Photodefinable Materials for Advanced Packaging

- Spin-On Dielectrics
- Wafer Bonding Dielectrics
- Dry Film Dielectrics
- Electroplating Resists
Spin-On Dielectrics
Applications for Dielectric Materials

- **RDL Dielectric:** SINR, SIPR-AP
- **Stress Buffer:** SINR
- **TSV Filling:** SINR
- **Wafer bonding:** SINR
SINR Photosensitive Silicone Dielectrics

SINR Materials Platform

- Based on novel siloxane chemistry
- i-line or broadband sensitive
- Negative tone
- IPA or PGME developable
- Ultra-low modulus (as low as 90 MPa) for low residual stress
- Low-temperature & rapid cure (180°C/1 hr or 160°C/2 hr)
- Low shrinkage after cure (<10%)
- Low dielectric constant (2.6)
- Excellent adhesion to organic & inorganic materials
- Excellent shelf-life (6 months/0-15°C or 1 month at RT)
- Available in various forms:
  - Spin-on
  - Dry film
SINR Mechanical Properties

Wafer warpage and stress controlled by siloxane content

<table>
<thead>
<tr>
<th>Product</th>
<th>Siloxane Content (%)</th>
<th>Young’s Modulus (GPa)</th>
<th>CTE (ppm/°C)</th>
<th>Wafer Warpage (μm)</th>
<th>Stress on Si (MPa)</th>
<th>Elongation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINR-3110</td>
<td>10</td>
<td>1.4</td>
<td>80</td>
<td>15.5</td>
<td>2.6</td>
<td>15</td>
</tr>
<tr>
<td>SINR-3150</td>
<td>50</td>
<td>0.24</td>
<td>130</td>
<td>12</td>
<td>2.0</td>
<td>40</td>
</tr>
<tr>
<td>SINR-3170</td>
<td>70</td>
<td>0.15</td>
<td>180</td>
<td>1.2</td>
<td>0.2</td>
<td>40</td>
</tr>
</tbody>
</table>

30μm of SINR on 725μm-thick 200mm Si wafer
### SINR-3170PFM on Aluminum

<table>
<thead>
<tr>
<th>Mask CD</th>
<th>20 μm L&amp;S</th>
<th>30 μm L&amp;S</th>
<th>40 μm L&amp;S</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exp. (i-line)</strong> = 1000 mJ</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
</tr>
<tr>
<td>1200 mJ</td>
<td><img src="image4.png" alt="Image" /></td>
<td><img src="image5.png" alt="Image" /></td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>

- FT = 22μm
- SB = 100°C / 120 sec
- PEB = 110°C / 120 sec
## SINR-3170PFM on Aluminum

<table>
<thead>
<tr>
<th>Exp. (i-line) = 1000 mJ</th>
<th>30 μm Hole</th>
<th>40 μm Hole</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mask CD = 20 μm Hole</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
</tr>
<tr>
<td>1200 mJ</td>
<td><img src="image3.png" alt="Image" /></td>
<td><img src="image4.png" alt="Image" /></td>
</tr>
</tbody>
</table>

- FT = 22μm
- SB = 100°C / 120 sec
- PEB = 110°C / 120 sec
Wafer Bonding Dielectrics
SINR-3570 Series Dielectrics for Wafer Bonding

- Based on SINR-3170 chemistry
  - Modified for bonding at room temperature
- Good adhesion for bonding:
  - Chip-to-wafer
  - Wafer-to-wafer
  - Wafer-to-glass
- 70%-siloxane content for minimal wafer bowing
- Same 180°C/1 hour cure as for SINR-3170
- Minimal resist outgassing after wafer bonding
Adhesion

- SINR materials have excellent adhesion to most organic, inorganic materials, and itself
- Typical values for Si and SiON:

<table>
<thead>
<tr>
<th>Product</th>
<th>Substrate</th>
<th>Adhesion strength</th>
<th>Mode of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>SINR-3570PFM (Spin-on)</td>
<td>Si</td>
<td>11.2 MPa</td>
<td>SINR-wafer surface</td>
</tr>
<tr>
<td>SINR-DF3570PFM (Dry Film)</td>
<td>Si</td>
<td>11.7 MPa</td>
<td>SINR-wafer surface</td>
</tr>
<tr>
<td>SINR-3570PFM (Spin-on)</td>
<td>SiON</td>
<td>13.6 MPa</td>
<td>Wafer broke</td>
</tr>
<tr>
<td>SINR-DF3570PFM (Dry Film)</td>
<td>SiON</td>
<td>13.8 MPa</td>
<td>Wafer broke</td>
</tr>
</tbody>
</table>

Die shear test method:
Attach/Cure Process 1

- **Top wafer**
- **SINR after develop**
- **Bottom wafer**

Insert in vacuum chamber
- Vacuum <1Pa
- Pressure = 0.1-2MPa

Ramp to 180°C and hold for 1 hour
Attach/Cure Process 2

1. Insert in vacuum chamber for ~3min
   - Vacuum <1Pa
   - Pressure = 0.1-2MPa
   - Temperature = 140-160°C

2. Remove from vacuum and put in oven
   Ramp to 180°C and hold for 1 hour
Dry Film Dielectrics
SINR Dry Film Dielectrics

- Family of products
- Chemistry and physical properties similar to spin-on SINR products
- Current applications:
  - Wafer bonding
  - Backside stress buffer/RDL
  - TSV filling
SINR Dry Film Dielectrics

Construction for 200mm wafer and 300mm wafers:

- **PE Coversheet (t = 50μm)**
- **SINR-DF (t = 15-100μm)**
- **PET Base Film (t = 50μm)**

Dry film thickness: 12-100μm
Electroplating Resists
SIPR-7120 Series Electroplating Photoresists

- Applications
  - Solder bump plating
  - Copper pillar plating
  - Gold bump plating
  - Copper redistribution plating
  - Etching

- Properties
  - i-line sensitive (broadband tool OK)
  - Positive tone
  - Chemically amplified for faster photospeeds
  - Capable of 10-100µm in a single coat
  - No PEB required
  - TMAH developable
  - Good plating resistance
  - Easily stripped in acetone or NMP
Copper Pillars After Resist Strip

Cu Pillar CD Linearity

FT (SIPR-7123M) = 55µm
Resist removal: Acetone, 10 min @ 21°C
Cu pillar height ~ 30µm
Cu seed wafers

Iso- and Dense 50µm Pillars

(a) 30 µm pillar  (b) 50 µm pillar  (c) 100 µm pillar

(a) 12.5 µm spacing  (b) 50 µm spacing  (c) 100 µm spacing
Metal Adhesion Promoters

**PR1P**
- Designed to enhance adhesion to copper
- Two functional groups to maximize adhesion to copper and copper oxide

**PR20P**
- Designed to enhance adhesion to gold

**SIPR-9740 on Copper**
With and Without PR1P