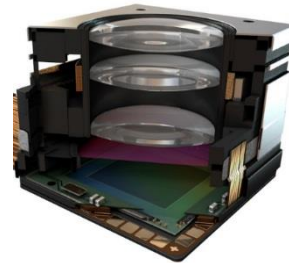
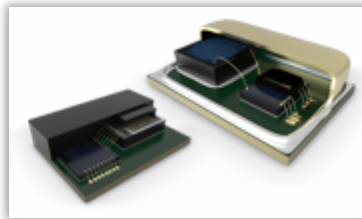
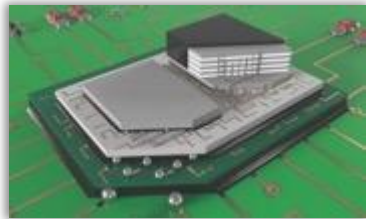


Enabling Materials for Wafer Level Packaging, MEMS & Sensor Assembly

28th Chemnitzer Seminar | June 12th, 2018
by Ruud de Wit | Henkel Electronic Materials



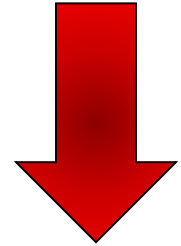
| Content

- Henkel Electronic Materials Introduction
- Semiconductor Market Trends & Developments
- Enabling Materials for **Advanced Wafer Level Packaging**
 - Wafer Applied Underfill Film (WAUF)
 - Ultra-Low Warpage Liquid Encapsulation
- 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

| Consumer Businesses | | Industrial Business |
|--|---|---|
| Laundry & Home Care  | Beauty Care  | Adhesive Technologies  |
| Persil Purex Pril | Schwarzkopf Dial syoss | LOCTITE BERGQUIST TECHNOMELT |

Henkel Adhesive *Electronics*

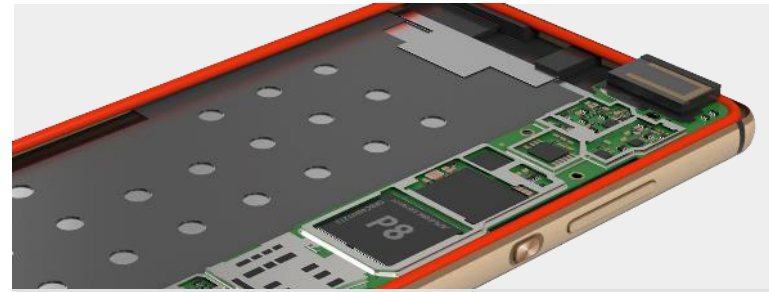
Markets, Applications and Brands

Semiconductor Packaging



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

Electronic Devices Assembly



- Connecting
- Protecting
- Bonding
- Cooling
- Shielding
- Sealing
- Cleaning
- Dispensing

