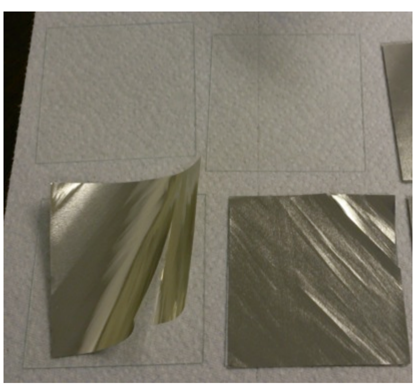
Debonding by Peeling



- Foil peeled off from adhesive after 350C
- Integrity based upon thickness, tool, & process
- Adhesive can be tunable to customer's process and requirements

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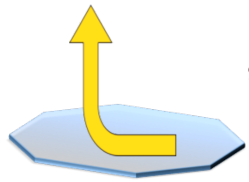
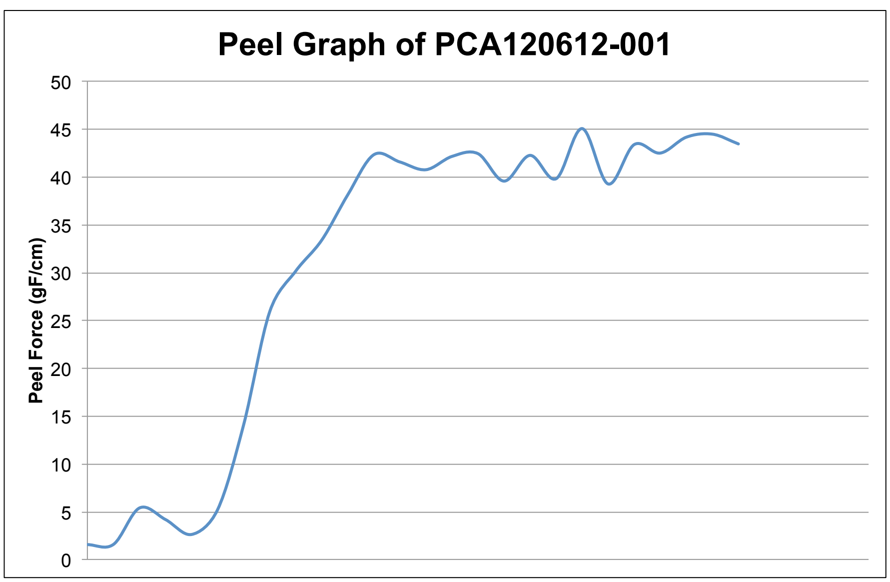
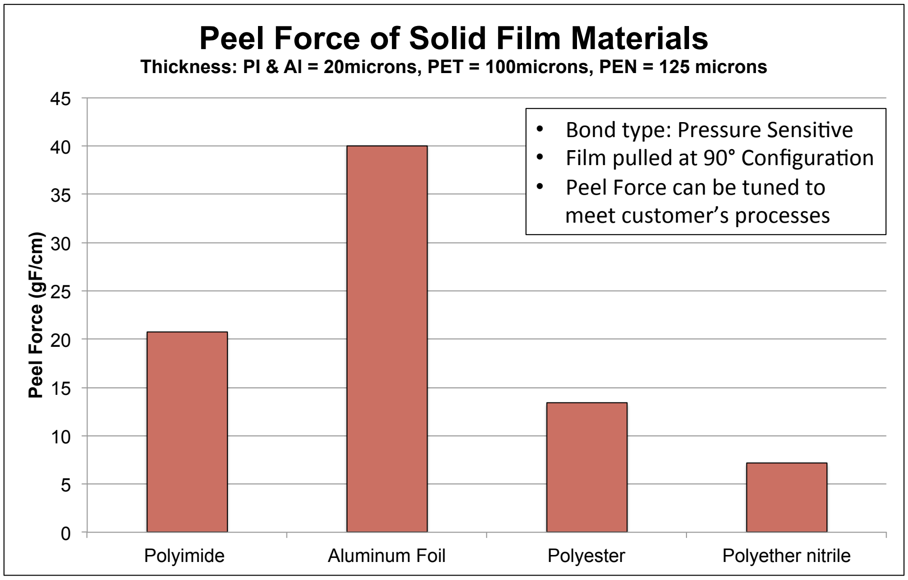
Peel Testing



- 90º Peel test following ASTM protocol
  - 5 mm/s peel speed
  - 1 cm cut width
  - Use of Mark 10 motorized force test stand and M5-10 force gauge with MESUR™ gauge software.



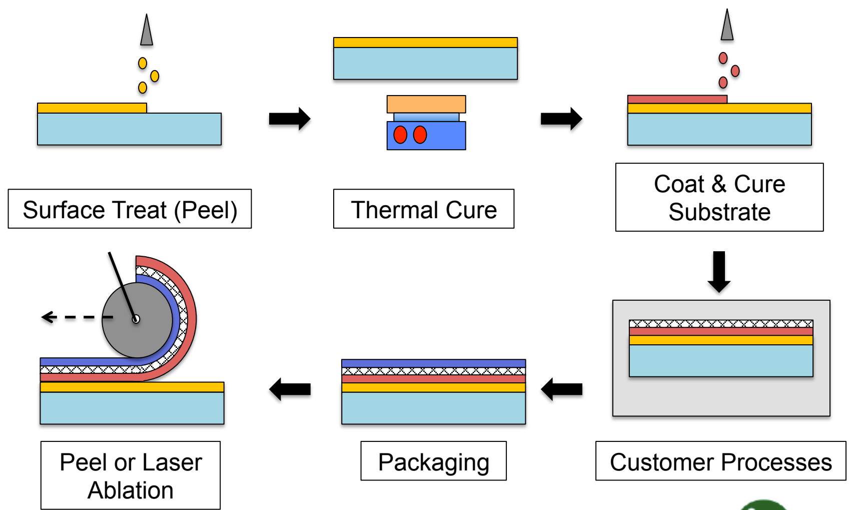


Castable Substrates

- Slit or Spray Coat
- Debond Types:
  - Laser Ablation
  - Peel

Castable Substrates

Process Flow



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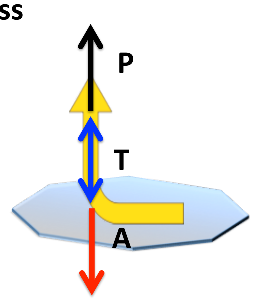
Tunable Adhesive

Objectives for Robust Process

- High tensile product
- Ability to withstand many artifacts, especially as the process varies



Robust Process:

- **High A – tune until no irregularities**
- **Ensure T >> A**
- **Then proceed to adjust P for demount**

- Daetec is working on a tunable adhesive for the thermal resistant film between the primer and the glass

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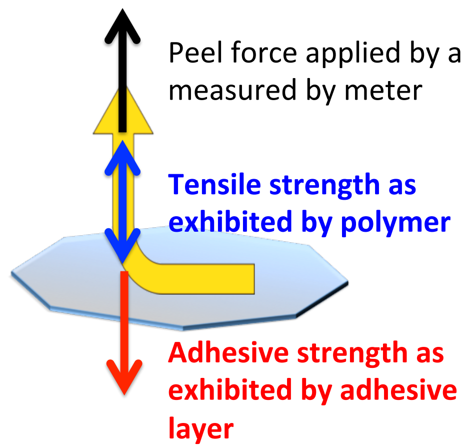
Discussion



Model of thin substrate peeling with adhesive layer, minimizing bubble formation

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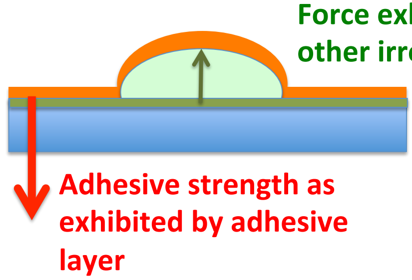
Bubble Model

Bubble forms when force of irregularity > adhesive



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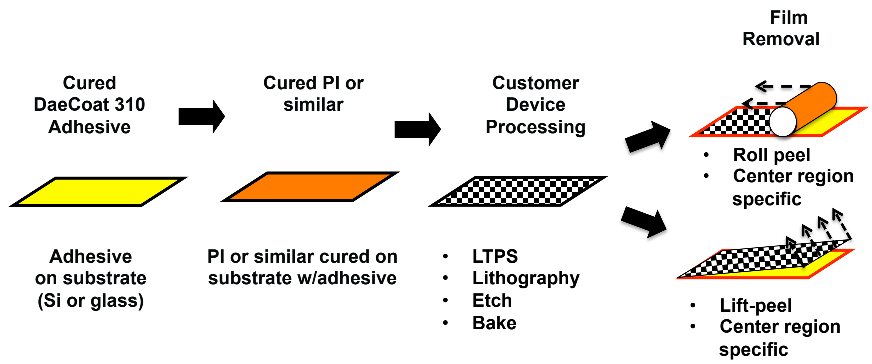
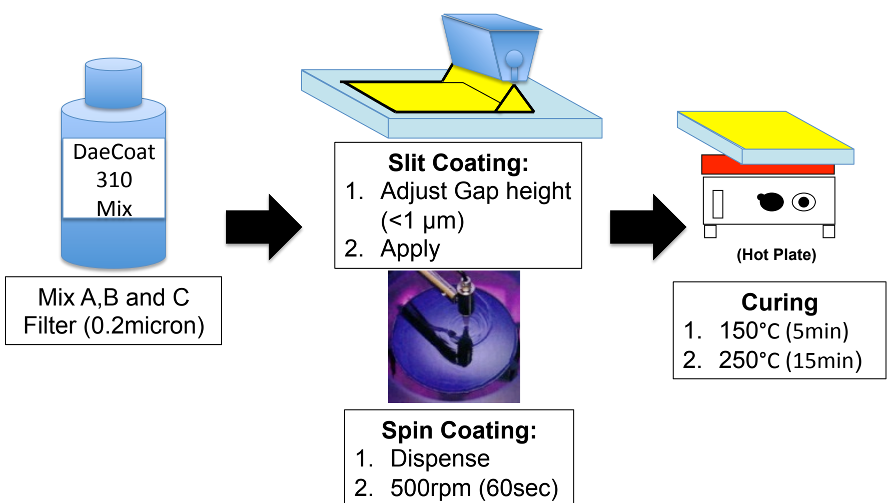
Common Use – Process Flow

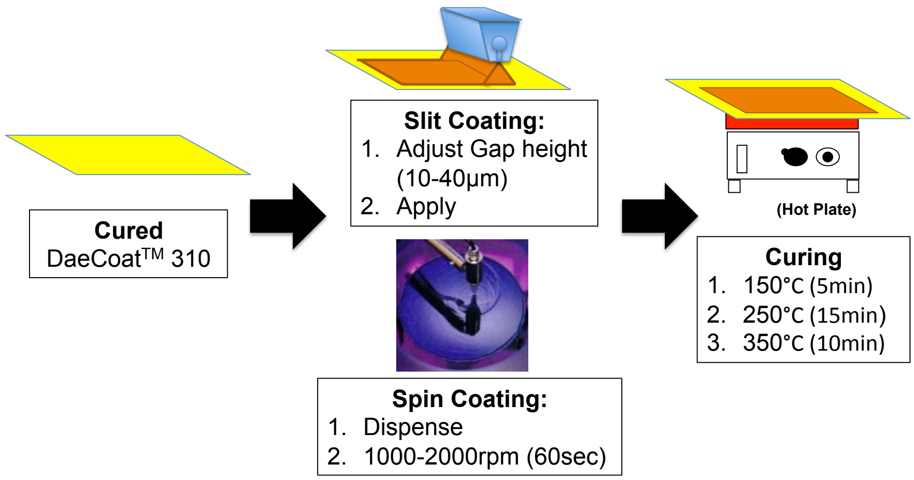


Adhesive: DaeCoat™ 310



PI or Similar Coating

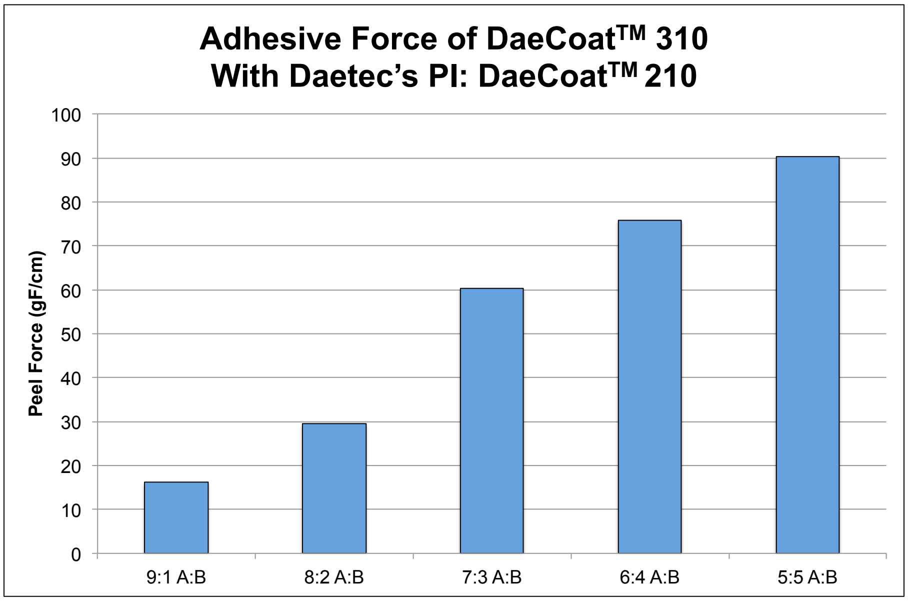
Daetec's Polyimide: DaeCoat™ 210



Mixing DaeCoat™ 310

310 Product	Description	9:1	8:2	7:3	6:4	5:5
Part 1	Polymer A	18	16	14	12	10
Part 2	Polymer B	2	4	6	8	10
Part 3	Solvent	80	30	30	30	30

* Ratios reported relative to polymer A:B.



