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- Enabling Materials for **MEMS and Sensor Assembly**
  - Low & Constant Modulus Adhesives for MEMS
  - Al Polymer Stripper for MEMS Wafer Processing
  - Dual Cure Adhesives for 3D Sensing (Face ID)
  - Medical Sensing in Smart Wearables
Who We Are
Globally Leading in Consumer and Industrial Businesses

- Headquartered in Düsseldorf (DE)
- Preferred stocks since 1985, family owns >59% of ordinary stocks
- Henkel products and technologies available worldwide
- 170 manufacturing and 21 major R&D sites around the world
- Employees from 125 nations

More than 53,000 employees
Over €20 bn sales, >3% growth
Henkel Adhesive Electronics
Markets, Applications and Brands

Semiconductor Packaging
- Assembling
- Protecting
- Cleaning
- Connecting
- Shielding
- Handling
- Cooling

Electronic Devices Assembly
- Connecting
- Protecting
- Bonding
- Cooling
- Shielding
- Sealing
- Cleaning
- Dispensing
## Henkel Adhesive Electronics
### Assembly Solutions vs Market Needs

#### Henkel Solutions

<table>
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<tr>
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<th>Die Attach Adhesives</th>
<th>Assembly Adhesives</th>
<th>Underfills &amp; Encapsulants</th>
<th>Inks &amp; Coatings</th>
<th>Solder Materials</th>
<th>Thermal Materials</th>
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<td><strong>Market Needs</strong></td>
<td></td>
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<tr>
<td>Manufacturing Efficiency (uph)</td>
<td></td>
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<tr>
<td>High Reliability</td>
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<tr>
<td>Miniaturization</td>
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<tr>
<td>Sustainability</td>
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<tr>
<td>EMI Shielding, Pastes, Coatings</td>
<td></td>
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</tr>
<tr>
<td>Underfills, Pastes, Films &amp; Liquids</td>
<td></td>
<td></td>
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<tr>
<td>Liquid Encapsulants, Thermal &amp; UV Cure, Compression Molding</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Die Attach Adhesives, Pastes, Films &amp; B-Stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Electrically Conductive Adhesives and Inks, Solder Pastes</td>
<td></td>
<td></td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>
“Semiconductor in Europe is Back in Business”

- Strong European Semiconductor Market players focusing on
  - Automotive
  - MEMS/Sensors
  - Imaging

- Significant European Semiconductor investments
  - New Bosch and GloFo wafer fabs in Dresden (>$2B)
  - Infineon investing $1.9B in new wafer fab for power in Villach (AT)
  - Infineon setting up new Development Center in Dresden for Automotive Electronics and Artificial Intelligence (~100-250 FTE)
Semiconductor Innovation Curve and Solutions

**Market Drivers**
- Internet of Things
- Wearables
- Cloud Storage
- Mobile
- Display
- General Lighting
- PC & Computing
- Automotive

**Henkel Solutions**
- Wafer Level Encapsulation
- In Package EMI Shielding
- Wafer Applied Underfills
- Dicing Die Attach Films
- Flip Chip Underfills
- MEMS, CMOS Image & Biometric Sensor Adhesives
- High Thermal Die Attach
- Low Cost Die Attach
- Wirebond Encapsulation

**UNITS**

**GROWTH Segments**
- 3D TSV Memory & Application Processors
- Flip Chip Application Processors
- CMOS Image & Bio Sensors

**MATURE Segments**
- Stacked Die Memory
- Compact ICs, SiP
- Power ICs
- Flip Chip BGA
- Wirebond (PDIP, QFP)
| Continued Miniaturization                                                                 | • Upgrade product offering for thinner wafer and flow control  
|                                                                                     | • Die Attach Film (DAF), resin bleed-out control, fine filler choice |
| Thinner Packages                                                                    | • Continue to build competitive edge in stress/warpage control  
|                                                                                     | • Leverage expertise for new applications, e.g. WAUF and CUF |
| Thermal Management                                                                  | • Promote semi-sintering technology for die and lid attach  
|                                                                                     | • Develop high thermal solutions for CUF, WIA and LCM |
| Application Specific Packages                                                       | • Enrich and expand product portfolio for sensor applications  
|                                                                                     | • Unique mechanical properties, low temperature cure |
| Automotive Reliability                                                             | • Improve reliability of key products  
|                                                                                     | • Automotive grade DAP, (c)DAF and CUF |
Semiconductor Market Trends & Developments
Continuous Package Miniaturization