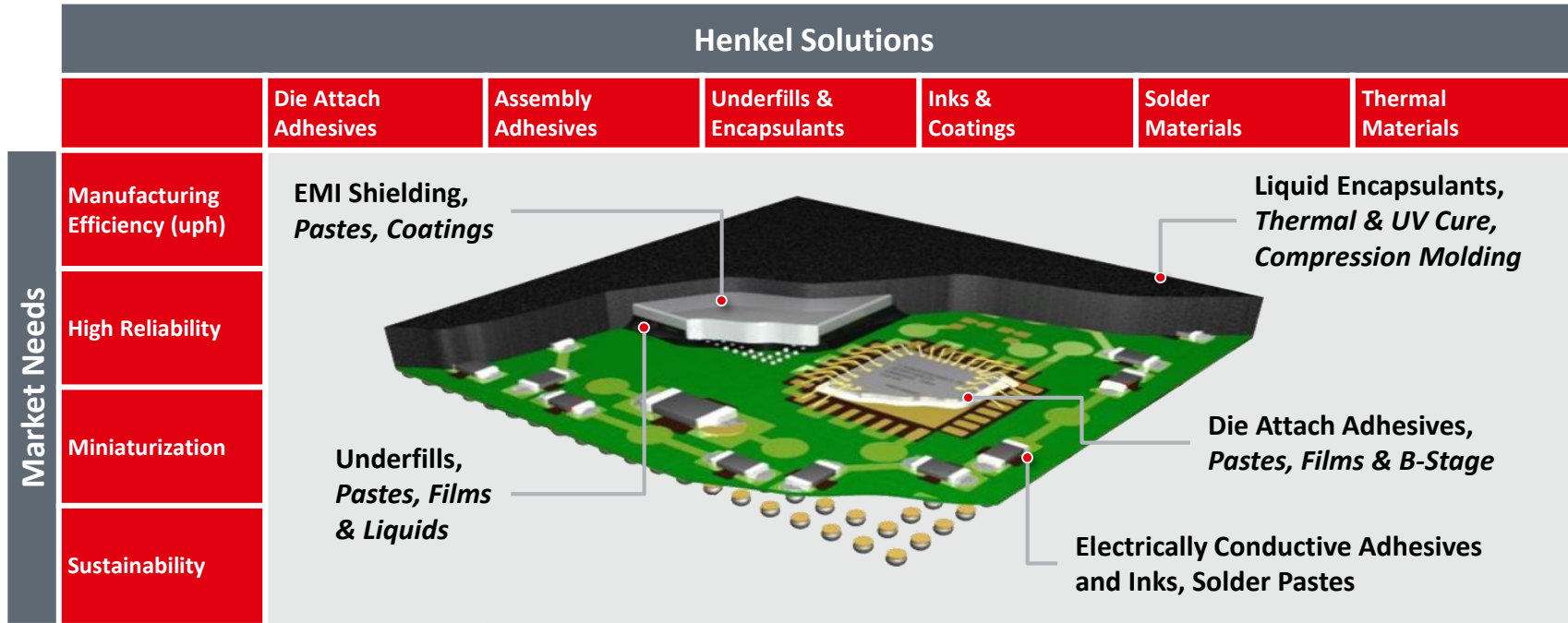
LOCTITE®

TECHNOMELT®

BERGQUIST

Henkel Adhesive *Electronics*

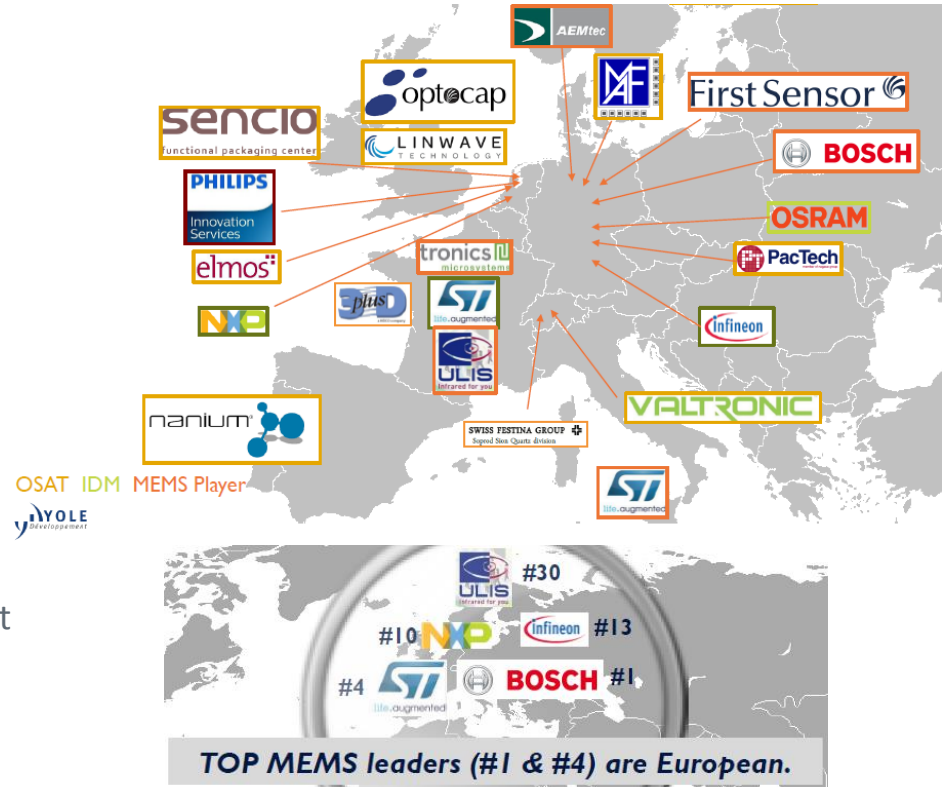
Assembly Solutions vs Market Needs



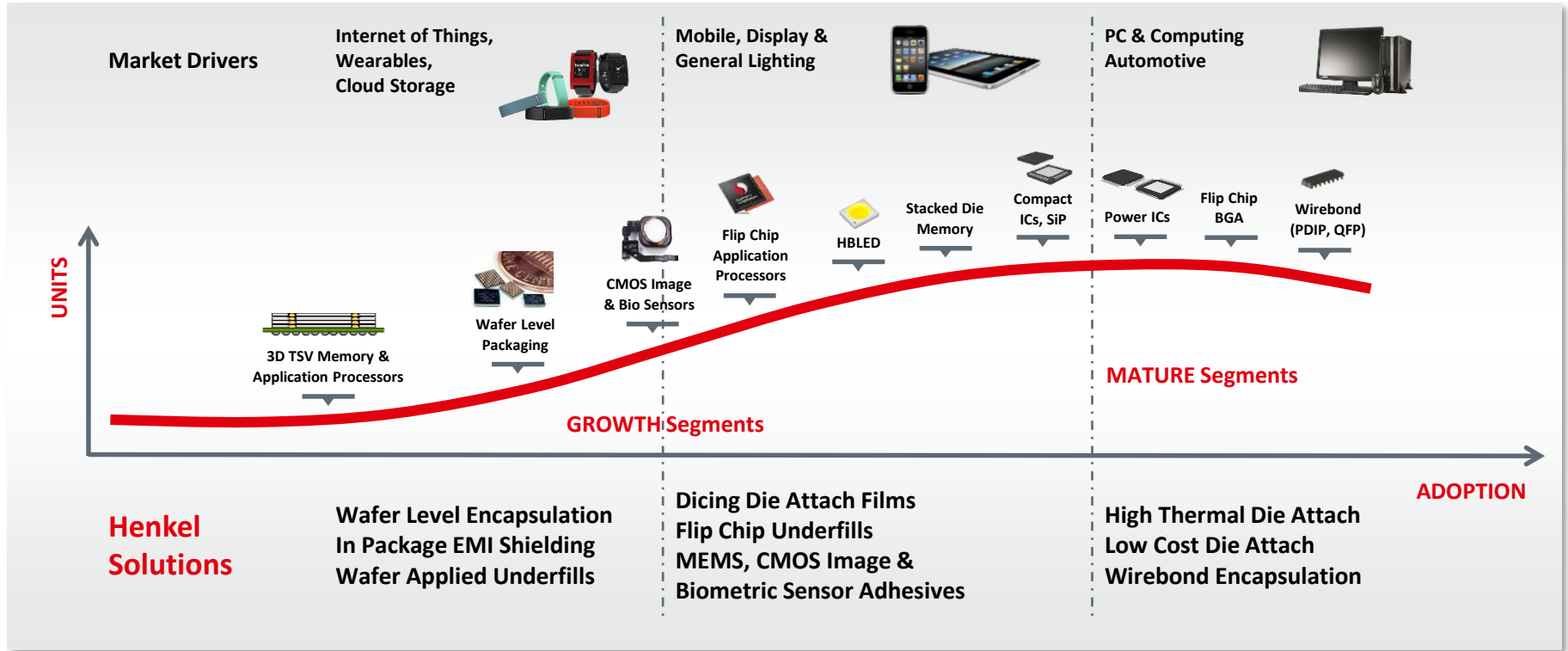
“Semiconductor in Europe is Back in Business”

- 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



| Semiconductor Market Trends & Developments

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/warping 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