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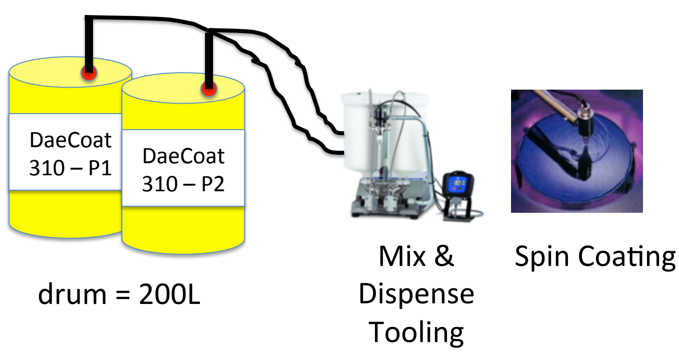
High Volume Manufacturing



DaeCoat™ 310 components are stable for long shelf-life prior to mixing.

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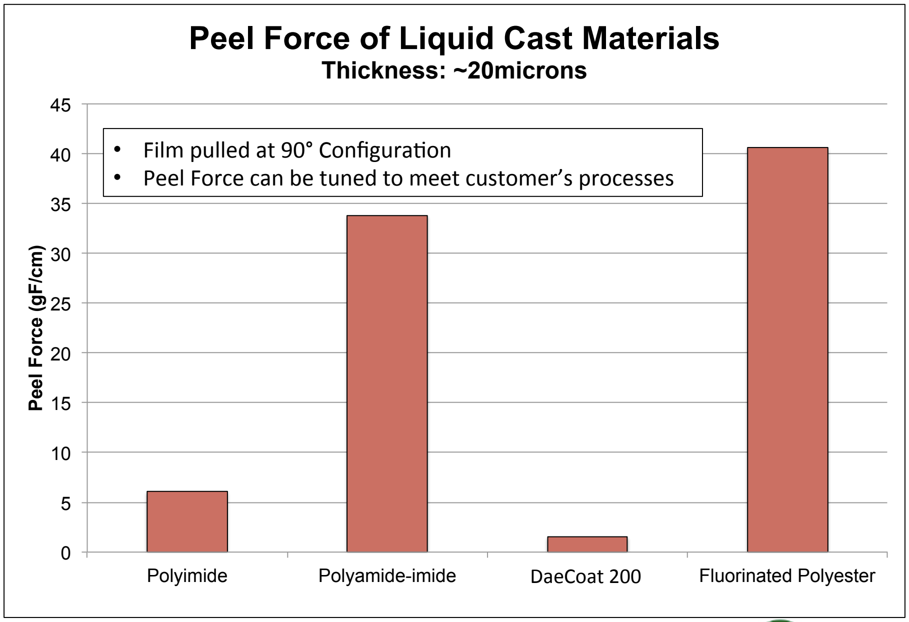
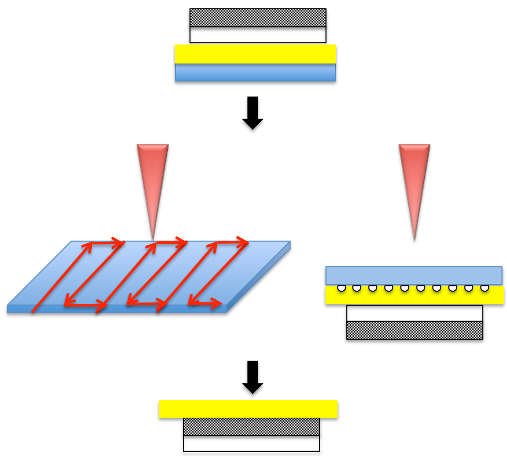


Debond Methods

Debond Method	Equipment	Throughput
Laser Ablation	Laser Ablation System	Low
Chemical	Wet Bench	High
Back Grinding	Grinding System	Low
Saw Separation	Diamond Saw	Low
Chemical Etching	Wet Bench	Low
Vacuum Pull	Vacuum Chuck	Medium
Peel	Peel Tool with Drum	Medium

Laser Ablation



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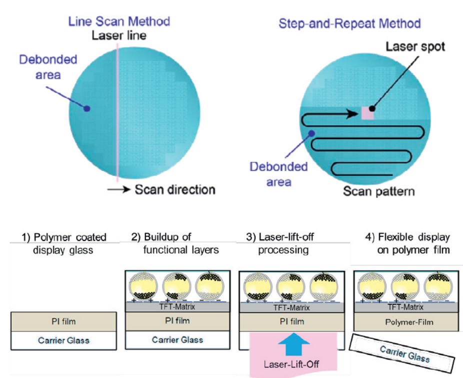
Laser Ablation

- Proven process
- Effective for small substrates
- Commercially available equipment



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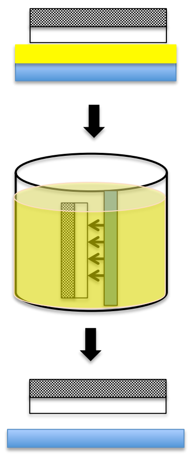
Chemical



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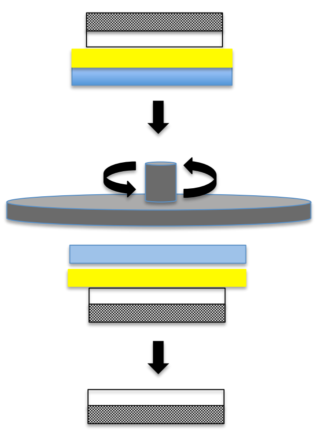
Back Grinding



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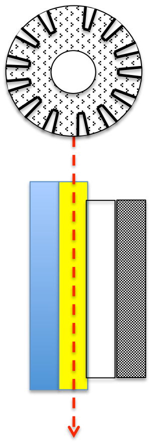
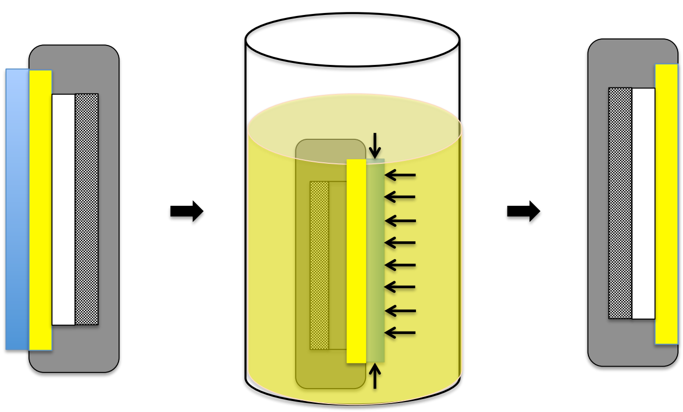
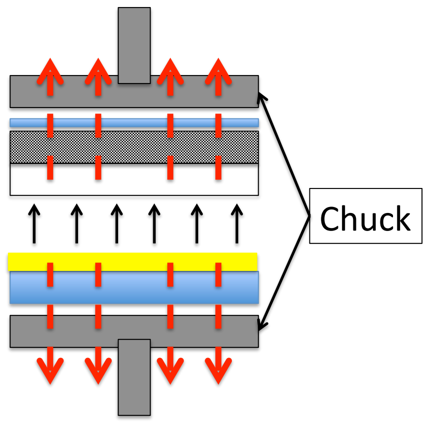
Diamond Saw Separation

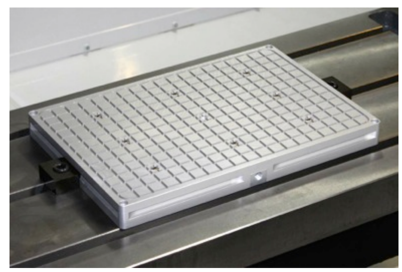


Chemical Etching



Vacuum Pull





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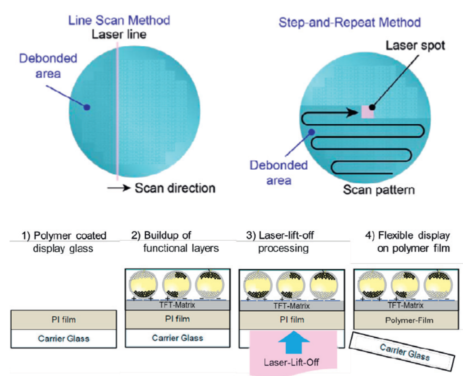
Peeling

- Proven process
- Effective for any size substrates
- Peel equipment must be developed in house



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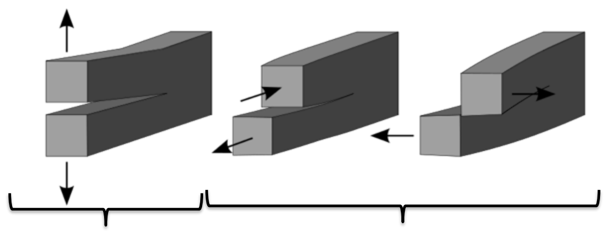
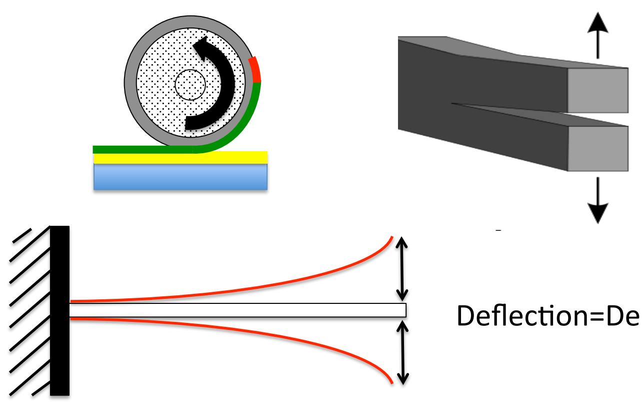
Peel De-bond Mechanics



Used by Daetec

Common Practices

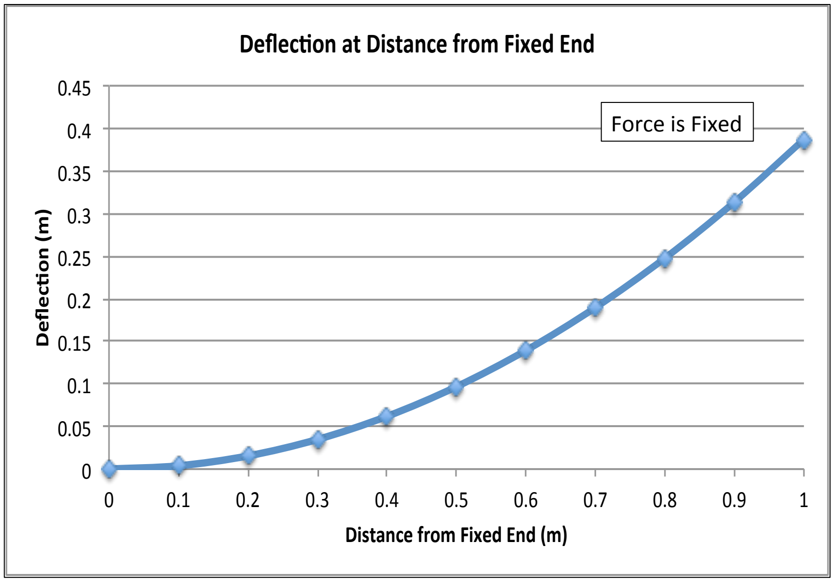
Modeling



Deflection=Debonding

Fixed End

Free End



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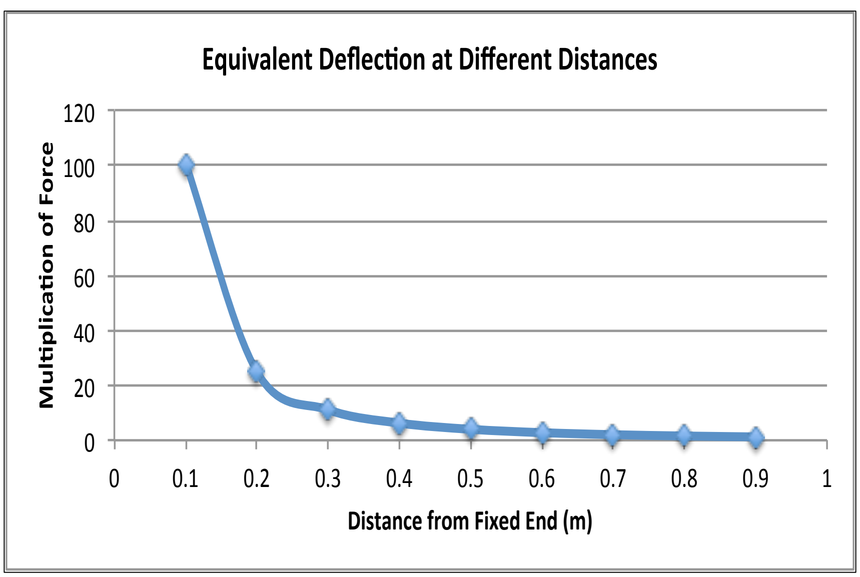

