Optical Profilometry of Substrate Bow Reduction Using Temporary Adhesives

Paul Flynn, FRT of America LLC
John Moore, DAETEC LLC
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Fries Research & Technology (pflynn@frtfoamerica.com)
Diversified Applications Engineering Technologies (jmoore@daetec.com)
Agenda

- Background
- Equipment
- TSI Baseline
- Application
- Results
- Summary
Background
Thin Substrate Support

- **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 Substrate 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 is similar between popular practices. Primary differences occur during “DE-BOND”.

Coat          Bond          De-Bond & Cleans

Customer Process
Grind, TSV, cleans, metal
## Wafer Bonding Chemistries

<table>
<thead>
<tr>
<th>Firm</th>
<th>Chemistry</th>
<th>DeBond Method</th>
<th>Batch or SW</th>
<th>Cleans</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSI</td>
<td>Rubber</td>
<td>Chemical, slide, peel</td>
<td>SW</td>
<td>Non-polar solvent</td>
</tr>
<tr>
<td>3M</td>
<td>Acrylic</td>
<td>Ablate/peel</td>
<td>SW</td>
<td>Polar solvent</td>
</tr>
<tr>
<td>TMAT &amp; Dow</td>
<td>Silicone</td>
<td>Peel</td>
<td>SW</td>
<td>Non-polar solvent</td>
</tr>
<tr>
<td>Corning</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DuPont</td>
<td>Polyimide</td>
<td>Ablate/peel</td>
<td>SW</td>
<td>Polar solvent</td>
</tr>
<tr>
<td>TOK</td>
<td>Urethane</td>
<td>Chemical</td>
<td>Batch</td>
<td>Polar solvent</td>
</tr>
<tr>
<td>Daetec</td>
<td>Rosin Acid</td>
<td>Chemical</td>
<td>Batch</td>
<td>Detergent</td>
</tr>
</tbody>
</table>
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

↑ cleans 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
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
Stress Introduction

Bowing – observed internal stress, metal layers

Full thickness ~ 700um  Thinned ~ 100um
Materials Overlay

Temperature

100  150  200  250  300

Amorphous/plastic  SP

Waxes  rosins  urethane sulfone…PI/PA, PBI  acrylic

De-Bond ?

Thermoset  Acrylic, silicone, PI
Equipment

- Entire substrate/wafer needs to be mapped
- Optical profilometry is preferred choice
- Bow, warp, TTV, flatness
- High resolution, speed, reliability
FRT MicroProf®

Wafer Metrology Tools

MicroProf® 300
Multi Sensor metrology tool with 300 mm stage and optional housing

FRT MFE - Metrology for Frontend
Fully automated Multi Sensor metrology tool with 300 mm stage, bridge tool, class 1 EFEM, SECS/GEM interface

MicroProf® 300 TTV MHU
Multi Sensor metrology tool with 300 mm stage, sensor setup for wafer thickness measurement (TTV), fully automated
FRT MicroProf®
Semi Automated Metrology Tools

- Manual Operation
- Optical sensor acts as an OM
- 2D profile and 3D raster scanning
- Z working distance to 5mm
- Z-resolution can be set to 3nm
- IR and film thickness sensors
- TSV depth measurements
- fully Semi compliant
- sawn, ground, polished wafers
- material independent (Si, sapphire, glass,..)
- recipe driven Semi compliant software
<table>
<thead>
<tr>
<th>Roughness:</th>
<th>Profile:</th>
<th>3D Map:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ra</td>
<td>Wafer Thickness</td>
<td>Thickness</td>
</tr>
<tr>
<td>Rmax</td>
<td>Center Thickness</td>
<td>Center Thickness</td>
</tr>
<tr>
<td>Rz</td>
<td>Wafer TTV</td>
<td>Wafer TTV</td>
</tr>
<tr>
<td>Rp</td>
<td>BowBF</td>
<td>Bow BF</td>
</tr>
<tr>
<td>Rt</td>
<td>Wafer Warp</td>
<td>Wafer Warp</td>
</tr>
<tr>
<td>Rv</td>
<td>Sori</td>
<td>Sori</td>
</tr>
<tr>
<td>Rq</td>
<td>TIR</td>
<td>TIR</td>
</tr>
<tr>
<td>Wt</td>
<td>TIR95</td>
<td>TIR95</td>
</tr>
<tr>
<td>Sag X</td>
<td>Sag X</td>
<td>Sag X</td>
</tr>
<tr>
<td>Sag Y</td>
<td>Sag Y</td>
<td>Sag Y</td>
</tr>
<tr>
<td>Profile Warp</td>
<td>Profile Warp</td>
<td>NTV</td>
</tr>
<tr>
<td>Profile Sori</td>
<td>Profile Sori</td>
<td>NTD</td>
</tr>
<tr>
<td>NTD</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NTV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Profile TTV</td>
<td></td>
<td>Profile TTV</td>
</tr>
<tr>
<td>TV5 / TV9</td>
<td></td>
<td>3D map</td>
</tr>
<tr>
<td>3D map</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **SFLD**
- **SFQR**
- **SF3D**
- **SF3R**
- **Wafer FPD**
TSI Baseline