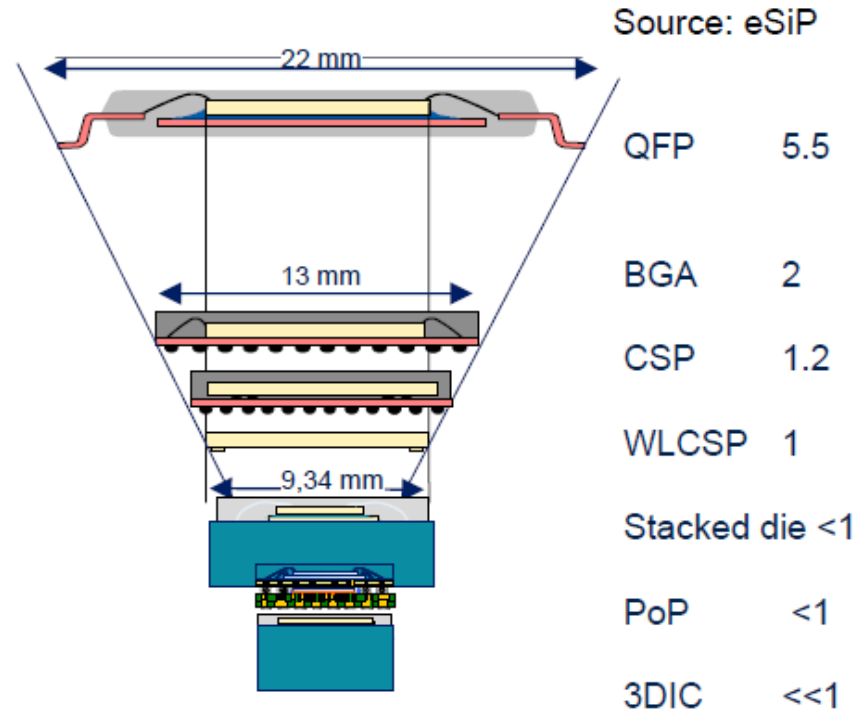
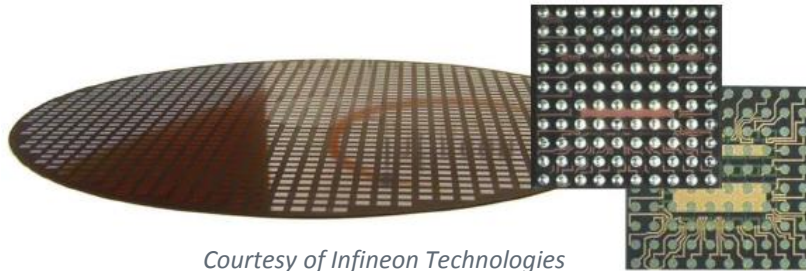
Automotive Reliability

- **Improve reliability** of key products
- Automotive grade DAP, (c)DAF and CUF

Semiconductor Market Trends & Developments

Continuous Package Miniaturization

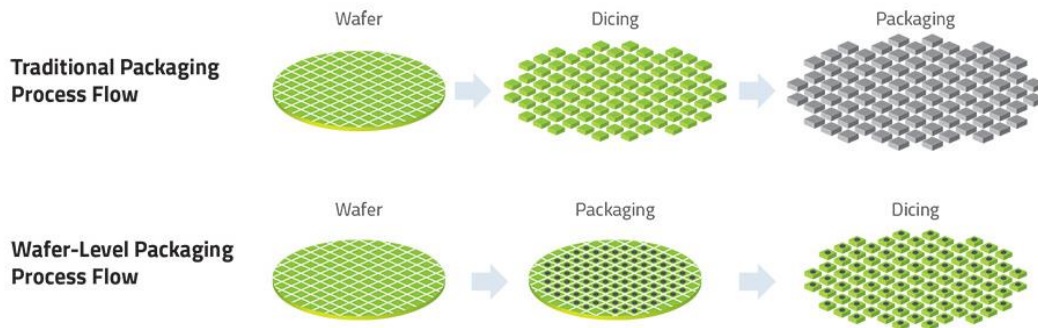
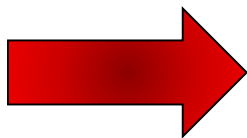
- Package / die area ratio moving $\ll 1$ by stacking and 3D integration
- Higher reliability requirements by automotive applications leveraging successful mobile package developments (like Infineon's eWLB for 77GHz Radar)