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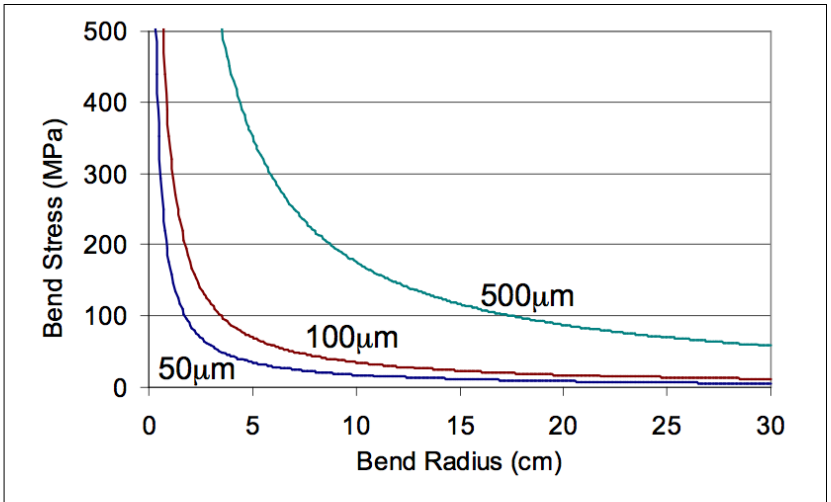
Glass Properties



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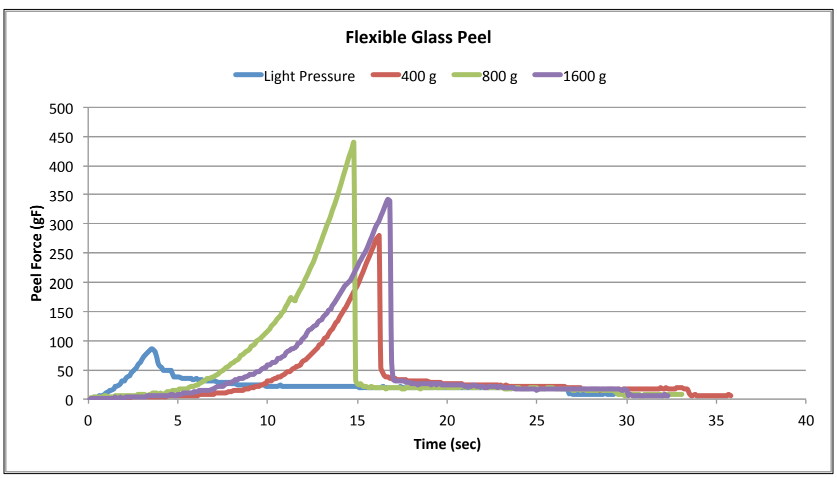
Peel Results



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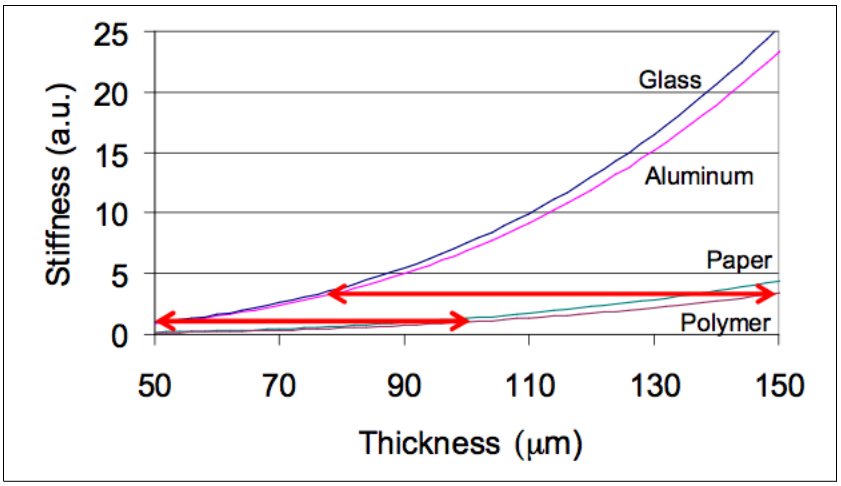
Material Behavior



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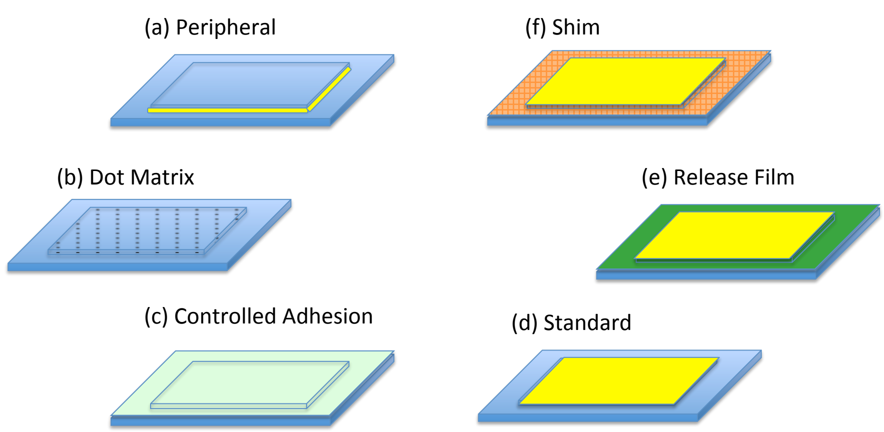
All Configurations



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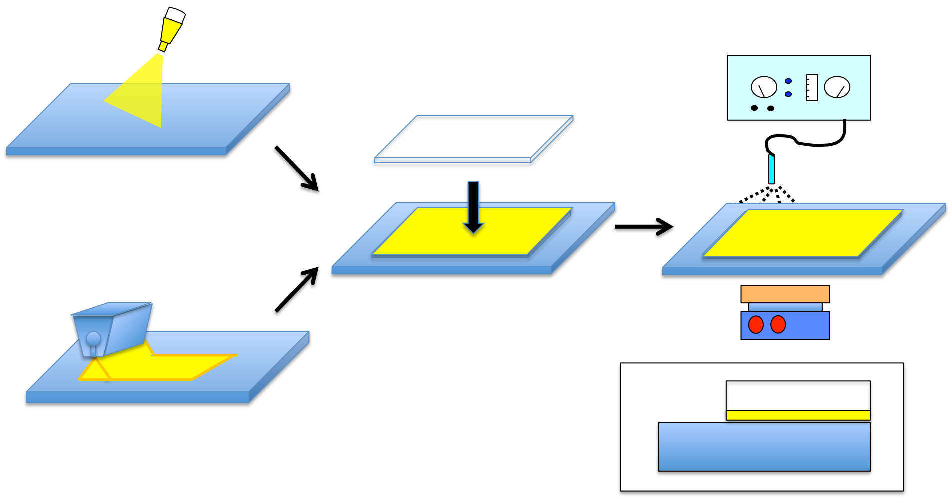
(a) Standard Bond



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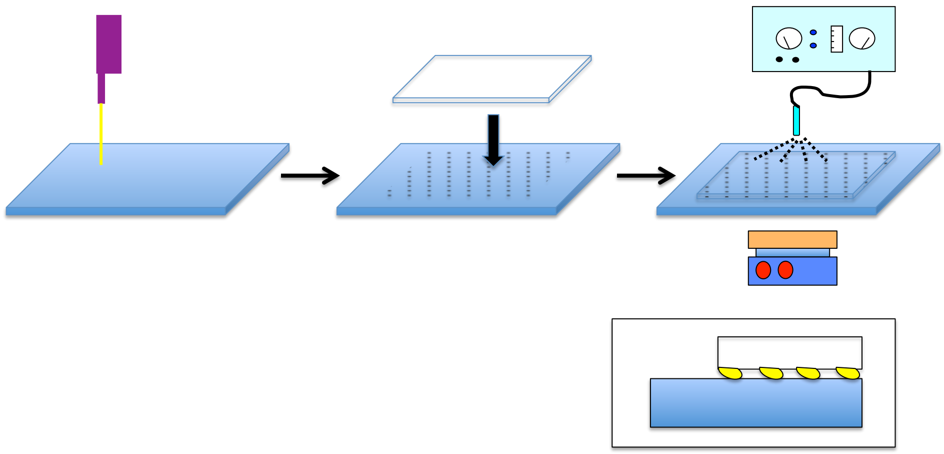
(b) Dot Matrix



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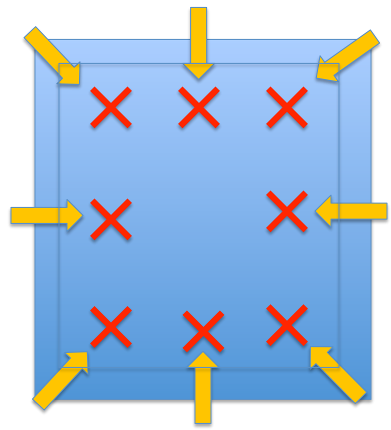
Dot Matrix vs. Standard Bond



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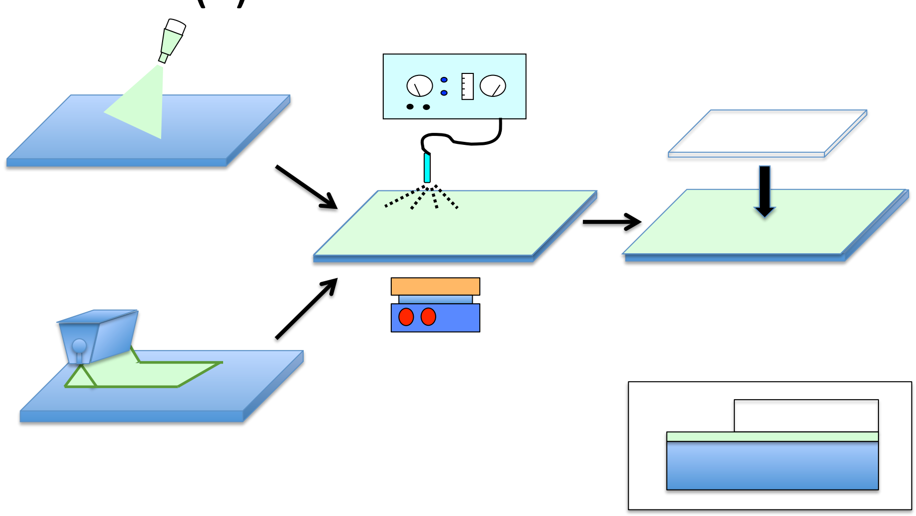
(c) Controlled Adhesion