- Package / die area ratio moving <<1 by stacking and 3D integration
- Higher reliability requirements by automotive applications leveraging successful mobile package developments (like Infineon’s eWLB for 77GHz Radar)

Source: eSiP

QFP 5.5
BGA 2
CSP 1.2
WLCSP 1
Stacked die <1
PoP <1
3DIC <<1

Courtesy of Infineon Technologies
Semiconductor Market Trends & Developments
Moving to “Advanced” Wafer Level Packaging and 3D Stacking

- Packaging of chip on wafer level BEFORE singulation

- Successful introduction of **FAN-OUT Wafer Level Packaging** and **Through Silicon Vias (TSV)** (replacing traditional and proven wire bond technology)
Advanced Semiconductor Packaging

What Does That Mean for Packaging Materials?

- **Declining need for traditional die attach adhesives and transfer mold compounds!** (like in use for SO, QFN, QFP and BGA type of lead frame and laminate devices)

- Need for **very thin “Wafer Applied Underfill Films”** for 3D Stacking of thin TSV Wafers

- Need for **low shrinkage and ultra-low warpage wafer encapsulation** using liquid compression molding, stencil printing or sheet lamination technologies
Advanced Semiconductor Packaging
Materials versus Applications

Advanced Packaging

Panel Level

Flip Chip
- CSP
  - CUF
  - NCP
  - NCF
- BGA
  - CUF
  - Lid Attach
- PoP
  - WIA (Warpage Improvement)

Wafer Level
- Fan-In
  - UV WBC
    - BSP (Back Side Prot.)
    - FSP (5 Side Prot.)
- Fan-Out
  - DAF (Face Up)
  - LCM (Liquid Molding)

Memory 3D TSV
- NCF (WAUF)
- LCM (Liquid Molding)
**Advanced Semiconductor Packaging**

**Innovative Underfill Solutions**

### Capillary Underfill (CUF), >75um pitch
- Existing process
- High UPH
- No bump protection after chip attach

### Non Conductive Paste (NCP), >30um pitch
- Enable fine pitch & narrow gap
- Bump protection after bonding
- Tight design by fillet size control
- Low UPH
- Filler entrapment possible

### Non Conductive Film (NCF), >15um pitch
- Enable fine pitch & narrow gap
- Thin wafer and bump protection
- Tight design by fillet size control
- Low UPH
- Different film thickness per design

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Enabling Materials for Wafer Level Packaging, MEMS & Sensor Assembly
Wafer Applied Underfill Film (WAUF)
Non Conductive Film for 3D Memory TSV

- Reliable Fine Pitch TSV Die Stacking using **Thermal Compression Bonding (TCB)**
  - Bond each die in stack individually (recommended) or by “collective bonding” (tack each die in place at lower temperature, then press and cure whole stack with hot bond head within seconds)
Ultra-Low Warpage Liquid Encapsulation

Liquid Compression Molding (LCM) for Fan-Out WLP (eWLB)

1. Thermal Release Tape on Carrier
2. Die P&P on Carrier
3. Dispensing on Die
4. Compression Molding & Post Mold Cure (PMC)
5. Remove Carrier
6. Back Grinding
7. Redistribution Layer (RDL)
8. Ball Mount & Simulation
Ultra-Low Warpage Liquid Encapsulation
5/6 Side WLCSP Protection Process (by Molding or Printing)

Enabling Materials for Wafer Level Packaging, MEMS & Sensor Assembly

June 19, 2018

Wafer from Foundry → Copper Pillar Pad → Trench Dicing (half cut)