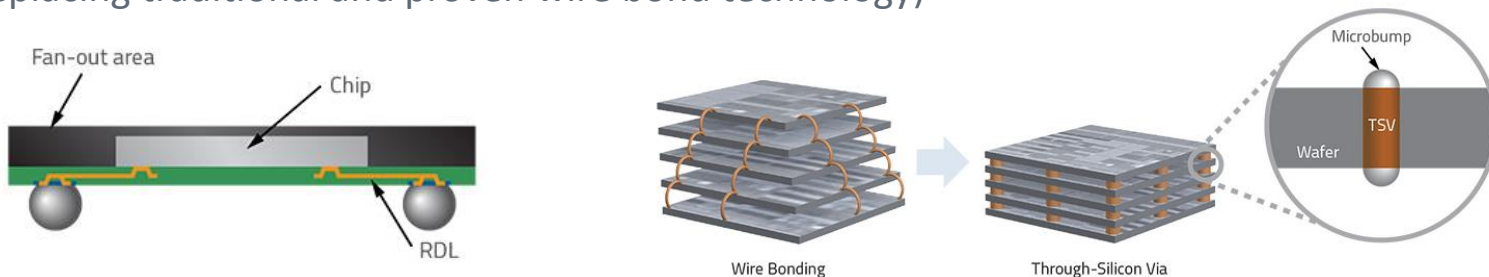
| Semiconductor Market Trends & Developments

Moving to “Advanced” Wafer Level Packaging and 3D Stacking

- Packaging of chip on wafer level BEFORE singulation



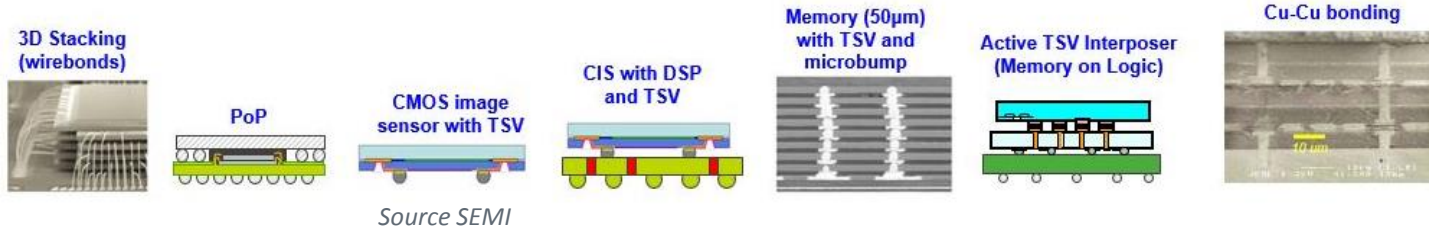
- Successful introduction of **FAN-OUT Wafer Level Packaging** and **Through Silicon Vias (TSV)** (replacing traditional and proven wire bond technology)



| Advanced Semiconductor Packaging

What Does That Mean for Packaging Materials ?

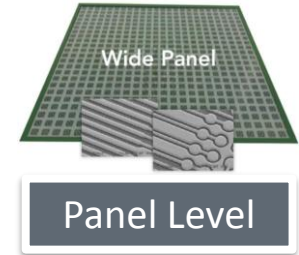
- **Declining need for traditional die attach adhesives and transfer mold compounds !**
(like in use for SO, QFN, QFP and BGA type of lead frame and laminate devices)
- Need for **very thin “Wafer Applied Underfill Films”** for 3D Stacking of thin TSV Wafers
- Need for **low shrinkage and ultra-low warpage wafer encapsulation** using liquid compression molding, stencil printing or sheet lamination technologies



Advanced Semiconductor Packaging

Materials versus Applications

Advanced Packaging



Flip Chip

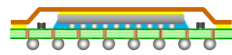
CSP

- CUF
- NCP
- NCF



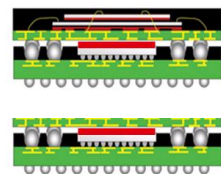
BGA

- CUF
- Lid Attach



PoP

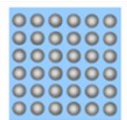
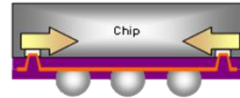
- WIA (Warpage Improvement)



Wafer Level

Fan-In

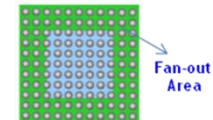
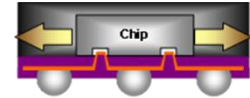
- BSP (Back Side Prot.)
- FSP (5 Side Prot.)



