Low-Cost Adhesives for Temporary Substrate Support

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Trending to Thin Substrates

- 2011 - 25% of all wafers are thinned
- ~2yrs, this is expected to double – nearly half of all wafers will be thinned
Thinning below 100um

- 2011, 80-100um
- ~2yrs, 50um
- ~5yrs, 20-30um

Thin Wafers Revenues Breakdown in 2016 - in US$M

![Graph showing general wafer thickness trends 2010-2016 in μm] (Trends by application)

![Pie chart showing thin wafers revenues breakdown in 2016] (MEMS, CIS, Memorie, Logic, Power, RF, LED, Interpose)

Courtesy: Yole Developpement
Daetec’s Business

Semiconductor: Daetec’s major business surrounds the manufacturing of semiconductor devices. Coatings and cleaners for improving yield and reducing costs.

Aerospace: Thermal resistant systems & washable temporary systems.

Panel making: Daetec’s newest markets include TFTLCD and OLED panel making practices. Coatings based upon silicone, UV cure acrylics, washable and peelable, and thermal resistant systems to >450C.
Daetec’s Customers

• Daetec has developed products, patents, written papers, and presented work with a wide number of leaders in many industries. Our work spans many technologies enabling growth and market capture with our customers.
Product Development

Substrate Handling

Fab Mfg. Support

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Bridging Your Success

Daetec

Intellectual Property

Toll Support
Temporary Adhesive & Backside Processing

- **Adhesive**: Mount product wafer to carrier
- **Carrier**: Silicon or glass, sapphire
- **Temporary**: Apply to meet mechanical and chemical properties, seal front side, removal when complete
- **Backside processing**: Achieve connectivity (lithography, etch, metallization)
- **Removal**: Cleaning complete, no residue
Typical Thin Wafer Support

- Tape
- Vacuum Chuck
- Carrier & Adhesive
## Thin Wafer support

<table>
<thead>
<tr>
<th>Thin Wafer Handling</th>
<th>Thickness Min (um)</th>
<th>Chem &amp; Therm Resistant</th>
<th>Single Wafer or Batch</th>
<th>Backside Processing Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tape</td>
<td>&gt;50</td>
<td>No</td>
<td>Both</td>
<td>No</td>
</tr>
<tr>
<td>Vacuum Chuck</td>
<td>&gt;50</td>
<td>No</td>
<td>Single</td>
<td>No</td>
</tr>
<tr>
<td>Adhesive Bonded Carrier</td>
<td>&lt;25</td>
<td>Yes</td>
<td>Both</td>
<td>Yes</td>
</tr>
</tbody>
</table>

- Thinner is Better
- Must be Resistant
- Versatility Is Best
- Must do Backside Processing
Temporary Bonding Process

Two ACTIVE steps occur with Temporary Bonding Technologies. The “BOND” step appears similar between popular practices. Primary differences occur during “DE-BOND”.

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De-Bonding

Rubber, olefinic & high MW hydrocarbon polymers, blends

Acrylic, styrenic, and blends

Polyimide & silicone
Roadmap to Dicing

Film Attachment Carrier Demount

Wafer Cleans Safe for Tape

Dicing

Evaluation underway for Adhesive compatible to tape or vice-versa
Adhesive Governs the Process

- Final properties & processing capacity
- Choice in bond & de-bond tool, time, yield
- Cleaning chemistry
- Tape/film compatibility
- Need for tuning for each process & customer
Special Properties

- **Thermal resistance**: Minimum 200 °C
- **Low-pressure safe**: Supports etch and deposition processes
- **Low-stress**: Reduced deflection and bow to product wafer
### Thermal Resistant Systems

