Thin Wafer Handling Using Mechanical- or Laser-Debondable Temporary Adhesives

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Key Drivers for Temporary Wafer Bonding

- Flip-chip, wafer-level, and 2.5D/3D packages are the market drivers for advanced packaging

- Key Drivers for 2.5D/3D Packaging:
  - Cost and complexity of scaling (“More Moore”)
  - Demand for Increased Performance and Functionality (“More than Moore”)

- Drivers have led to thinner and thinner wafers / devices
  - Problem: Thinned wafers are too flexible to be processed normally
  - Solution: Temporarily attach a carrier wafer to provide mechanical rigidity for processing
Current Market Trends

- Two Major Applications in TWB Market

<table>
<thead>
<tr>
<th>Fan-Out Wafer Level Packaging</th>
<th>3D Packaging (3D / 2.5D TSV)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Image of Wafer Level Packaging" /></td>
<td><img src="image2" alt="Image of 3D Packaging" /></td>
</tr>
</tbody>
</table>

**Market**
- Handheld device processors
- Market driven by end customer
- High performance computing/server
- Still large cost gap to adoption by market

**Technical Challenges in TWB**
- Wafer bow control
- No delamination defects during high temperature cure (~ 250°C)
- Low TTV (2~3 µm / 300 mm)
- Thermal stability during high vacuum / high temp back process (CVD / PVD)
- Low force/high yield debonding
Temporary Wafer Bonding: Materials Considerations
Fan-Out Packaging – eWLB, Thinned Wafers

Mold / Thinned Wafer

High-Throughput Bonding
Then Cure

Backside Processing (RDL, Bumping, etc.)

Carrier Removal

Completed Wafer after Tape Peel

AP and Adhesive Spun on Carrier

Reclaimed Carrier
3D Packaging – Bumped Wafers with TSV’s

- Adhesive Spun on Device
- High-Throughput Bonding Then Cure
- Thinning and Backside Processing
- Carrier Removal
- Completed Wafer

- AP Spun On Carrier
- Reclaimed Carrier
TWB Films for Multiple Applications

AP and Adhesive Spun on Carrier
- Fan-Out Packaging

- 25 µm thick TWB film coated over blank Si carrier wafer

Adhesive Spun on Device
- 3D Packaging

- 35 µm thick TWB film coated over 25 µm tall Cu pillar device wafer
Key Product Attributes

- **Excellent thermal stability**
  - Thermal stability up to 300°C

![Graph showing weight loss vs. temperature](image)

- No weight loss at 250°C
- 0.6% wt loss at 320°C
- 2.2% wt loss at 350°C
### Key Product Attributes

- **Exceptional chemical stability**
  - Resistant to all standard processing chemistries (i.e. Bases, Acids, Solvent)

<table>
<thead>
<tr>
<th>Category</th>
<th>Chemical</th>
<th>Time/Temp</th>
<th>Pass/Fail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developer</td>
<td>2.38% TMAH</td>
<td>25°C/10min</td>
<td>Pass</td>
</tr>
<tr>
<td>Solvent</td>
<td>Acetone</td>
<td>25°C/10min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>PGMEA</td>
<td>25°C/10min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>IPA</td>
<td>25°C/20min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>NMP:Ethylene Glycol (50:50)</td>
<td>65°C/25min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Methanol</td>
<td>25°C/10min</td>
<td>Pass</td>
</tr>
<tr>
<td>Wet Etch</td>
<td>Hydrochloric Acid (30%), HCl</td>
<td>25°C/90min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Persulfate, PREPOSIT™ Etch 748</td>
<td>25°C/5min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Ammonium Hydroxide (30%), NH₄OH</td>
<td>25°C/30min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Phosphoric Acid (8%), H₃PO₄</td>
<td>45°C/10min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>Hydrogen Peroxide (15%), H₂O₂</td>
<td>60°C/40min</td>
<td>Pass</td>
</tr>
<tr>
<td>Clean</td>
<td>SC1 (NH₄OH:H₂O₂:H₂O 1:1:5)</td>
<td>75°C/10min</td>
<td>Pass</td>
</tr>
<tr>
<td></td>
<td>SC2 (HCl:H₂O₂:H₂O 1:1:6)</td>
<td>75°C/10min</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Key Product Attributes

- Low film TTV after coating and low device TTV after processing
- Fast, low temperature bonding process (2 min, 80-100°C)

25 µm TWB film after coating

15 µm TWB film after bonding/cure

Image courtesy of Süss MicroTec

25.6 µm mean film thickness
TTV = 0.36 µm

15.2 µm mean film thickness
TTV = 1.6 µm
Temporary Wafer Bonding: Debonding Modes
Debonding Modes

Mechanical Debond

Laser Ablation Debond
Debonding Mechanisms – Advantages / Disadvantages

**Mechanical Debond**

**Pros**
- Lower CoO due to instrument simplicity and decreased processing time
- No special modification of TWB material

**Cons**
- Higher wafer stress due to higher required debond force
- Potential wafer damage from debond process

**Laser Ablation Debond**

**Pros**
- Less wafer stress due to lower debond force

**Cons**
- Higher CoO due to expensive laser source and increased processing time
- TWB modification to enable laser ablation
- Potential wafer damage from unabsorbed laser energy
# Debonding Mechanisms – Advantages / Disadvantages

## Debonding Methods

**Mechanical Debond**

![Mechanical Debond Diagram]

**Laser Debond, Tape Peel**

![Laser Debond Diagram]