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

Top side

Bottom side (contains solder bumps)
Interposer Initial Bow/Warp

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

1 Substrate w/Topography

2 Application Coverage

3 Cure to Planarize

4 Apply/Cure to Carrier

5 Apply to Substrate Bond to Carrier

6 Cure to Mount

Recyclable porous substrate
Post-Bonding Process

7 Customer Process
- Bonded interposer
- Attach chips to interposer
- Reflow 250-300C

8 Debond & Cleans
- Debond and Cleans
- Rinse, dry
- Recycle carrier

9 Acquire Final Product
Adhesive Planarization

No adhesive

Adhesive

~75% Bump height
Planarization and Thermal

- Voids -

Serious Damage

No Voids

No Damage
Peripheral Bond

- The adhesive is applied on the edges of the carrier – known as *peripheral bond*
- Thin substrate is bonded onto carrier
- Adhesive is cured
Peripheral Bond

Top View
Film Adhesive

Horizontal View
Film Adhesive

Side View
Peripheral Bond

Adhesive
Porous Carrier

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

TSI on adhesive

A = 0.5 – 0.8mm
B = 0.1 – 0.25mm
C = 0.5 – 1mm
Planarized & Bonded

Glass  Semi-porous  Porous
Results – baseline TSI
Profilometry Measurement of Bow vs. Process Condition

- **Max**
- **Ave**

Free Standing Interposers

Affixed Interposers

<table>
<thead>
<tr>
<th>Type</th>
<th>Process Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1, 2, F</td>
<td>Peripheral</td>
</tr>
<tr>
<td>NW</td>
<td>Porous Subst</td>
</tr>
</tbody>
</table>

Measured Bow (um)

Process Condition

- H1
- H2
- L
- 1
- 2
- F
- NW1
- NW2
- NW3

# Type

1, 2, F  Peripheral
NW     Porous Subst
Bow Reduction of Affixed Interposer Die

Reduction as % of original condition

<table>
<thead>
<tr>
<th>Reduction (%)</th>
<th>H1</th>
<th>H2</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>69.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>87.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>73.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Results – Bonded TSI

Variation <12μm
# Results – Adhesives/Cleans

<table>
<thead>
<tr>
<th>Adhesive</th>
<th>Form</th>
<th>Chemistry</th>
<th>Cleaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>DaeCoat FS300</td>
<td>Film</td>
<td>Silicone</td>
<td>DaeClean SL1750, SL3200</td>
</tr>
<tr>
<td>DaeCoat CS300</td>
<td>Liquid/gel</td>
<td>Silicone</td>
<td>DaeClean SL1750, SL3200</td>
</tr>
<tr>
<td>DaeCoat CD170</td>
<td>Liquid</td>
<td>Acrylic</td>
<td>DaeClean DP-108</td>
</tr>
<tr>
<td>DaeCoat CD300</td>
<td>Liquid</td>
<td>Acrylic</td>
<td>DaeClean DP-108</td>
</tr>
</tbody>
</table>
Rapid Bond/DeBond Options

Glass Substrate
• Planarized interposer
• Peripheral bond

Porous Substrate
• Planarized interposer
• Bulk adhesive bond
## Results – DeBonding

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Prior activity involved applying adhesive to interposer &amp; silicon wafer, holding interposer in place</td>
</tr>
<tr>
<td>2</td>
<td>Bond interposer to silicon wafer, observe flatness and other process details</td>
</tr>
<tr>
<td>3</td>
<td>Debond from silicon in Daetec digesting fluid, observe time</td>
</tr>
</tbody>
</table>

![Diagram showing the process of DeBonding](image)
Results - Cleans

- Debond & cleans all occurred <15min, batch
- Cleans chemistry varied with adhesive, solvent to detergent
- Silicone film – solvent cleans
- High temp acrylic – detergent cleans
Summary

- Optical profilometry - critical for measurement
- Bow reduction to 90% is demonstrated using simple tooling, manual practice
- Demonstration of peripheral & porous bond
- Temporary adhesives w/detergent cleans
- Batch debond/cleans <15min
Contact for More Information

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

- Diversified Applications Engineering Technologies (DAETEC)
  Camarillo, CA (USA) (805) 484-5546
  jmoore@daetec.com; www.DAETEC.com