Back Side Grinding

Top Side Grinding for Pad Exposure

Film or Print on Back Side for 6 Side Protection

Dicing to Single Units → Protected WLCSP

Chip
Ultra-Low Warpage Liquid Encapsulation
Trench Filling for 5/6 Side WLCSP Protection

- Low warpage and trench filling test results using LCM 1000AA (10um filler) on 200um and 300um 8” wafers with 40um wide and 400um deep trenches
  - Yamada MS-150HP molding machine with Asahi Fluon ETFE film release liner
  - 4min @ 120°C in-mold cure, 1hr @ 150°C post mold cure

<table>
<thead>
<tr>
<th></th>
<th>200um wafer + 70um LCM</th>
<th>300um wafer + 70um LCM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within 2 hour after PMC</strong></td>
<td>5.57mm</td>
<td>349um</td>
</tr>
<tr>
<td><strong>24 hour after PMC</strong></td>
<td>4.80mm</td>
<td>331um</td>
</tr>
</tbody>
</table>

Excellent 40um trench filling down to 400um without voiding
# Ultra-Low Warpage Liquid Encapsulation

## Material Properties

- **Compression Molding and Stencil Printing for „FAN-IN“ (WLCSP)**
- **Compression Molding for „FAN-OUT“ (eWLB)**

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>LCM-1</th>
<th>LCM-2</th>
<th>LCM-3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LOCTITE ECCOBOND</strong></td>
<td><strong>LCM 1000AA</strong></td>
<td><strong>EN 8000AA</strong></td>
<td><strong>LCM 5000AA</strong></td>
</tr>
<tr>
<td>Type</td>
<td>WLCSP Molding (Fan-In)</td>
<td>WLCSP Printing (Fan-In)</td>
<td>eWLB Molding (Fan-Out)</td>
</tr>
<tr>
<td>Base resin</td>
<td>Non-Anhydride</td>
<td>Non-Anhydride</td>
<td>Non-Anhydride</td>
</tr>
<tr>
<td>Filler size, max (um)</td>
<td>10</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Viscosity (25°C, Pa.s)</td>
<td>430</td>
<td>55</td>
<td>550</td>
</tr>
<tr>
<td>Tg by TMA, (°C)</td>
<td>166</td>
<td>149</td>
<td>163</td>
</tr>
<tr>
<td>CTE1/CTE2 (ppm/°C)</td>
<td>6/18</td>
<td>10/27</td>
<td>7/17</td>
</tr>
<tr>
<td>Tg by DMA (°C)</td>
<td>177</td>
<td>142</td>
<td>194</td>
</tr>
<tr>
<td>Modulus @ 25°C, GPa</td>
<td>14</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>In-mold cure condition</td>
<td>120°C/4min</td>
<td>N/A</td>
<td>120°C/4min</td>
</tr>
<tr>
<td>Post mold cure</td>
<td>150°C/1hr</td>
<td>150°C/1hr</td>
<td>150°C/1hr</td>
</tr>
</tbody>
</table>

Enabling Materials for Wafer Level Packaging, MEMS & Sensor Assembly  
June 19, 2018
Adhesives for MEMS & Sensors
Typical Applications Running in High Volume

Microphone, Pressure Sensors
- Lid/Cap Attach
- ASIC Attach
- Glob Top
- MEMS Attach

Optical Sensors
- Lid Attach
- ASIC Attach
- LED Attach

Accelerometers, Gyroscope, Magnetometers
- Mold Compound
- ASIC Attach
- MEMS Attach
Adhesives for MEMS & Sensors
Specific MEMS Challenges & Needs

- MEMS dies are very sensitive and fragile
  - Response sensitivity (stability) key challenge to control functionality
  - Die bending in case of stress variation leading to (re)calibration issues
  - Potential die cracking in case of high stress

- Need for **low stress, low warpage and low temperature cure** materials
  - Low and constant modulus over operational temperature range preferred for accurate and stable sensor performance
  - Low temperature cure below 100°C to minimize stress in package