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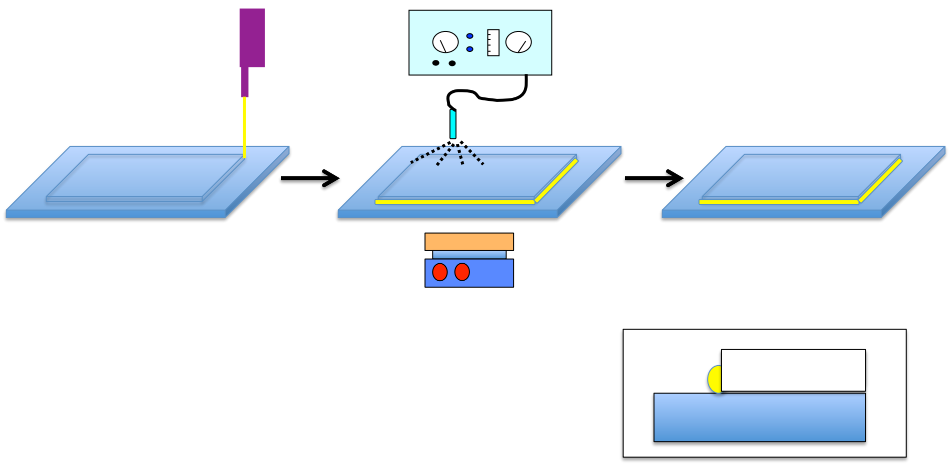
(d) Peripheral Bond



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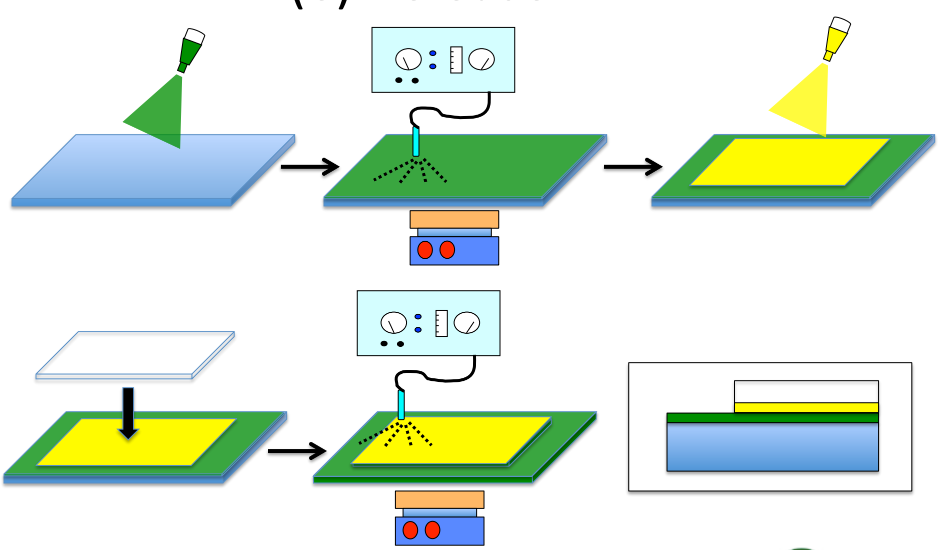
(e) Release Film



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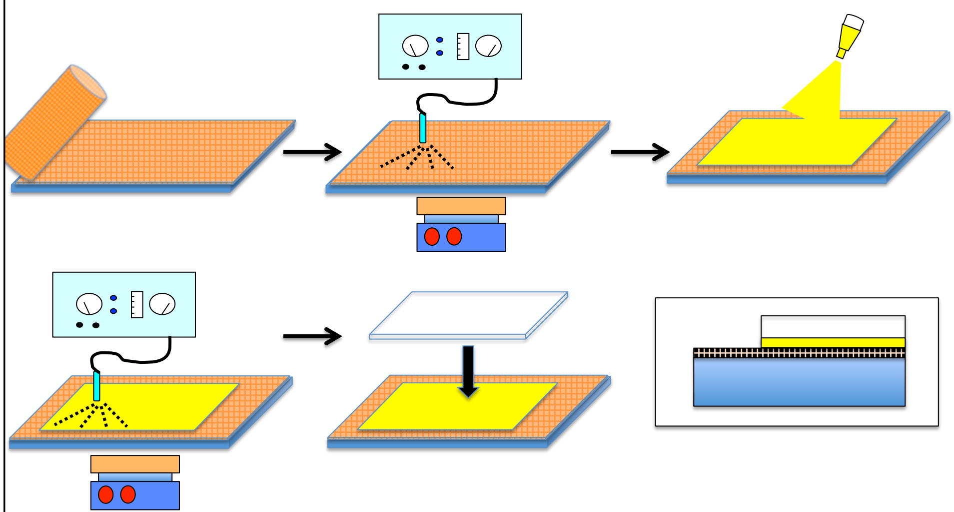
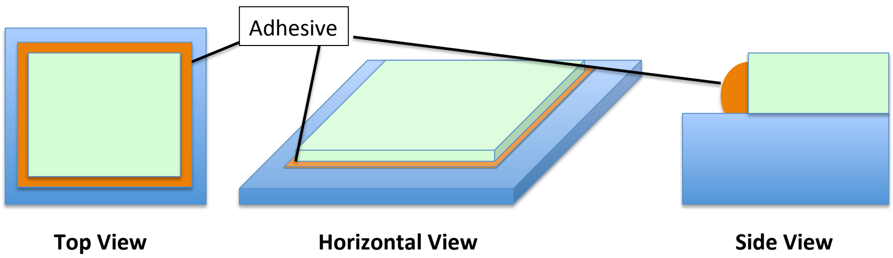
(f) Shim



(A)Peripheral Bond

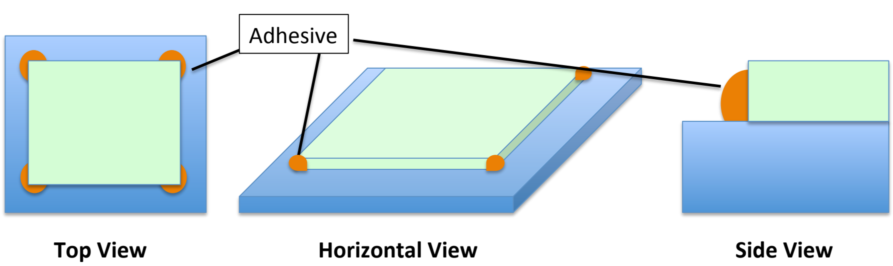
Parameter	Standard Bond	Peripheral/Spot Bond
Clarity	Adhesive Dependent	Not Applicable
Thickness	< 30 um	Not Applicable
Coat Method	Spin, Slit, Spray	Syringe Dispense
Air Bubble	Pressure, Time, TTV	Not Applicable
Cure Method	Thermal, Catalytic	Thermal, Catalytic
Thermal Resistance	Less Concern	Adhesive Dependent
Chemical Resistance	Less concern	Apart from Cleaner
Align	Optical	Optical
Debond Method	Not Debondable	Wet Chemical
Equipment	Coater, Laser Ablator, Saw	Syringe Dispenser, Dip

(A)Peripheral Bond



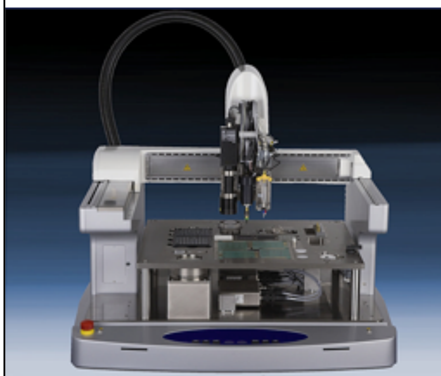
- Peripheral bond uses a minimal amount of adhesive to achieve and maintain a very strong temporary bond between substrate and carrier during substrate processing.

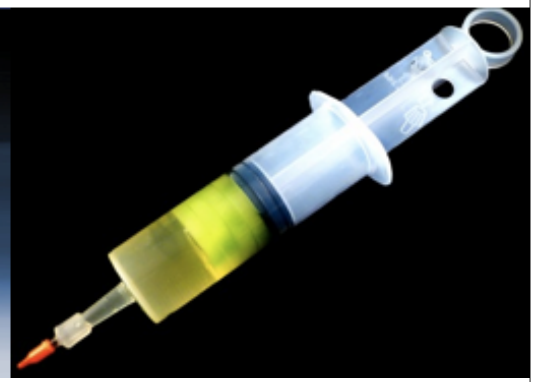
(A)Peripheral Bond: Spot Bond



- Spot bond uses a minimal amount of adhesive to achieve and maintain a very strong temporary bond between substrate and carrier during substrate processing.

(A)Peripheral Bond: Syringe Dispense





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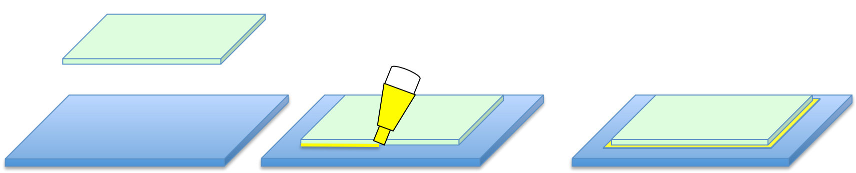
(A)Peripheral Bond: Syringe Dispense



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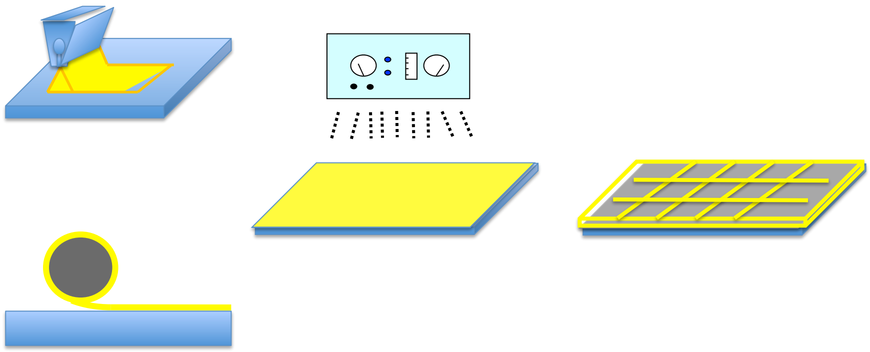
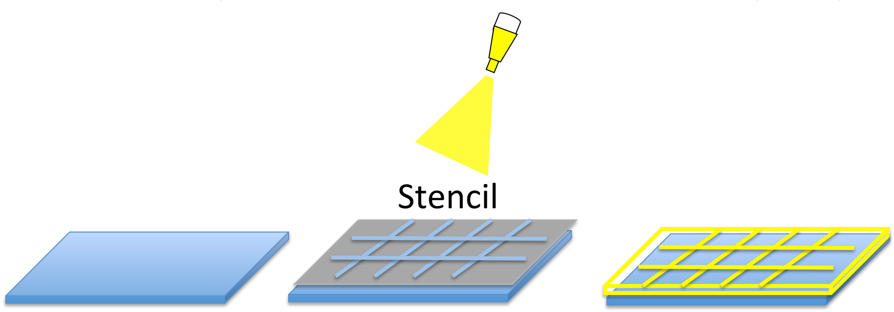
(A)Peripheral Bond: Pattern Deposit

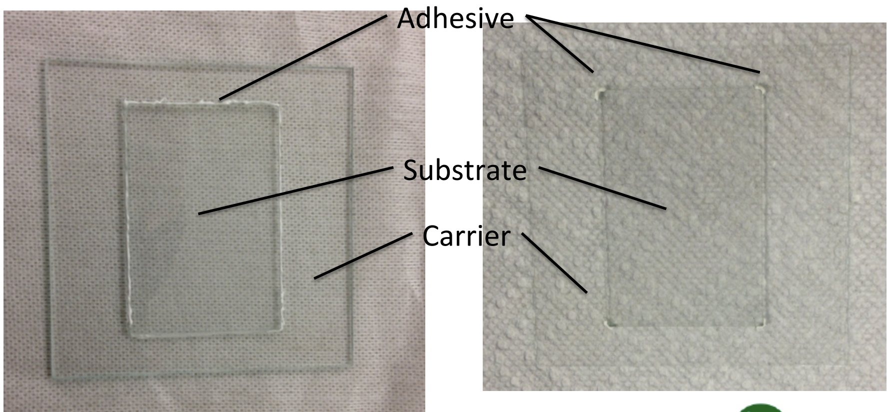


(A)Peripheral Bond: Pattern Spray



(A)Peripheral Bond

Peripheral Bond | **Spot Bond**



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(A)Peripheral Bond: Comments

- Peripheral bond does not require 100% solids, transparency, or special debonding tools.
- Voids may not be a concern for many applications.
- Minimal adhesive usage (very large substrate may only be several grams)
- This permits many new polymers to be considers for peripheral Bond.
  - Polyimide (>450C stability)
  - Polybenzimidazole (>500C stability)
  - Glassy polymers (>500C stability)

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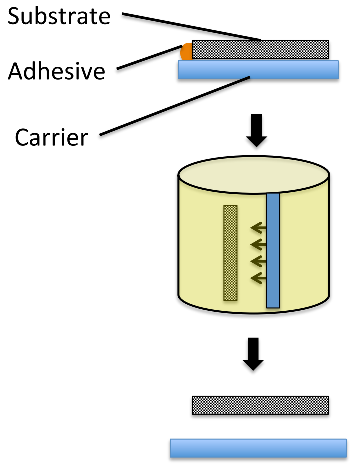
(A)Peripheral Bond: Batch Debond