<table>
<thead>
<tr>
<th>Chemistry</th>
<th>Cure Method</th>
<th>Thickness</th>
<th>Thermal Resistance</th>
<th>Moisture Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Epoxy</td>
<td>UV</td>
<td>&lt;20um</td>
<td>&gt;275°C</td>
<td>Yes</td>
</tr>
<tr>
<td>Rubber</td>
<td>Evap</td>
<td>&lt;15um</td>
<td>&gt;250°C</td>
<td>Yes</td>
</tr>
<tr>
<td>Poly-phenylene</td>
<td>Evap</td>
<td>&lt;10um</td>
<td>&gt;330°C</td>
<td>Yes</td>
</tr>
<tr>
<td>Imidazole</td>
<td>Evap.</td>
<td>&lt;5um</td>
<td>&gt;450°C</td>
<td>Yes</td>
</tr>
<tr>
<td>Biphenyl Sulfonate + Polyester</td>
<td>Evap.</td>
<td>&lt;10um</td>
<td>&gt;300°C</td>
<td>No</td>
</tr>
<tr>
<td>Acrylic</td>
<td>UV</td>
<td>&lt;20um</td>
<td>&lt;250°C</td>
<td>Yes</td>
</tr>
<tr>
<td>Silicone</td>
<td>Catalytic</td>
<td>&lt;10um</td>
<td>&gt;300°C</td>
<td>Yes</td>
</tr>
<tr>
<td>PEI</td>
<td>Evap</td>
<td>&lt;10um</td>
<td>&gt;400°C</td>
<td>Yes</td>
</tr>
<tr>
<td>Hybrid system</td>
<td>Evap</td>
<td>&gt;50um</td>
<td>&gt;500°C</td>
<td>Yes</td>
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</table>
## Polymer Gas Permeability

Gas permeability: cm³-mm/m²-day

<table>
<thead>
<tr>
<th>Polymer</th>
<th>N²</th>
<th>O²</th>
<th>CO²</th>
<th>H²</th>
<th>H₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parylene N</td>
<td>1.7</td>
<td>39</td>
<td>214</td>
<td>540</td>
<td>1.5</td>
</tr>
<tr>
<td>Parylene C</td>
<td>1</td>
<td>7.2</td>
<td>7.7</td>
<td>110</td>
<td>0.2</td>
</tr>
<tr>
<td>Parylene D</td>
<td>4.5</td>
<td>32</td>
<td>13</td>
<td>240</td>
<td>0.2</td>
</tr>
<tr>
<td>Epoxies</td>
<td>4</td>
<td>5-10</td>
<td>8</td>
<td>110</td>
<td>1.8-2.4</td>
</tr>
<tr>
<td>Silicones</td>
<td>-</td>
<td>50,000</td>
<td>300,000</td>
<td>45,000</td>
<td>4.4-7.9</td>
</tr>
<tr>
<td>Urethanes</td>
<td>80</td>
<td>200</td>
<td>3,000</td>
<td>-</td>
<td>2.4-8.7</td>
</tr>
</tbody>
</table>

Parylene conformal coating systems, [www.scscookson.com](http://www.scscookson.com)
Barrier Usage for Reduced Outgas

Gas Barrier Properties

Assist with formulating low outgas coatings
Volatile Component vs. Temperature Exposure

HB 180  HT 210  Outgas 180

Coat ==> SB ==> HB ==> HT ==> Outgas

110C  180C  210C  180C

Cure

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Low Outgas Product for CVD

Targets for successful CVD processing:

• Low permeability coating
• High Tg
• If amorphous, high softening/melting point
• Softening/melt pt is > process temp
• Design cure program as > process temp
Process Overlay