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Not acceptable

Acceptable

Minimal change in modulus during assembly processing

Minimal shift is preferred after post assembly temperature cycling

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Enabling Materials for Wafer Level Packaging, MEMS & Sensor Assembly  June 19, 2018  20
Adhesives for MEMS & Sensors
Ultra Low & Constant Modulus below 1 MPa

- New ABP 8145A development – Lowest stress die attach adhesive with modulus below 1 MPa from -25°C up to 300°C for very stress sensitive MEMS applications (like pressure sensor & microphone, non-conductive)
Adhesives for MEMS & Sensors
Application Examples of Non Conductive SIL Series

**MEMS Microphone**
- Magnet Attach + Encapsulant
  - 25 MPa @ RT
  - 20 MPa @ 250°C
  - TI = 3.5
  - Black color

**Automotive Speed Sensor**
- **MEMS Attach**
  - 2.8 MPa @ RT
  - 3.0 MPa @ 250°C
  - TI = 3.3
  - No slumping
  - Black color

- **Magnet Attach + Encapsulant**
  - 25 MPa @ RT
  - 20 MPa @ 250°C
  - TI = 3.5
  - Black color

**Accelerometer**
- **ASIC to MEMS**
  - 100 MPa @ RT
  - Z-direction stable modulus
  - 0.8 W/mK (Al2O3)
  - White color

**Ambient Light Sensor**
- **LED Attach**
  - 125 MPa @ RT
  - Thermally stable light transmittance
  - Non filled
  - Transparent color
Adhesives for MEMS & Sensors
Electrically Conductive Silicones

- **LOCTITE ABLESTIK ICP 4000 / 4001**
  Ag filled SILICONES running in automotive HVM applications requiring high flexibility over broad temperature range (up to 200°C)

- **LOCTITE ABLESTIK ICP 4015**
  modified for temperature sensitive applications (<100°C cure)

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<table>
<thead>
<tr>
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<th>ICP 4000</th>
<th>ICP 4001</th>
<th>ICP 4015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>Silicone</td>
<td>Silicone</td>
<td>Silicone</td>
</tr>
<tr>
<td>Appearance</td>
<td>Silver</td>
<td>Silver</td>
<td>Silver</td>
</tr>
<tr>
<td>Viscosity @ 25°C</td>
<td>25-40 Pa.s</td>
<td>30-50 Pa.s</td>
<td>18-25 Pa.s</td>
</tr>
<tr>
<td></td>
<td>(@ 15s⁻¹)</td>
<td>(@ 15s⁻¹)</td>
<td>(@ 15s⁻¹)</td>
</tr>
<tr>
<td>Worklife</td>
<td>2 days, change of viscosity &lt; 50%</td>
<td>1 day, change of viscosity &lt; 50%</td>
<td>2 days, change of viscosity &lt; 50%</td>
</tr>
<tr>
<td>Cure Schedule</td>
<td>35 min 140°C or 60 min 130°C</td>
<td>35 min 140°C</td>
<td>60 min 80°C or 35 min 140°C</td>
</tr>
<tr>
<td>Thermal Expansion</td>
<td>330 +/- 30ppm</td>
<td>365 +/- 70ppm</td>
<td>NA</td>
</tr>
<tr>
<td>Elongation</td>
<td>&gt; 20%</td>
<td>&gt; 20%</td>
<td>&gt; 20%</td>
</tr>
<tr>
<td>Volume Resistivity</td>
<td>5x10⁵ Ohm cm</td>
<td>5x10⁴ Ohm cm</td>
<td>5x10⁵ Ohm cm</td>
</tr>
<tr>
<td>Hardness Shore A</td>
<td>NA</td>
<td>73 - 85</td>
<td>NA</td>
</tr>
<tr>
<td>Die Shear Strength</td>
<td>&gt; 400gr</td>
<td>&gt; 1500gr</td>
<td>&gt; 350gr</td>
</tr>
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</table>
Al Polymer Stripper for MEMS Wafer Processing
Qualified by European Foundry

