DuPont Wafer Level Packaging
High temperature temporary bonding solutions

AGENDA

• DuPont Materials for 3D/TSV
• HDM Polyimide Adhesives for 3D/TSV
• Avoiding Thin Wafer Handling
• DANM Slurries for Backside Grind
• EKC Post Backside Grind Cleaner
• EKC Pre bonding BTA/CuOx Cleaner
• EKC HDM Polyimide Adhesive Remover
DuPont Wafer Level Packaging
Materials Characterization for Target Applications

**Bump & RDL Formation**
- Copper CMP
  - CopperReady® / DA NanoMaterials
- RDL Dielectric Coatings
  - HD Series PI & PBO / HD MicroSystems
- RDL Structuring
  - MX Series Dry Film / Dry Film Resist
  - Wafer Bumping
  - WB Series / Circuit and Packaging Materials

**Wafer Thinning**
- Colloidal Silica Slurries
- Back Grinding/Wafer Polishing
- Syton® & Mazin™ / DA NanoMaterials
- Temporary bonding
- Polyimide adhesive
  - HD3000 Series / HD MicroSystems
- Bonding Polyimide adhesive removal
  - Bonding Cleaner / EKC Technology

**Via Creation & Fill**
- Electronics grade C4F8 for Bosch etching
  - Zytron® / Fluoro products
- Dry Film Photoresist
  - TSV Creation/Filling
  - MX Series / Circuit and Packaging Materials
- Photoresist Removers
  - EKC Technology
- Specialty Fluids
  - Cleaning
  - Vertrel® / Fluoro products

**Bonding / Stacking**
- Wafer level Polyimide Adhesive/Underfill
  - HD7000 Series / HD MicroSystems
- Photo definable Dry Film Adhesive
  - PerMX™ Series / Circuit and Packaging Materials
- BTA / CuOx Cleans
  - EKC4000 / EKC Technology

**Thermal Management**
- Substrate System
  - Coolam™

**Via Creation & Fill**
- Wafer Thinning
- Bonding / Stacking

**Bump & RDL Formation**
- Copper CMP
- RDL Dielectric Coatings
- RDL Structuring
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**Via Creation & Fill**
- Dry Film Photoresist
- Photoresist Removers

**Bonding / Stacking**
- Wafer level Polyimide Adhesive/Underfill
- Photo definable Dry Film Adhesive

**Thermal Management**
- Substrate System
Organic based Adhesives Product Mapping
Advantage of PI adhesives

- Temperature
- Cost
- Liquid
- PI/PBO Coatings
- Kapton
- Solder Resist
- Pyralux
- Acrylic
- Epoxy Film
- ACF
- Under fill
- EMC
- Epoxy
- Amide-Imide
- PAI
- Polyimide
- Low
- High
- Cost
- Temperature
- High
### Temporary bonding Polyimide
**HD3007 Example of end properties**

<table>
<thead>
<tr>
<th>Property/Condition</th>
<th>Units</th>
<th>HD-3007</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Viscosity</td>
<td>St</td>
<td>8-10</td>
</tr>
<tr>
<td>Weight Solids</td>
<td>%</td>
<td>25-30</td>
</tr>
<tr>
<td>Cure Temp Range</td>
<td>°C</td>
<td>250-350</td>
</tr>
<tr>
<td>Bonding Temp Range</td>
<td>°C</td>
<td>300-350</td>
</tr>
<tr>
<td>Bonding Press</td>
<td>N/cm²</td>
<td>&gt;14-22</td>
</tr>
<tr>
<td>Contact time</td>
<td>minutes</td>
<td>5-10*</td>
</tr>
<tr>
<td>Cured Dielectric Thickness</td>
<td>microns</td>
<td>2-20</td>
</tr>
<tr>
<td>Glass Transition Temp (Tg)</td>
<td>°C</td>
<td>188</td>
</tr>
<tr>
<td>Weight loss @ 350°C</td>
<td>%</td>
<td>0.2</td>
</tr>
<tr>
<td>CTE</td>
<td>ppm/ °C</td>
<td>60</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>z</td>
<td>3.4</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Mpa</td>
<td>140</td>
</tr>
<tr>
<td>Modulus</td>
<td>Gpa</td>
<td>3.6</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/m*K</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* Bond times dependent on adhesive thicknesses used
  - Thicker adhesive layers will bond faster
  - Thinner adhesive layers will bond slower
Wafer Bonding HD-3007 – Test Matrix