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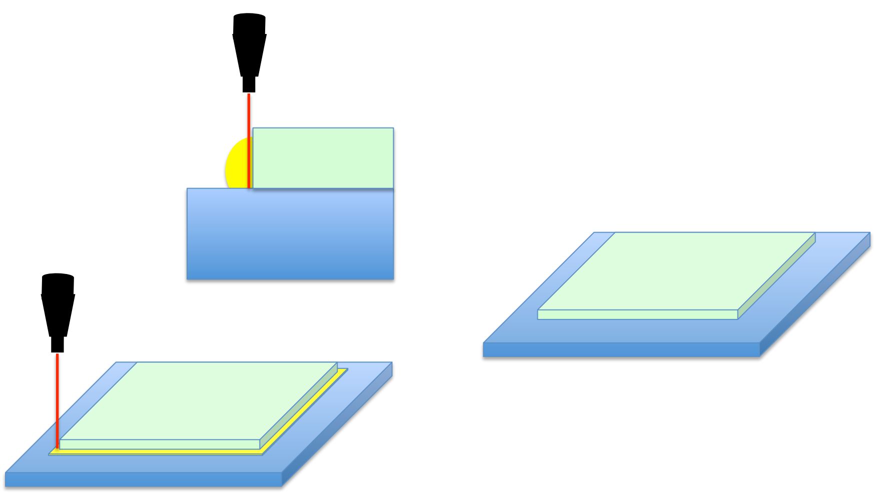
(A) Peripheral Bond: Cut Debond



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(A)Peripheral Bond: Glass Fusion

- 2 Glass substrates bonded by peripheral bond
- Spontaneous thermal fusion between glasses can occur during high temp. processes (>350C)

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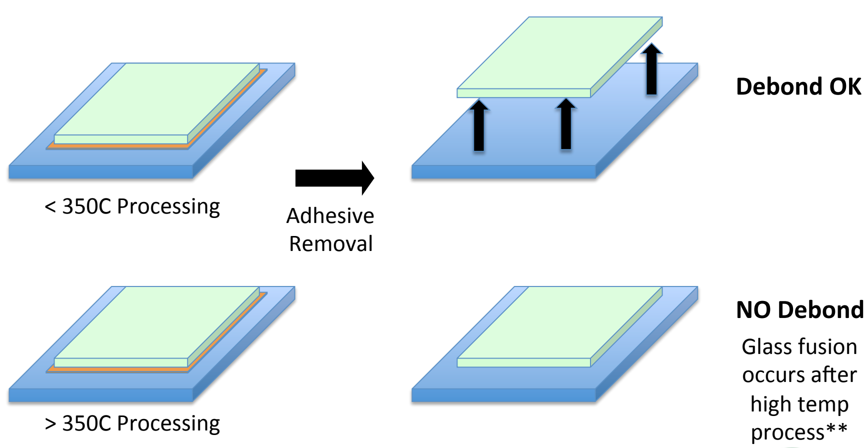
(A)Peripheral Bond: Glass Fusion



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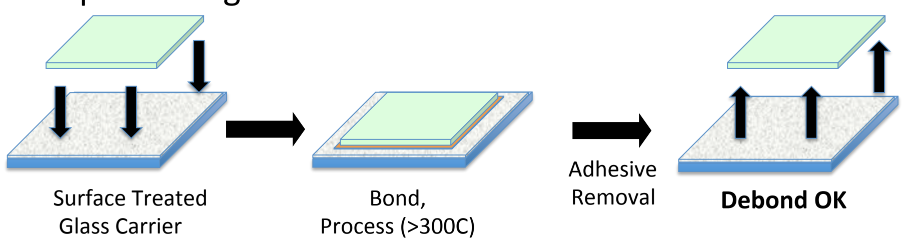
Glass on Glass Bonding

- To prevent spontaneous thermal fusion at high, glass carrier is treated with surface coating before bonding
- Allows glass substrate to debond after high temp processing



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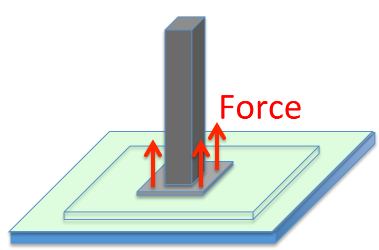
(B)Controlled Adhesion: Center Pull



No Graph:

- 3000gF Before part breaks
- All Adhesives

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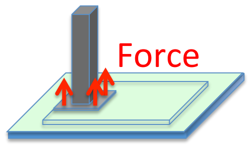
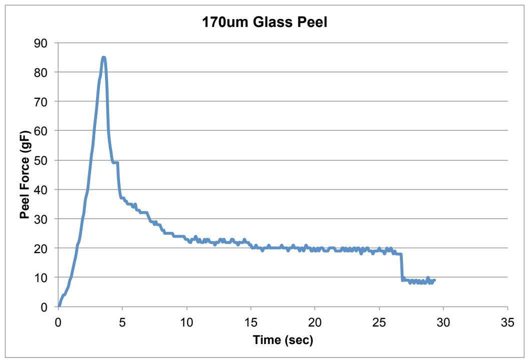
(B)Controlled Adhesion: Edge Pull



Low Bond Force Weaker Adhesive



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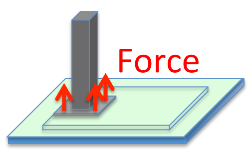
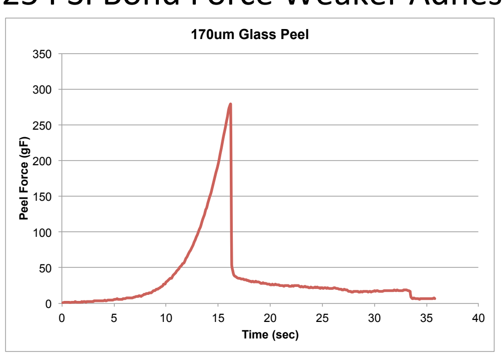
(B)Controlled Adhesion: Edge Pull



0.25 PSI Bond Force Weaker Adhesive



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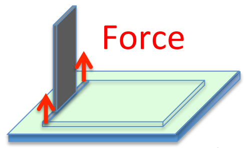
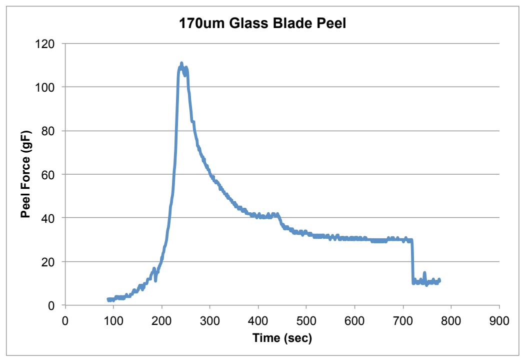
(B)Controlled Adhesion: Blade Pull



0.25 PSI Bond Force Weaker Adhesive



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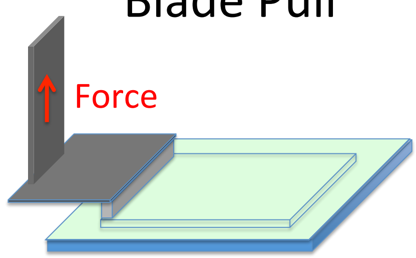
(B)Controlled Adhesion: Past Edge Blade Pull



Use this if you want it, mainly almans data.

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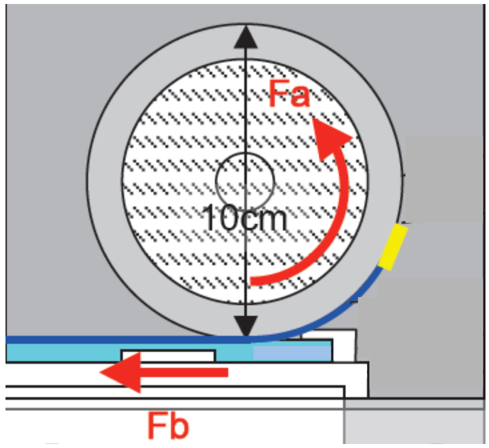
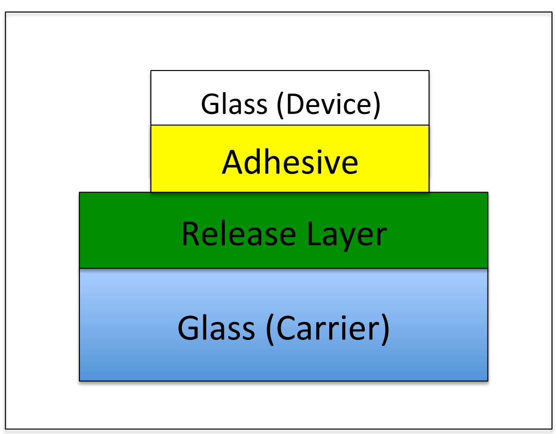
(B)Controlled Adhesion: Roll Peel

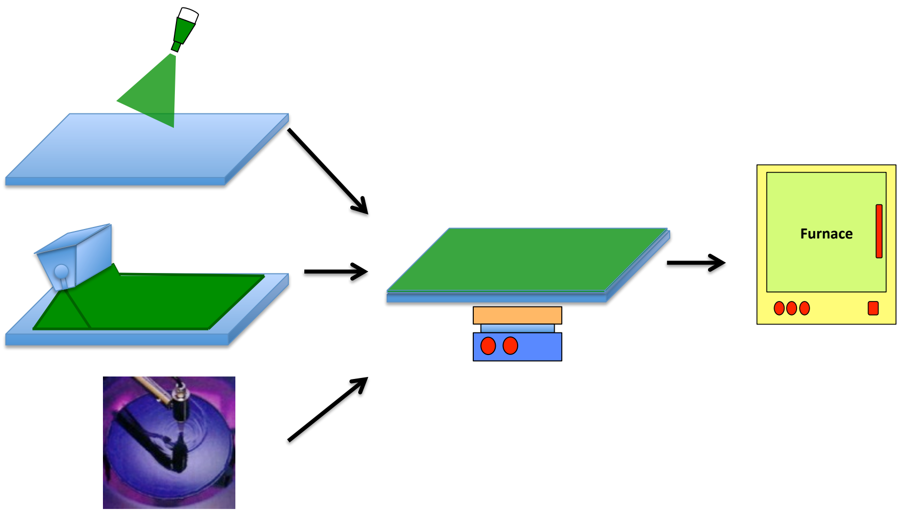


Must Be Custom Equipment

(c) Release Film



Release Film Coat & Cure



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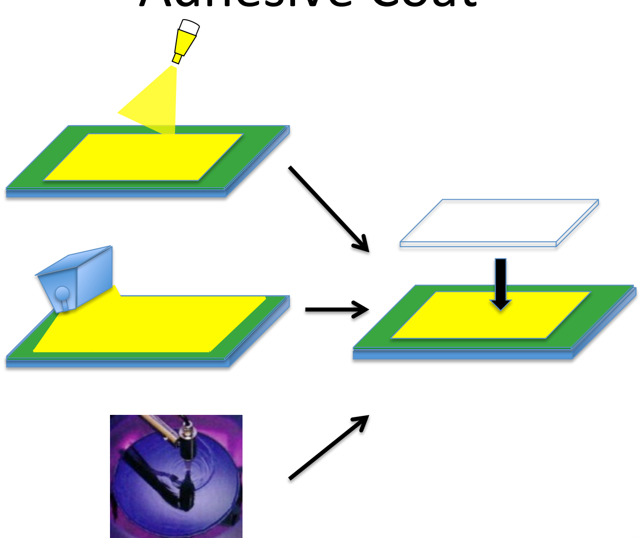
Adhesive Coat