UV WBC

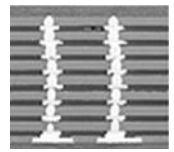
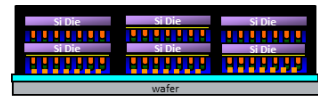
Fan-Out

- DAF (Face Up)
- LCM (Liquid Molding)



Memory 3D TSV

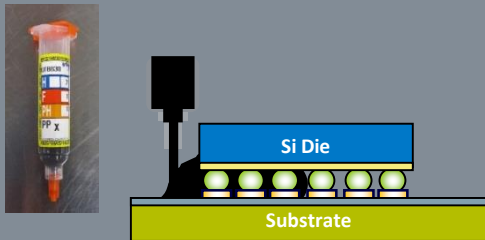
- NCF (WAUF)
- LCM (Liquid Molding)



Advanced Semiconductor Packaging

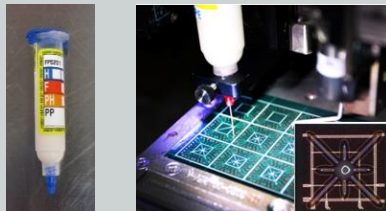
Innovative Underfill Solutions

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

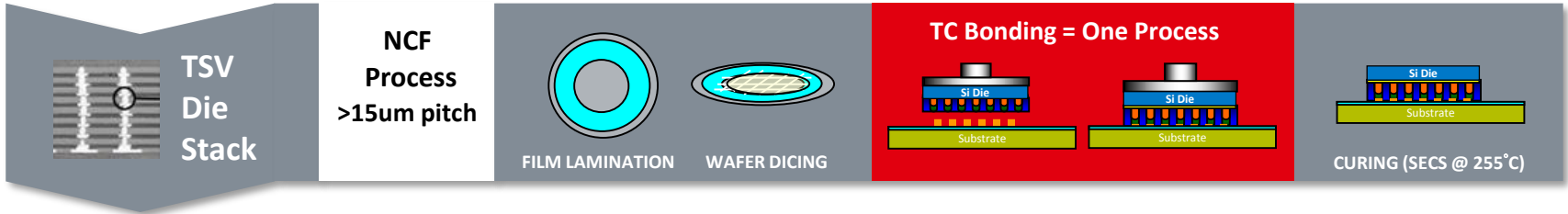
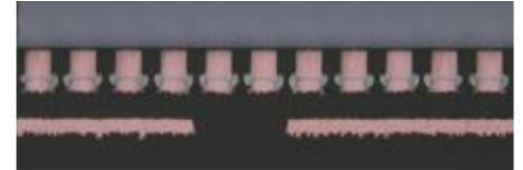
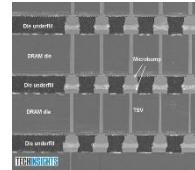
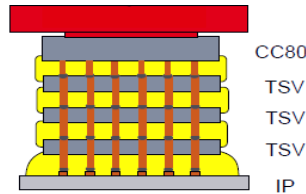
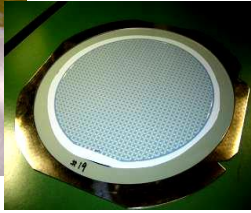
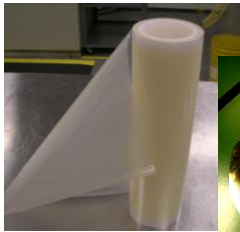


- + Enable fine pitch & narrow gap
- + Thin wafer and bump protection
- + Tight design by fillet size control
- Low UPH
- Different film thickness per design

Wafer Applied Underfill Film (WAUF)