- Newly developed cleaner for MEMS wafer processing
  - NMP-free, TMAH-free and HDA-free formulation (amine based)
  - No IPA step needed (go direct to DI rinsing step after photoresist strip)
  - No flashpoint (no explosion-proof equipment and environment needed)
  - Possibility to clean in acid etching tool (both etching and polymer stripping in same machine)
  - Lower total cost of operation

- Processing conditions
  - 65ºC for 20 minutes
Adhesives for CMOS Image Sensors

Typical Compact Camera Module (CCM) Design
Adhesives for CMOS Image Sensors
Multiple Bonding & Other Applications in CCM

- Lens Barrel Attach
- Spring to VCA
- Magnet bonding
- Lens Holder Attach & ACTIVE alignment
- VCM terminal bonding (Grounding & Signal)
- Die Attach Paste
- IR Filter attach
- Bracket Fill (BF)
- Grounding (ECA)
- Bracket Attach (BA)
Adhesives for CMOS Image Sensors
3D Sensing Driven by Face Recognition in Mobile Segment

3D Cameras include Emission Sensor, Receive sensor, Proximity sensor and CCM

Source: IHS Markit 2018

Global 3D Face Sensor Shipments in Mobile Handsets (Millions of Units)
### Adhesives for CMOS Image Sensors

#### Dual Cure Adhesive Comparison (UV + Thermal)

<table>
<thead>
<tr>
<th>Product Name</th>
<th>OGR-150THTG</th>
<th>LOCTITE 3217</th>
<th>LOCTITE 3707</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resin type</td>
<td>Acrylate</td>
<td>Acrylated Epoxy</td>
<td>Cationic Epoxy</td>
</tr>
<tr>
<td>Recommended cure conditions</td>
<td>100mW/cm² 365nm + 1h @ 100ºC / 2h @ 85ºC</td>
<td>100mW/cm² 220-260nm + 20min @ 80ºC / 30min @ 60ºC</td>
<td>100mW/cm² 220-260nm + 2min @ 130ºC</td>
</tr>
<tr>
<td>Color</td>
<td>Colorless (amber)</td>
<td>Colorless (amber)</td>
<td>Opaque (white)</td>
</tr>
<tr>
<td>Basic properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity @ 25ºC (mPa.s)</td>
<td>1,000 (@ 10rpm)</td>
<td>38,000 (@ 20rpm)</td>
<td>10,000 (@ 20rpm)</td>
</tr>
<tr>
<td>Thixotropic index @ 25ºC, 0.5/5.0rpm</td>
<td>NA</td>
<td>2.9</td>
<td>NA</td>
</tr>
<tr>
<td>Work life @ 25ºC (days)</td>
<td>&gt;90</td>
<td>&gt;14</td>
<td>&gt;7</td>
</tr>
<tr>
<td>Physical properties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tg (ºC), by TMA</td>
<td>145</td>
<td>82</td>
<td>53</td>
</tr>
<tr>
<td>CTE (ppm/ºC), by TMA</td>
<td>Below Tg</td>
<td>61</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>Above Tg</td>
<td>157</td>
<td>178</td>
</tr>
<tr>
<td>Modulus @ 25ºC (GPa), by DMA</td>
<td>1.3</td>
<td>0.33</td>
<td>4.4</td>
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<tr>
<td>Hardness, Shore D</td>
<td>76</td>
<td>86</td>
<td>NA</td>
</tr>
</tbody>
</table>
Medical Sensing in Smart Wearables ("Health Patches")
Multiple Printing, Bonding & Other Applications

- Printed Electronics
  - Highly conductive inks with Sheet Resistance <0.005 ohm/sq/25μm

- Soldering
  - High reliability automotive grade 90iSC alloy

- Circuit board protection
- Electrically conductive adhesives
- Medical grade assembly adhesives and pressure sensitive adhesive tapes
Key Take Aways

- Semiconductor market moving gradually from traditional Wire Bond packaging to “Advanced” Wafer Level packaging having a big impact on back end assembly materials needed

- New MEMS and Image Sensor developments asking for customized adhesives with very specific mechanical, (di)electrical and processing properties
Many Thanks!

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