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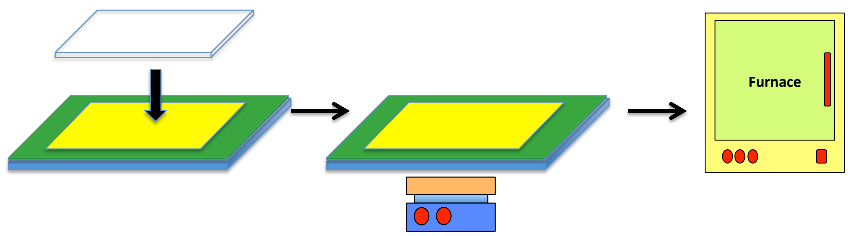
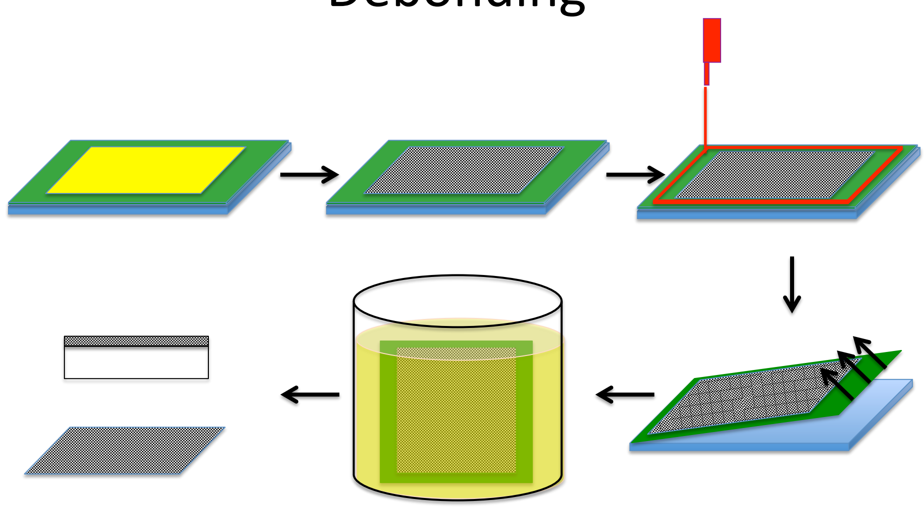
Glass Temporary Bonding



Debonding

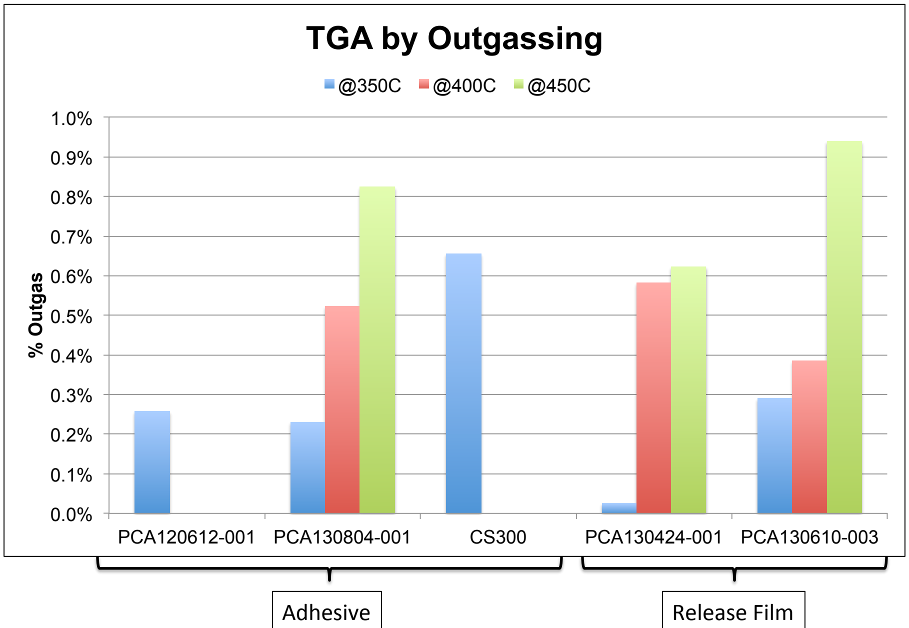


Release Layer

Properties	PCA 130424-001	PCA 130610-003
Appearance	Clear Liquid	Yellow Liquid
Solid ($\%^w/_w$)	~30%	～35%
Compatibility	DMAC, NMP	DMAC, NMP
Coating Method	Spin, Spray, Slit	Spin, Spray, Slit
Cure Temp	350°C (20min)	350°C (20min)
Polymer Type	Thermoplastic	Thermoset
Transparency @ ≥ 380nm (%T)	>80%	>10%
Thermal Resistance (Inert Atmosphere)	≤500°C	≤500°C

Adhesive

Properties	PCA 120612-001	PCA 130804-001	CS-300
Appearance	Clear Liquid	Clear Liquid	Clear Liquid
Solid ($\%^w/_w$)	100%	～80%	100%
Compatibility	THF, Dioxolane	PM, Xylene, THF	THF, Dioxolane
Coating Method	Spin, Spray, Slit	Spin, Spray, Slit	Spin, Spray, Slit
Cure Temp	150°C (10min)	350°C (20min)	150°C (10min)
Bond Method	Wet Bond	Dry Bond	Wet Bond
Transparency @ ≥ 380nm (%T)	>90%	>90%	>90%
Thermal Resistance (Inert Atmosphere)	≤400°C	≤450°C	≤400°C



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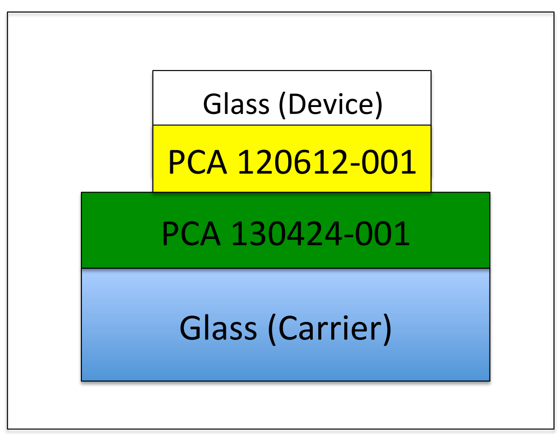
Sample with Daetec's Adhesive



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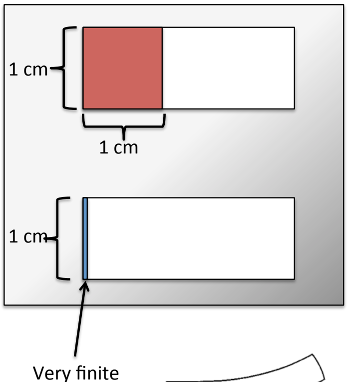
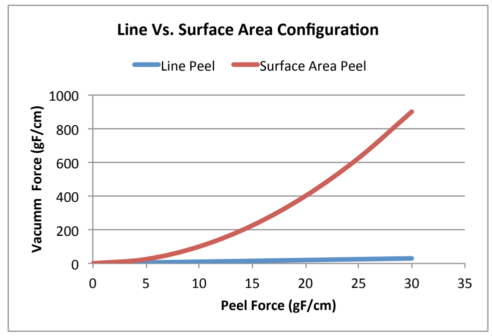
Peel Configurations

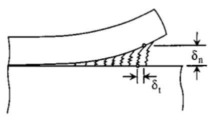


Area Peel

Vs.

Line Peel





- Line Peel method is breaking adhesive bonds at localized section, not over a larger are
  - Yields lower force, shear, and stress

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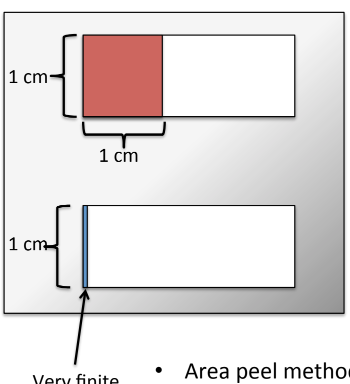
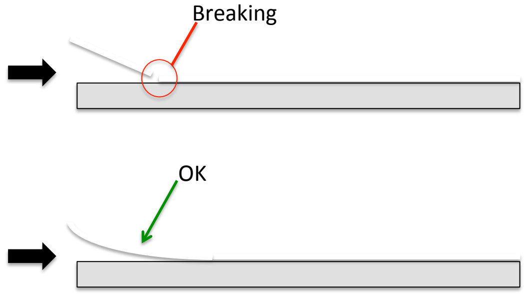
Peel Configuration – Cont.





- Area peel method leads to thin glass breaking
- Line peel method has maximum shear at beginning
  - Allows adhesive bonds to begin breaking and keeps glass intact

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4. Devices

- Desire to attach device, process, remove with no residue. Adhesive is thermal & chemical resistant, conforms to device substrate
- Various adhesives are available
- Device substrates can be irregular
- Bond/edge seal (A) desired, best w/thickness
- Adhesive may be applied by several methods
- Carrier recycle with cleaning
- Total cost must be considered

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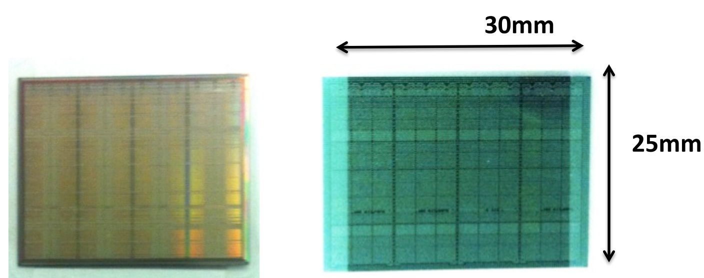
Thin Silicon Interposers (TSIs)

- Substrate ~100um thickness
- Underlying bumps ~100um height



Top side

Bottom side (contains solder bumps)

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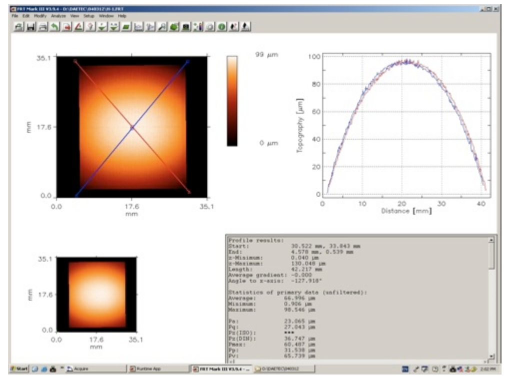
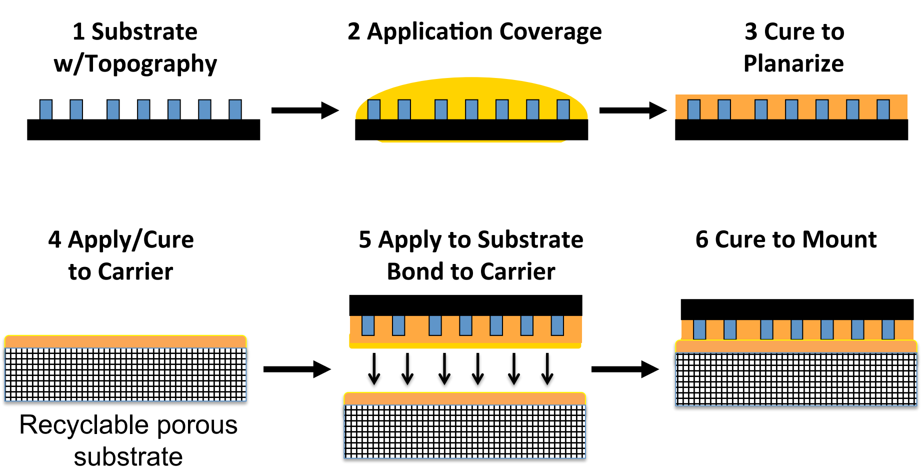
Interposer Initial Bow/Warp

- Bow, measured by optical profilometry
- Beginning bow varies from 100-120um
- Convex shape
- Must reduce to <40um

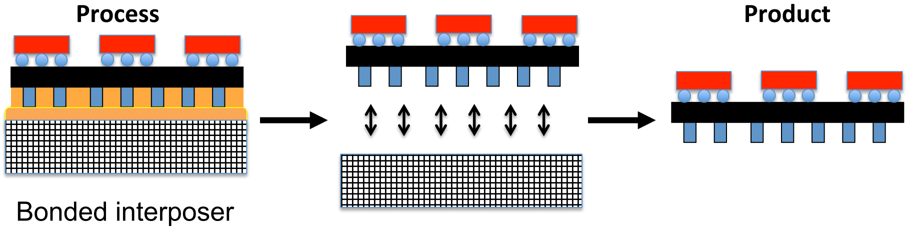


Application



Post-Bonding Process

7 Customer Process | **8 Debond & Cleans** | **9 Acquire Final Product**



Bonded interposer attach chips to interposer
Reflow 250-300C

Debond and Cleans rinse, dry

Recycle carrier

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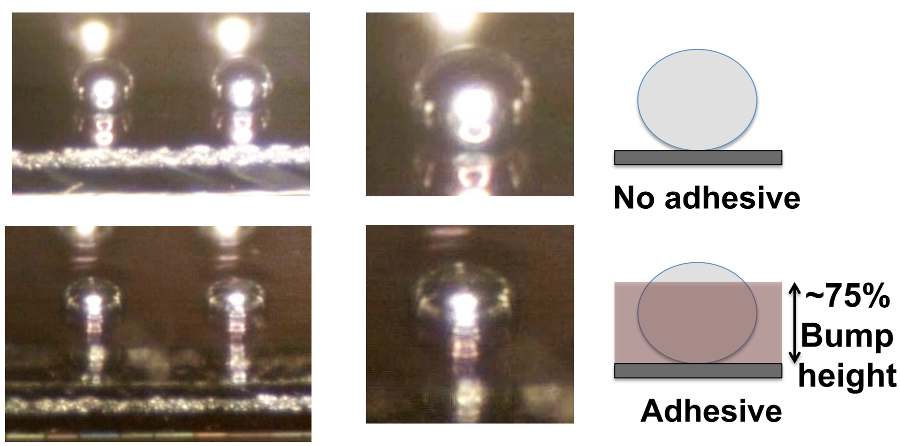
Adhesive Planarization