Non Conductive Film for 3D Memory TSV

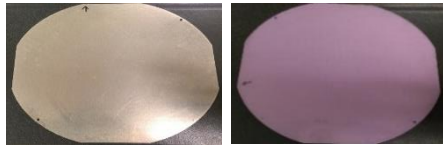
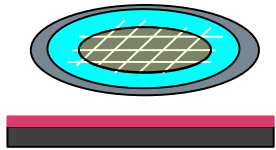
- Reliable Fine Pitch TSV Die Stacking using **Thermal Compression Bonding (TCB)**
 - Bond each die in stack individually (recommended) or by “collective bonding” (tack each die in place at lower temperature, then press and cure whole stack with hot bond head within seconds)



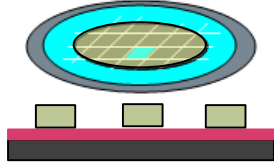
Ultra-Low Warpage Liquid Encapsulation

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

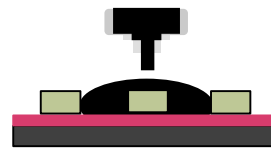
Thermal Release Tape on Carrier



Die P&P on Carrier



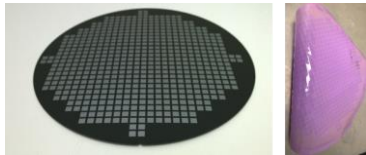
Dispensing on Die



Compression Molding & Post Mold Cure (PMC)



Remove Carrier



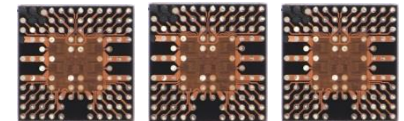
Back Grinding



Redistribution Layer (RDL)