SP – softening point

CVD
Cure Program
SP
De-Bond

Temperature
Stress Introduction

Bowing is observed from internal stress of microelectronic layers

Full thickness ~ 700um

Thinned ~ 100um

Wafer Bow
Materials Overlay

Temperature

100 150 200 250 300

Amorphous/plastic
Waxes rosins urethane sulfone...PI/PA, PBI acrylic

SP

Thermoset
Acrylic, silicone, PI

De-Bond ?
PBI UV Cure System

- Thermal resistant (tunable) >300C
- Applied by spin-coating, spray, roll-coat, pipet
- Low temp cure, <150C in minutes
- Low outgas at high temps (300C)
- Debond and cleans (chemical)
PBI – High Temp Thermoplastic

\[ \begin{align*}
T_g &= 427 \, ^\circ C \\
CTE \, (ppm) &= 23 \\
Modulus \, (Gpa) &= 5.9 \\
Elongation \, (%) &= 3 \\
Moisture \, abs \, (%) &= 0.4 \\
Breakdown \, (v/mil) &= 580
\end{align*} \]
Polybenzimidazole (PBI)

Thermal Resistance for Multiple Applications

Automotive
Injection Molding
Electronics & Semiconductor
Compression Molding
Aerospace
Metal Working
Aviation
Compression Molding

Fire Fighting & Protection

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PBI Polymer Blends

Blends of PBI/PEKK* represent PBI (i.e. Tg >400C) when >50% PBI

*polyetherketoneketone
Evaporative vs UV

Coating
Spin, spray, wipe, brush
(Spin: 500 rpm, 10sec + 750 rpm, 10sec + 1000 rpm, 40sec)

Thermal Cure
(150°C, 5min)

Coating
Spin, spray, wipe, brush
(Spin - 500 rpm, 10sec + 750 rpm, 10sec + 1000 rpm, 40sec)

UV Cure
≤ 400 watts, ≤ 60 sec
PBI “Recon”

PBI ppt  Filter  Dry
Coating Application Options

Spin-Coating

Spray-Coating
Transparency for UV Applications
Hg Lamp Unit (Fusion)
PBI/Acrylic UV Cure System

Evaporative PBI System

PBI Coating Thickness vs Concentration

- DMAC
- Dioxolane
- THF
- PM

PM has limited effect
Dioxolane & THF increase

PBI/Acrylic System

<table>
<thead>
<tr>
<th>Item #</th>
<th>Thickness (µm)</th>
<th>Appearance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>50</td>
<td>Irregular, peeling up</td>
</tr>
<tr>
<td>#1 UV</td>
<td>221</td>
<td>Smooth</td>
</tr>
<tr>
<td>#2 UV</td>
<td>203</td>
<td>Smooth</td>
</tr>
<tr>
<td>#3 UV</td>
<td>230</td>
<td>Smooth</td>
</tr>
<tr>
<td>#4 UV</td>
<td>288</td>
<td>Smooth</td>
</tr>
<tr>
<td>#5 UV</td>
<td>253</td>
<td>Smooth</td>
</tr>
<tr>
<td>#6 UV</td>
<td>280</td>
<td>Smooth</td>
</tr>
<tr>
<td>#7 UV</td>
<td>268</td>
<td>Smooth</td>
</tr>
<tr>
<td>#8 UV</td>
<td>176</td>
<td>Smooth</td>
</tr>
</tbody>
</table>
Thermal Stability by Lab TGA - Hg Lamp Cure

Solids (%)

<table>
<thead>
<tr>
<th></th>
<th>100C</th>
<th>150C</th>
<th>200C</th>
<th>300C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>99%</td>
<td>99%</td>
<td>97%</td>
<td>93%</td>
</tr>
<tr>
<td>1</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>100%</td>
<td>100%</td>
<td>99%</td>
<td>99%</td>
</tr>
</tbody>
</table>
PBI UV Cured Coatings

- Use of PBI-R (reconstituted, pwdr)
- Dissolve in UV cure agent w/sensitizer
- Cures in seconds
- Very high adhesion
- Uniform and smooth coatings
- Thickness >300um
- Thermal resistance >300C
Adhesion Testing (ASTM D3359)

Surface Prep → Primer → SB Cure → Coat + HB

Adhesion → Coat + HB → Adhesion

ASTM 3359
- Crosshatch
- Tape-pull
- Observed result
Adhesion Testing
Following Cure & TGA (300C)