## Debond Force Equations

<table>
<thead>
<tr>
<th>Debond Method</th>
<th>Debond Force Equation</th>
<th>Debond Force*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical Debond</td>
<td>[ P = \sqrt[3]{\frac{4GE_s h^3(0.3-a)^2}{3a(0.75-2a)}} ]</td>
<td>13.0 N</td>
</tr>
<tr>
<td>Laser Debond Tape-Peel</td>
<td>[ P = 2G\sqrt{0.3a-a^2} ]</td>
<td>0.6 N</td>
</tr>
</tbody>
</table>

* - Significantly less force required for tape-peel removal, assuming:
- Si carrier
- \( a = 100\) mm
- \( G = 2 \text{ J/m}^2 \)
Debonding Mechanisms – Advantages / Disadvantages

Mechanical Debond
Step 1 – Crack initiation and debond completion

• Mechanical debonding more economical due to decreased number of processing steps
• Laser equipment more expensive to install and maintain

Laser Ablation Debond
Step 1 – Laser ablation debond followed by carrier removal

Step 2 – Apply tape for TWB adhesive film removal

Step 3 – Tape peel TWB adhesive film
Mechanical Debonding - 300mm Wafer with 32µm Bumps

Adhesive Spun on Device → Bonding Then Cure → Carrier Removal → Carrier Reclaim via tape peel → Clean Carrier Wafer

Completed Wafer → Adhesion Promoter Spun On Carrier

Photos courtesy of Süss MicroTec

Clean 300mm Debonded Wafer → TWB Film

Carrier Reclaim via tape peel

Electronic Materials
Mechanical Debonding - 300mm Wafer with 32µm Bumps

Device Wafer

Peeled-off Adhesive Layer

Cross section
Debonding from 90µm Solder Bumps
Mechanical Debonding - 300 mm Epoxy Mold Wafer

Epoxy Mold Wafer

Bonding Then Cure

Carrier Removal

Adhesive Spun on Carrier

Adhesive remains on epoxy wafer with no visible void defects.
Mechanical Debonding - 300 mm Epoxy Mold Wafer

Adhesive transferred to tape

Clean epoxy Mold Wafer
Laser Ablation Debonding

Device Wafer (CVD Cu on Si) → Bonding Then Cure → Laser Ablation Debonding → Carrier Removal → Reclaimed Carrier

AP and Adhesive Spun on Carrier

Tape peel to complete

2 available laser wavelengths:
- 248nm (Fraunhofer IZM)
- 308nm (SÜSS Microtec)
# Laser Ablation Debonding

## 248 nm SÜSS Microtec ELP300 (Fraunhofer IZM)

<table>
<thead>
<tr>
<th>Pass</th>
<th>Fluence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250 mJ/cm²</td>
</tr>
<tr>
<td>2</td>
<td>350 mJ/cm²</td>
</tr>
<tr>
<td>3</td>
<td>450 mJ/cm²</td>
</tr>
<tr>
<td>4</td>
<td>550 mJ/cm²</td>
</tr>
</tbody>
</table>

No device damaged by laser

Adhesive found on device

## 308 nm SÜSS Microtec ELP300 (SÜSS Microtec)

<table>
<thead>
<tr>
<th>Pass</th>
<th>Fluence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>350 mJ/cm²</td>
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</tr>
<tr>
<td>3</td>
<td>350 mJ/cm²</td>
</tr>
<tr>
<td>4</td>
<td>350 mJ/cm²</td>
</tr>
</tbody>
</table>

Device damaged by laser

Adhesive found on Carrier
Effect of Wavelength on Debonding Mode

70~90% of 248 nm UV light is absorbed by glass substrate.

Absorption of 248 nm UV by adhesive is high.

Ablation is activated at glass interface due to absorption of adhesive.

Debonding at glass interface is possible.

308 nm UV light is >95% transparent at most of glass substrates.

Absorption of 308 nm UV by adhesive is low.

Ablation is activated at substrate interface due to absorption or reflection by substrate.

Debonding occurs at substrate interface.
TWB Film UV Absorbance

- Absorbance @ 308nm = 1.26
- Transmittance @ 308nm = 5.5%
- Absorbance @ 248nm = infinite
- Transmittance @ 248nm = 0%

- 1 µm TWB film coated onto quartz wafer
308 nm Sensitization

Device Wafer (CVD Cu on Si)

AP and Adhesive Spun on Carrier

Bonding Then Cure

Laser Ablation Debonding

Carrier Removal

Tape peel to complete

Sensitize AP through addition of ablation promoter
- Thermally/chemically stable
- Compatible with current TWB adhesive

Reclaimed Carrier
308 nm Sensitization

Absorbance @ 308nm = 1.26
Transmittance @ 308nm = 5.5%

Absorbance @ 308nm = 3.1
Transmittance @ 308nm = 0.08%

1 µm TWB film coated onto quartz wafer
1 um sensitive AP film coated onto quartz wafer
Laser Ablation Debonding – 200 mm Si Wafer

Si Wafer

AP and Adhesive Spun on Carrier

Bonding, Cure, Backgrind to 50 µm

Ablation then Carrier Removal

Reclaimed Carrier

Tape-peel adhesive off thinned wafer

Glass after separation = clean, adhesive found on device wafer
Laser Ablation Debonding – 200 mm Si Wafer

- Adhesive transferred to tape
- 50µm thin Si wafer after laser debond and tape-peel
DOW Temporary Wafer Bonding Adhesive Film

- Thermally and chemically stable TWB adhesive allows for low TTV and high throughput bonding

- Amenable to both mechanical debonding and laser debonding (with adhesion promoter modification)

- Designed for current and future industry applications in Fan-Out Packaging and 3D device integration
Thank You

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