Test Wafers:
Wafer ID: 6715

- **Bonding Process:**
  - Preheat top chuck to **300 °C**
  - Preheat bottom chuck to **180 °C**
  - Load bond tool to bond chamber
  - Evacuation on (no wait for certain value)
  - Heat bottom chuck to **300 °C**
  - Wait until temperature >= **300 °C**
  - Wait 3 min
  - Move separation flags out
  - Wait for 15 s
  - **Piston down** (top chuck starts pressing on glass wafer)
    - (2000 N/min, maximum pressure **6900 N**)
  - Wait for **1 min**
    - (top chuck stops pressing on glass wafer)
  - Purge **N₂**
  - Cooling to **180 °C**
  - Unload bond tool from bond chamber

- **Piston up**

- **Required time for chamber process:** **10 min**

**Result:** good,
300°C is working well

<table>
<thead>
<tr>
<th>Glass wafer</th>
<th>HD3007</th>
</tr>
</thead>
<tbody>
<tr>
<td>SI Wafer</td>
<td></td>
</tr>
</tbody>
</table>

Courtesy of IZM Fraunhofer
Polyimide based permanent bonding adhesives  
**HD7000series Example of end properties**

<table>
<thead>
<tr>
<th>Property/Condition</th>
<th>Units</th>
<th>HD7002</th>
<th>HD-7010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid Viscosity</td>
<td>Pa·sec.</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Weight Solids</td>
<td>%</td>
<td>25-40</td>
<td>25-40</td>
</tr>
<tr>
<td>Cure Temp Range</td>
<td>°C</td>
<td>250-350</td>
<td>250-400</td>
</tr>
<tr>
<td>Bonding Temp Range</td>
<td>°C</td>
<td>250-350</td>
<td>250-350</td>
</tr>
<tr>
<td>Bonding Press</td>
<td>N/cm²</td>
<td>&gt;14-22</td>
<td>&gt;14-22</td>
</tr>
<tr>
<td>Contact time</td>
<td>minutes</td>
<td>5-10*</td>
<td>5-10*</td>
</tr>
<tr>
<td>Cured Dielectric Thickness</td>
<td>microns</td>
<td>2-20</td>
<td>2-20</td>
</tr>
<tr>
<td>Glass Transition Temp (Tg)</td>
<td>°C</td>
<td>172</td>
<td>260</td>
</tr>
<tr>
<td>5% Weight loss Temp.</td>
<td>°C</td>
<td>413</td>
<td>395</td>
</tr>
<tr>
<td>CTE</td>
<td>ppm</td>
<td>80</td>
<td>70</td>
</tr>
<tr>
<td>Dielectric Constant</td>
<td>z</td>
<td>3.3</td>
<td>3.3</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>Mpa</td>
<td>152</td>
<td>173</td>
</tr>
<tr>
<td>Modulus</td>
<td>Gpa</td>
<td>2.6</td>
<td>2.6</td>
</tr>
<tr>
<td>Elongation</td>
<td>%</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/m*K</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* Bond times dependent on adhesive thicknesses used
  * Thicker adhesive layers will bond faster
  * Thinner adhesive layers will bond slower
Wafer Bonding with HD7010

Results: Test 18 Wafer ID 7242

- Bonding Process:
  Preheat top chuck to 250 °C
  Preheat bottom chuck to 180 °C
  Load bond tool to bond chamber
  Evacuation on (no wait for certain value)
  Wait for 8 min (pre-bake in chamber)
  Heat bottom chuck to 250 °C (30°C / min)
  Wait until temperature >= 250 °C
  Wait 3 min
  Move separation flags out
  Wait for 15 s
  Piston down (top chuck starts pressing on glass wafer)
    (2000 N/min, maximum pressure 6900 N)
  Wait for 10 min
  Piston up (top chuck stops pressing on glass wafer)
  Purge N₂
  Cooling bottom chuck to 180 °C
  Unload bond tool from bond chamber

Result:
Succeeded bonding a patterned HD7010 to glass w/o voids
Prior Temporary Bonding Scheme

(A) Laser release

(B) Solvent release

How to handle thinned wafers... ???
**Improved Temporary Polyimide Adhesive Wafer Thinning Process** (Eliminates thin wafer handling)

1. **HD3007 Coat / Prebake**
2. **HD3007 Cure**
3. **Thermo compression**
4. **Back grinding**
5. **Cu polish & PCMP Clean** CoppeReady® & PCMP5510
6. **P-TEOS Depo & Etch**
7. **HD7002 Coat / Prebake**
8. **HD7002 patterning**
9. **HD7002 Cure**
10. **Sn Plating**
11. **Thermo compression to Sub.**
12. **Laser Ablation/Solvent Release** EKC865™
13. **Detach**
14. **Adhesive Removal** EKC865™

**DuPont**
HD-3007 Laser Release Data

Laser lift-off of glass carrier from Si wafer has been carried out at the fluence of 200 and 225 mJ/cm².