Base PBI (DMAC cure)
Loss of adhesion, PBI peels
And lifts off substrate without
Stimulus (i.e. spontaneous
Lift-off)

PBI in DMAA – Photo cure
Adhesion very strong, not
Brittle, durable, flexible.
Material has noticeably strong
adhesion
Other Systems

- Aqueous cleans for panel making
- Peel systems – thin flexible substrates
Thermal Adhesive Bond and Debond

Substrate Coating (variety of applications)

Bonding (≤60sec)

Customer Process
Thinning, Litho, Acid Etch, Plate, Other backside process

Heat Cure (reduced outgassing)

Debonding & Washing (Detergent in DIW: DP-108 or DL-108) ≤15min, 60-70C
Polyimide Film Temporary Adhesive

Coating Substrate Metal (spray, brush, wipe)

Cure Adhesive & Bond

Process Polyimide

Detergent Clean in DP-108 (spray, immersion)

Thermal Debond Polyimide
UV Temporary Adhesive Application

- Substrate Coating (variety of applications)
- Bonding & UV Cure (<60sec)
- Post-UV Heat Cure (optional – for reduced outgassing)
- Customer Process: Thinning, Litho, Acid Etch, Plate, Other backside process
- Debonding & Washing (Detergent in DIW: DP-108 or DL-108) <15min, 60-70°C
UV Cured System – Peel Debond

**Coating**
Spin, spray, wipe, brush
(Spin - 500 rpm, 10sec + 750 rpm, 10sec + 1000 rpm, 40sec)

**Fixing (optional)**
Thermal fix
(100C, 1-3min)

**Bonding**
Apply film
(pressure is optional)

**UV Cure**
≤ 400watts, ≤ 60sec

**Post-Bake (optional)**
(100C, 3-5min)

- Modulus increase
- Squeeze-out decrease (bonding step)
- Reduce outgas during CVD
Film Application to Glass Substrate

1) UV Cure, 60sec, 365nm, 400w
2) Cure by Heat 100C, 5min

Flexible Film Substrate for Microelectronics Mfg

Coating on Glass Substrate

Film adhered to glass

IC Patterning of Flexible Film Customers process, chemical exposure, etch, thermal, etc.

Debonding of flexible film by peeling or similar practice
Debond Using Porous Carriers

- Under development
- Rigid support
- High fluid contact
- Enables batch processing
- Simple tank-type debond & cleans
- High Throughput (potential >400 wph)
Aq Soluble Planarization Layer

Wafer with Topography (able to planarize >100um)
Planarization Coating
Film Attachment
Adhesive Film Attachment

B – Film Adhesive w/capillary penetrant

A – Planarizing Coating

Film Attachment
“Reference” – Glass & Silicon

Closed substrate, allowing no communication of chemistry into the stack. The only opportunity for chemical penetration is through the adhesive bondline. This does not occur.

Debonding must occur by thermal sliding or other complex method. Slide or other complex de-bond methods damage the device wafer and drive throughput down.
Porous Design Example

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

Porosity higher for inside material (A). Outer coating (B) is lower porosity, more uniform, less voids.
Porous Carrier

Example Porous Carrier

Type A (fine)

Type B (Med. fine)

Type C (Coarse)
Benefits & Cost

• Product costs 10-75% of commercial
• COO <10% due to batch processing
ENABLES NEW TECHNOLOGIES

- 3D wafer level stacking using epoxy molding
- Embedded Micro Wafer Level Pkg (EMWLP)
Process – Debond/Cleans

Process flow after moulding differs: 1) rubber and 2) AQ

1) Rubber
   - Slide/Debond + Clean
   - ~12 wph

2) AQ
   - Batch Demount & Cleans
   - 100-400 wph

SW Debond & Cleans

Batch Debond & Cleans (Wet Bench)
COO Defined (SEMI E35)