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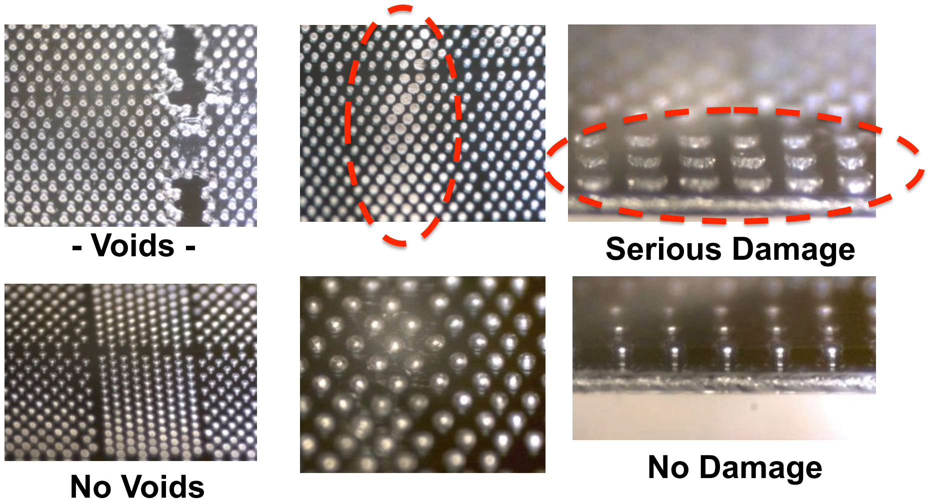
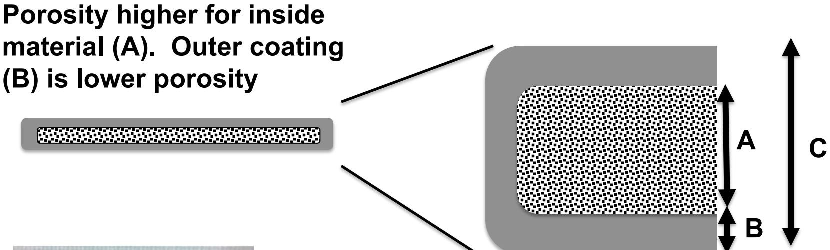
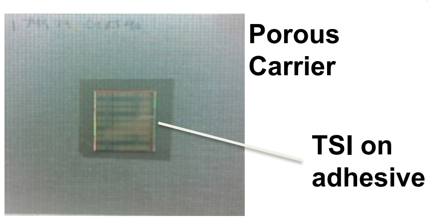
Planarization and Thermal



Porous Carrier

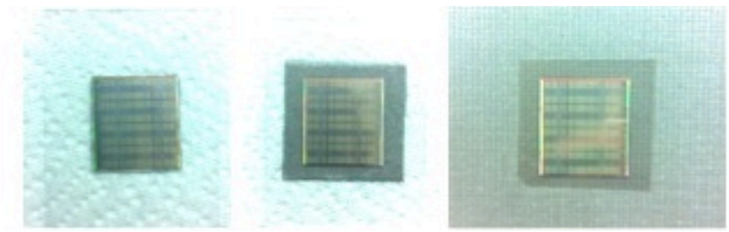
Porosity higher for inside material (A). Outer coating (B) is lower porosity



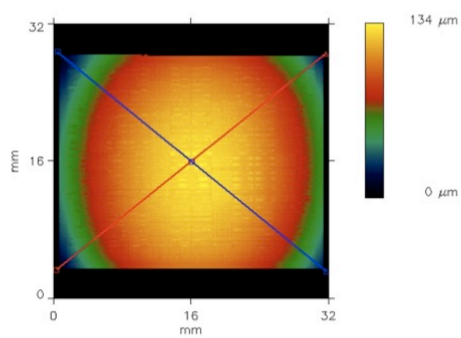


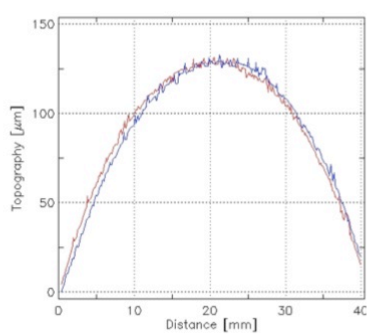
A = 0.5 – 0.8mm
B = 0.1 - 0.25mm
C = 0.5 – 1mm

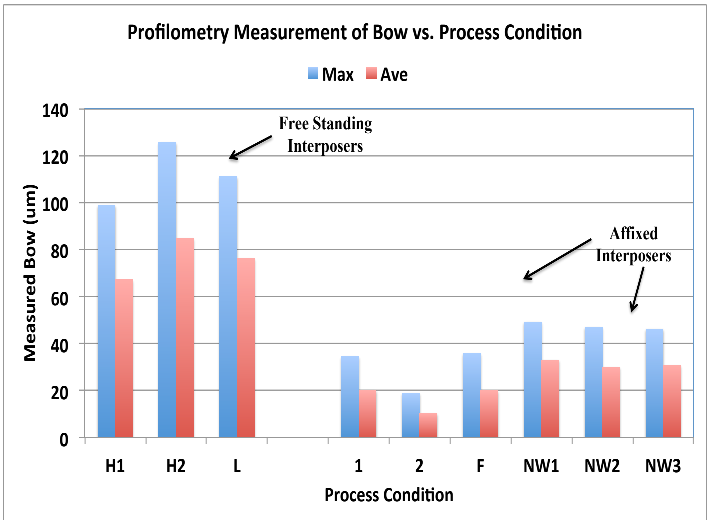
Planarized & Bonded



Results – baseline TSI







#	Type
1, 2, F	Peripheral
NW	Porous Subst

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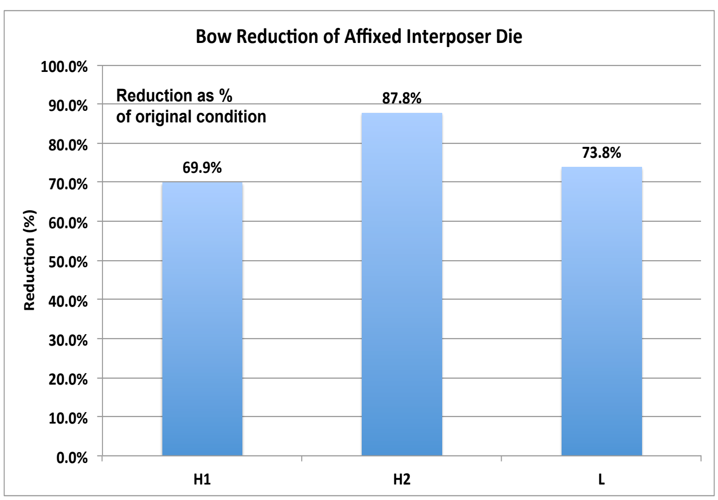

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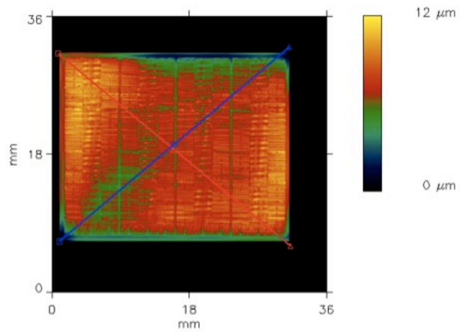
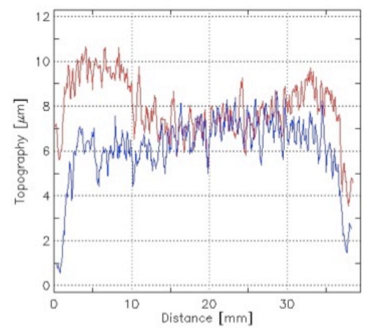
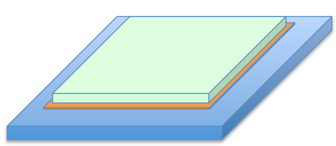
Results – Bonded TSI

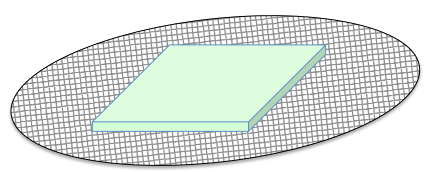




Variation <12um

Rapid Bond/DeBond Options





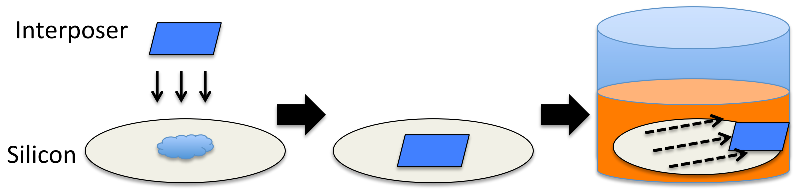
Glass Substrate

- **Planarized interposer**
- **Peripheral bond**

Porous Substrate

- **Planarized interposer**
- **Bulk adhesive bond**

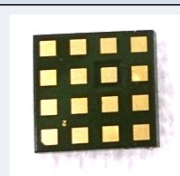
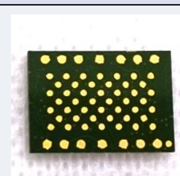
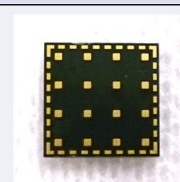
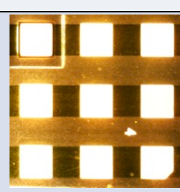
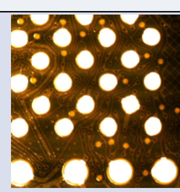
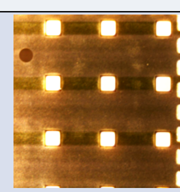
Results – DeBonding



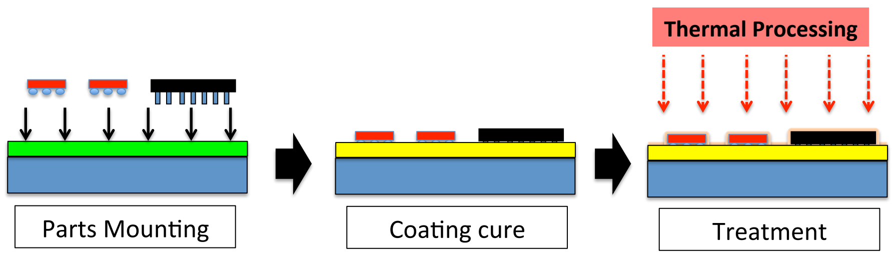
1	2	3
Prior activity involved applying adhesive to interposer & silicon wafer, holding interposer in place	Bond interposer to silicon wafer, observe flatness and other process details	Debond from silicon in Daetec digesting fluid, observe time

Small Devices for Thermal Processing

Appearance of Bottom

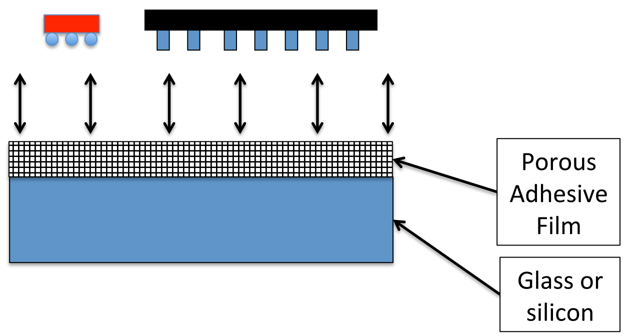
Name	#1	#2	#3
Dimension	0.95cm x 0.95cm	1.65cm x 1.15cm	0.95cm x 0.95cm
Overview			
Microscopic Picture			