Process Parameters:
- Wavelength: 248 nm (KrF)
- Fluence: 200 and 250 mJ/cm²
- Size of beam spot: 5.0 × 1.3 mm²
- Number of pulse: single pulse
- Machining method: step and repeat with overlap of 100 µm

Reference:
- Tamarack successfully performed wafer debonding, including wafer-edge de-activation in AP-278B, they de-bonded the wafers in two steps:
  1. Fully ablate the wafer in the X-direction. After ablation in the X-direction is complete; rotate the wafer 90 degrees.
  2. Fully ablate the wafer in the Y-direction (see diagram below):

Important: Clean glass carrier surface to insure that it does not contain any dirt, spots, etc. that could inhibit the laser light from reaching the adhesive layer.
**HD-3007 Laser Release Data**

**Tamarack Laser De-bonding**

**Wafer De-bonding Throughput Example:**

<table>
<thead>
<tr>
<th>(300mm Wafers) Throughput and TCO Estimates</th>
<th>Tamarack Model 414 with LSX 200K Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Size:</td>
<td>1.5mm x 120mm</td>
</tr>
<tr>
<td>Machine Capacity (wafers/year)</td>
<td>688.758</td>
</tr>
<tr>
<td>Throughput (wafers/hour)</td>
<td>110.00</td>
</tr>
</tbody>
</table>

**Process Assumptions:**
- LSX 200K Laser (248nm, 670mJ):
  - 20 hrd/day
- 200mJ/cm² 2.1-Pulse Ablation:
  - 6 days/week
- Two Passes:
  - 52 weeks/yr
- 1.5mm x 120mm Laser Beam:
  - 5-Year Depreciation
- Manual Load/Unload:
  - Does not include Laser Gases

**TCO Assumptions:**
- Standard Model 414 De-Bonder
DANM Selective Cu polish Slurry can eliminate additional plating process for bump

Slurry Target Specifications:

- Si Removal rates: 2-2.5 \( \mu \text{m/min} \)
- Selectivity Si:Cu: 1:1

Current best formulation is Si:Cu of 1:1 @ 16000 A/min using Additive D (need to optimize conc. of D to lower Cu etch rate).
PCMP5510™ Post Grind/Polish Metallic Contamination Removal

TOF-SIMS Analysis for Residual Copper

Excellent Trace Metal Cleaning Performance
EKC4000™ BTA/Cu Oxide Cleaner
For Cu - Cu Bonding

BTA Removal Summary

Summary of All Chemistries at Removal of BTA Layers

+ Citric and Formic are equally mediocre at removing BTA layers.
+ EKC 4000 appears to be excellent at removing BTA and underlying oxide layers.

Suss Confidential
EKC4000™ BTA/Cu Oxide Cleaner
For Cu - Cu Bonding

Oxide Removal Summary

Native Oxide Effects from All Chemistries

- Citric Acid is best for removal of oxides as is EKC 520
- Formic and EKC 4000 are roughly equivalent.
EKC865™ Selective Adhesive Remover

Flip down and bond to substrate/die

Laser ablation for release

Detach glass sub.

Solvent Release & Adhesive Removal
EKC865™ Adhesive Remover

Adhesive Removal
EKC865™ Adhesive Remover
EKC865™ Selective Adhesive Remover for HD3007

- **Test Wafer Process Conditions**
  - HD3007 thickness = 8um (4um standard thickness)
  - Cured at 200-240°C
  - De-bonded via laser ablation
  - Additional pieces of silicon wafer coated with HD4100 (blanket and patterned) and cured at 350°C were also tested for compatibility

- **Cleaning Results**
  - Rapid Cleaning at 60°C for a time of 60-180 secs
  - Compatible with HD4001 cured at 350°C
    - Tested at 60°C for 30min with no attack to HD4001
  - Excellent Compatibility to Sensitive Metal Films
    - Aluminum, Copper, Titanium, Nickel, Chrome, Tungsten, & other Metal Alloys
  - Chemistry can be re-circulated in a closed loop system
  - Water rinseable
  - Can be utilized in both automated and manual wet cleaning equipment platforms

(All tests run at 60°C)
Thanks for your attention!!