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

<table>
<thead>
<tr>
<th>Item</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>F$</td>
<td>Fixed Costs</td>
</tr>
<tr>
<td>R$</td>
<td>Recurring Costs</td>
</tr>
<tr>
<td>Y$</td>
<td>Yield Cost (scrap)</td>
</tr>
<tr>
<td>L</td>
<td>Equipment Life</td>
</tr>
<tr>
<td>T</td>
<td>Throughput</td>
</tr>
<tr>
<td>Y</td>
<td>Composite Yield</td>
</tr>
<tr>
<td>U</td>
<td>Utilization</td>
</tr>
</tbody>
</table>

\[
\frac{COO_2}{COO_1} = \frac{AQ \text{ DB/Cleans}}{Rubber \text{ DB/Cleans}}
\]
COO Value Calculation Example

\[
\frac{COO_2}{COO_1} = \frac{AQ \ dB/Cleans}{Rubber \ dB/Cleans}
\]

<table>
<thead>
<tr>
<th>Item</th>
<th>Definition</th>
<th>COO(_2) vs. COO(_1)</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F$</td>
<td>Fixed Costs</td>
<td>(F$_1 = 5.1 \times R$_1) (F$_2 = 0) or (1.2 \times R$_2)</td>
<td>SW tool as Materials Cost Use onsite tool or batch</td>
</tr>
<tr>
<td>R$</td>
<td>Recurring Costs</td>
<td>(R$_2 = 0.75 \times R$_1)</td>
<td>Materials Cost #2 (AQ) = 0.75 \times #1 (current)</td>
</tr>
<tr>
<td>Y$</td>
<td>Yield Cost (scrap)</td>
<td>(Y$_2 = Y$_1 = 0)</td>
<td>No loss for each tech.</td>
</tr>
<tr>
<td>L</td>
<td>Equipment Life</td>
<td>(L_2 = L_1)</td>
<td>Same life</td>
</tr>
<tr>
<td>T</td>
<td>Throughput</td>
<td>(T_2 = 8.3 \times T_1)</td>
<td>batch vs SW = 8.3 \times T_1</td>
</tr>
<tr>
<td>Y</td>
<td>Composite Yield</td>
<td>(Y_2 = Y_1)</td>
<td>Same yield</td>
</tr>
<tr>
<td>U</td>
<td>Utilization</td>
<td>(U_2 = U_1)</td>
<td>Same maintenance</td>
</tr>
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</table>
**COO$_2$/COO$_1$ Comparison Results**

<table>
<thead>
<tr>
<th></th>
<th>Use Existing Wet Bench (Batch)</th>
<th>New Wet Bench (Batch)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COO$_2$/COO$_1$</strong></td>
<td>1.5%</td>
<td>3.2%</td>
</tr>
</tbody>
</table>

**Summary:** The COO of the new technology (AQ adhesive) is projected to be between 1.5 – 3.3% of the COO of the current (rubber) technology.
## PP of New and Existing Lines

<table>
<thead>
<tr>
<th>Payback Period Method</th>
<th>Use Existing Wet Bench (Batch)</th>
<th>New Wet Bench (Batch)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput considered</td>
<td>&lt;1mo</td>
<td>~1mo.</td>
</tr>
<tr>
<td>Remove Throughput</td>
<td>4mos</td>
<td>10mos</td>
</tr>
</tbody>
</table>
Summary

• Demand for alternative adhesives
• Extreme properties as thermal, low outgas, and stress-free in adhesives for temporary applications are achievable
• Thick materials and unique carriers are suggested
• Low-cost is required for scaling, comparative COO of <50% is common, <10% is a target
• As designs change, so must the materials and process to achieve them
Contact for More Information

• DAETEC provides development, consulting, and technical training/support to solve manufacturing problems and introduce new options of doing business.

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  jmoore@daetec.com; www.DAETEC.com