Process Description

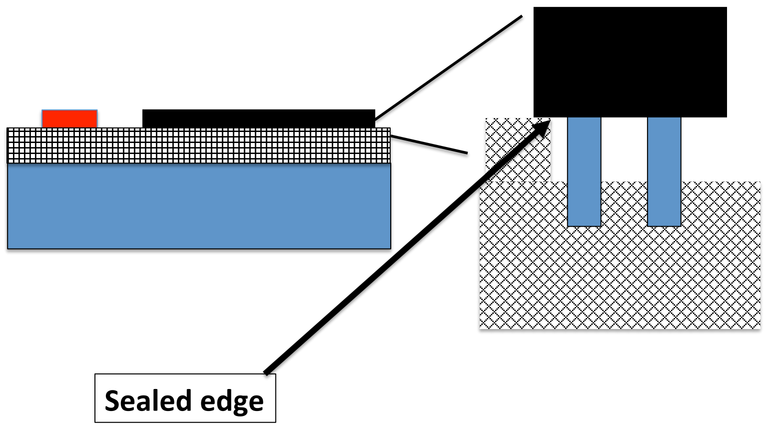


Process Description

Adhesive is applied as a film to carrier on Thick Glass, Open-Faced



Component Bonding



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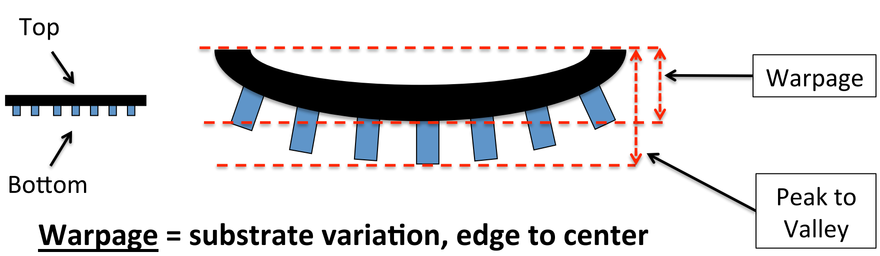
Substrate Description



<u>Warpage</u> = substrate variation, edge to center (no topography)
<u>Peak to valley</u> = min to max (with topography)

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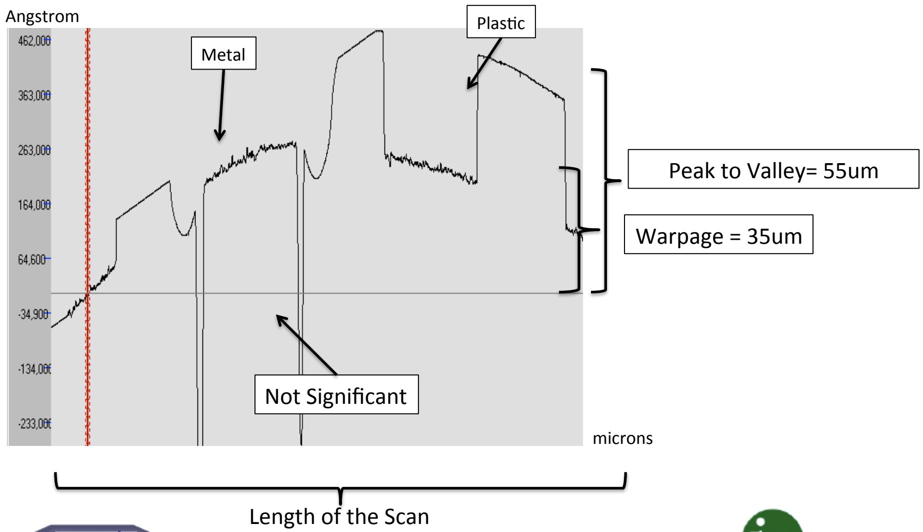
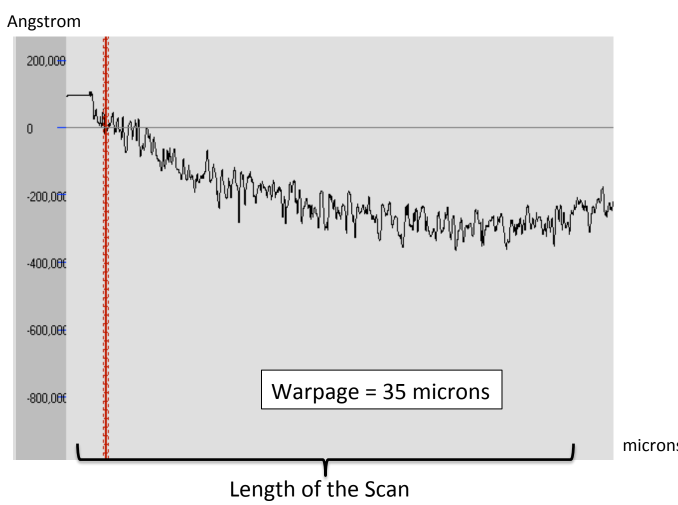
Surface Scan (Bottom of Substrate #1)



Surface Scan (Top of Substrate #1)



Ability to Bond & Seal w/Topography

Use of various DaeCoat products

Substrate	Peak to Valley (µm)	Warpage (µm)	Adhesive thickness <60µm	Adhesive thickness >60µm
#1	55	35	B	B
#2	14	<5	A	A
#3	26	23	B	B

A= Bond + Edge Seal (Ideal Process)
B= Bond

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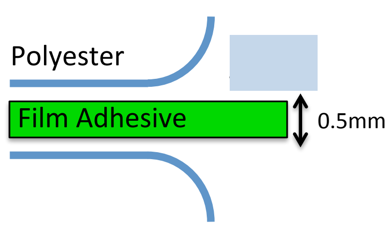
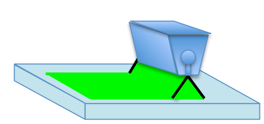
Adhesive Film - Options





1
Use as B-stage film, thickness can vary

2
Slit-coating to substrates, SB cure, process as desired

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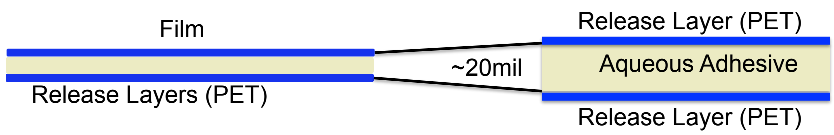
Film w/Release Layers



- Aqueous-based adhesive
- Thickness = 20mil ~500um ~0.5mm
- No backing
- Sandwiched between PET release layers
- Remove 1st PET liner, apply to substrate
- Use a rubber roller, apply exposed adhesive to substrate, increase pressure onto PET facing up, remove 2nd PET liner, proceed with bonding

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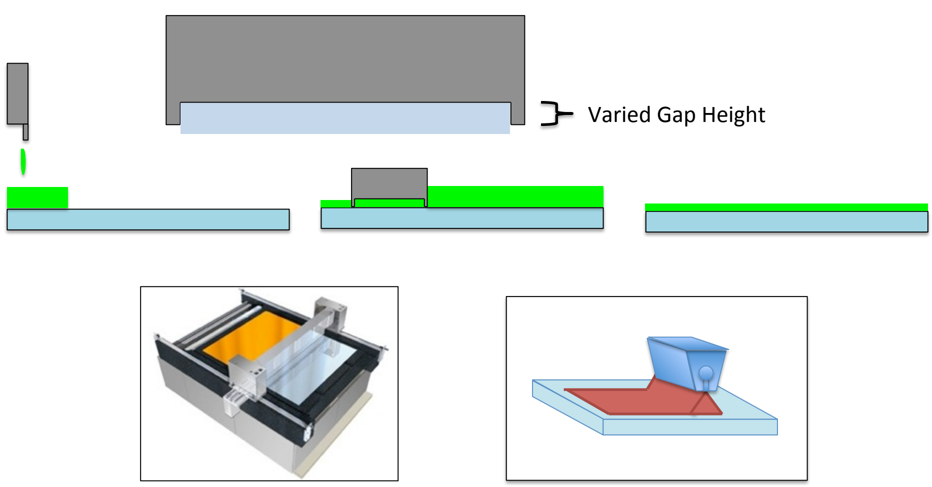
Slit Coating



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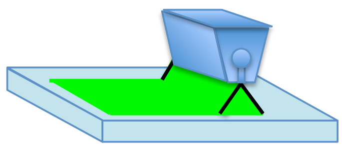
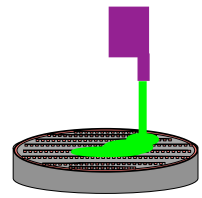
Slit vs Spin

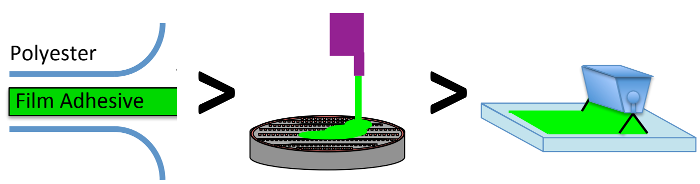




Slit Coating
"What you see it what you get"
Predominant in display
No waste

Spin Coating
"What you see is what you hope was applied"
Predominant Semiconductor
≥50% waste

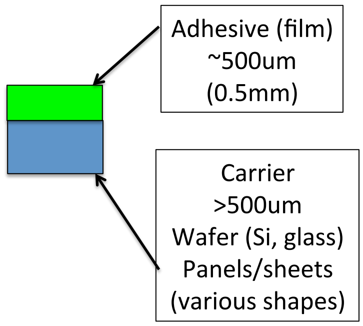
Cost Considerations



Parameter	Film w/release liners	Spin Coating	Slit Coating
Coating solids (%)	80-100	<100	100
Cost ($/cm2)*	<0.05	<0.05	<0.02
Convenience	High	Med	Med
Tool Required	-none-	coater	coater

*assume best case conditions with max solids for coating capability

Configuration Description



Challenges

Thickness ~0.5mm
Uniformity <10% variability
Deliverability (i.e. coating vs film)

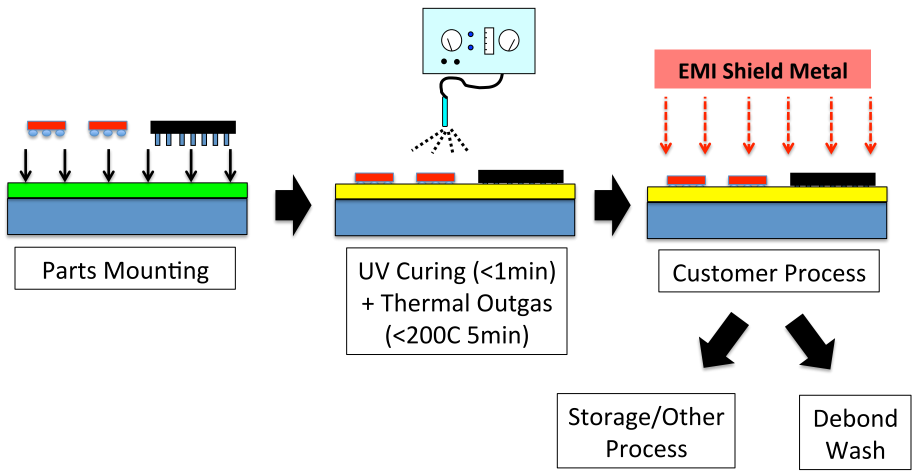
- **Tape style – highest cost, disposable peel layers**
- **Spin coat – also high cost, waste >50%**
- **Slit coat – lowest cost, display technology**

Each coating technology requires special product viscosity

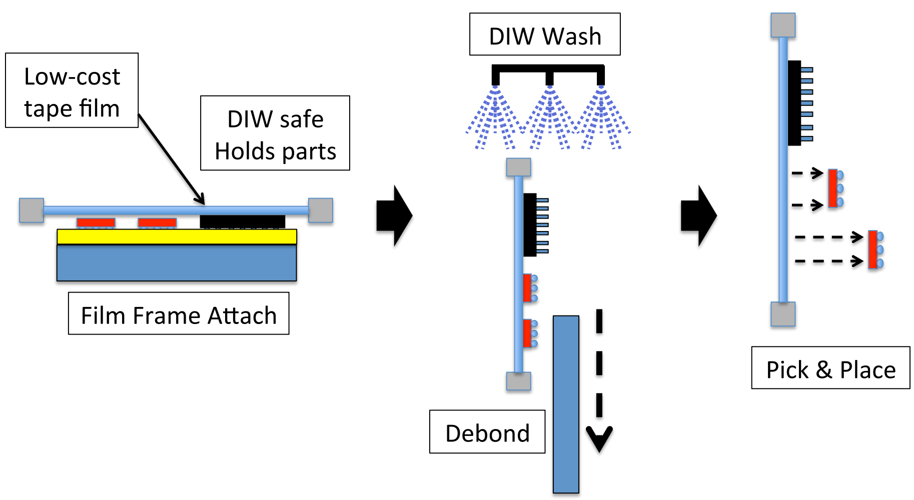
PSA Properties Development

- PSA coating properties: encapsulating
- Form as a thick film with release layers or coating onto substrate to create a thick film
- Very low outgas at >200C
- Simple removal in DIW, options:
  - Re-usable fixture to capture components
  - Simple tape apply to components during carrier release – similar to DaeBond 3D

UV Cure Film/Coating



Debond/Rinsing



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Contact for More Information

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