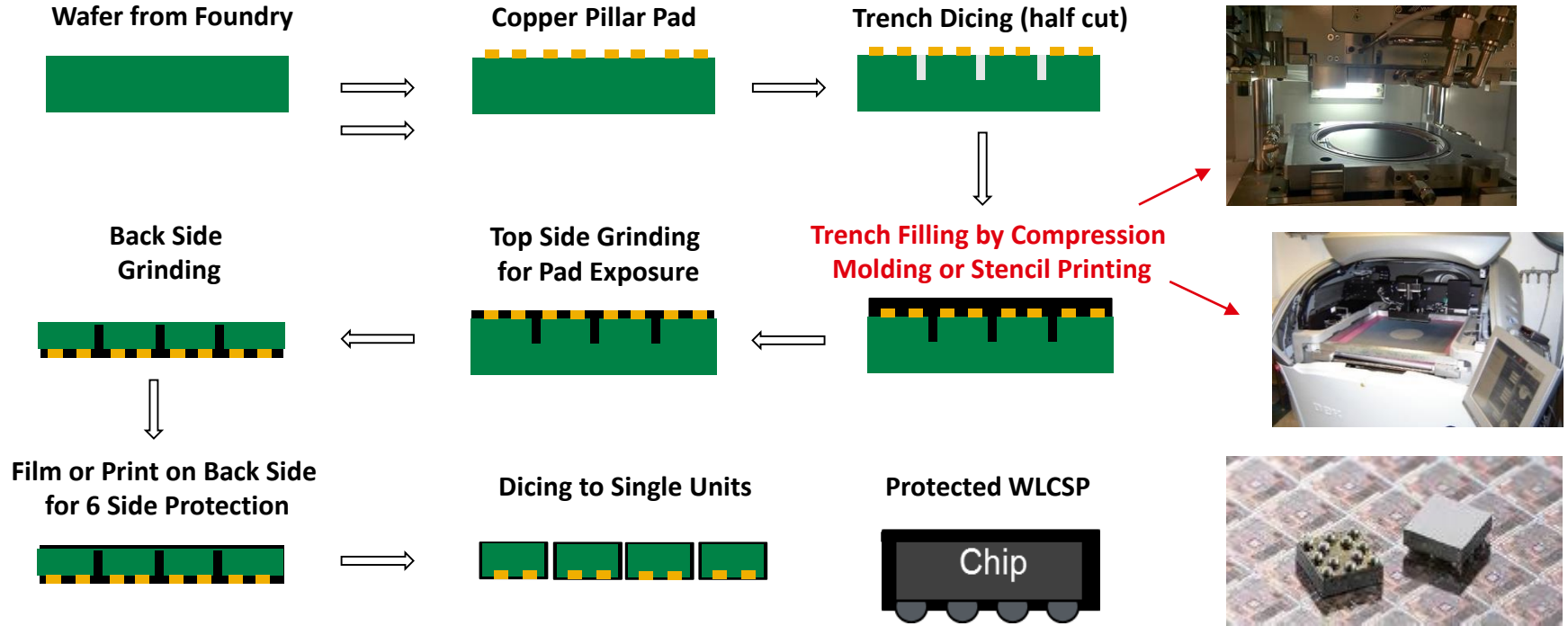


Ball Mount & Simulation



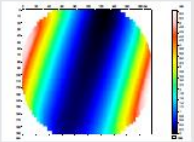
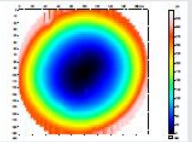
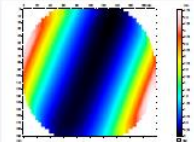
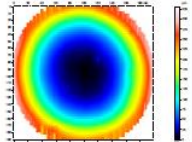
Ultra-Low Warpage Liquid Encapsulation

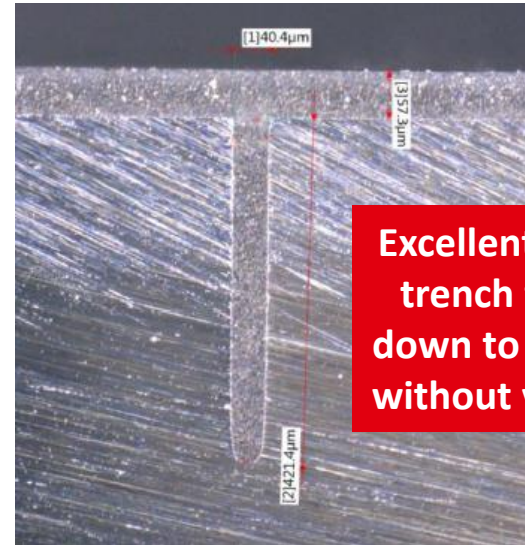
5/6 Side WLCSP Protection Process (by Molding or Printing)



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

| | 200um wafer + 70um LCM | 300um wafer + 70um LCM |
|-------------------------|---|---|
| Within 2 hour after PMC | 5.57mm  | 349um  |
| 24 hour after PMC | 4.80mm  | 331um  |



Excellent 40um trench filling down to 400um without voiding

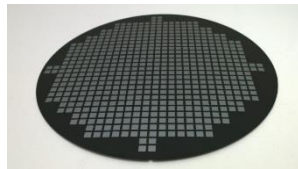
Ultra-Low Warpage Liquid Encapsulation

Material Properties

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



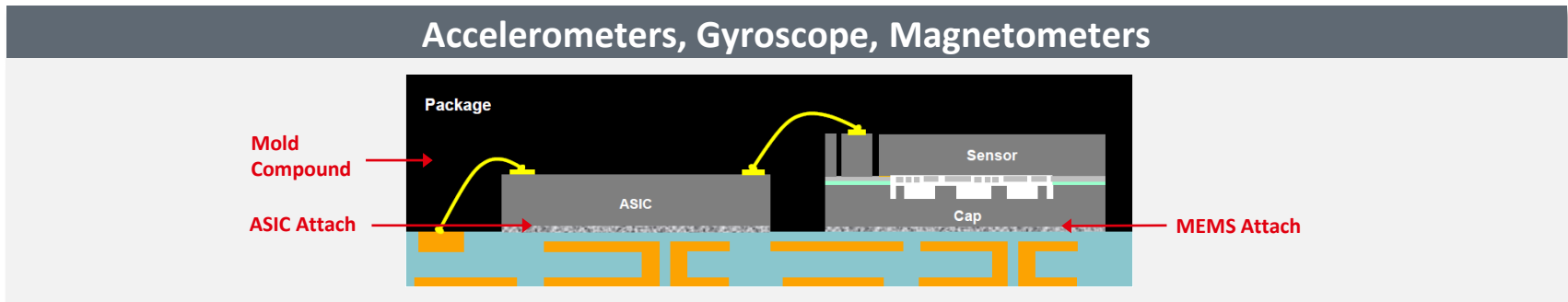
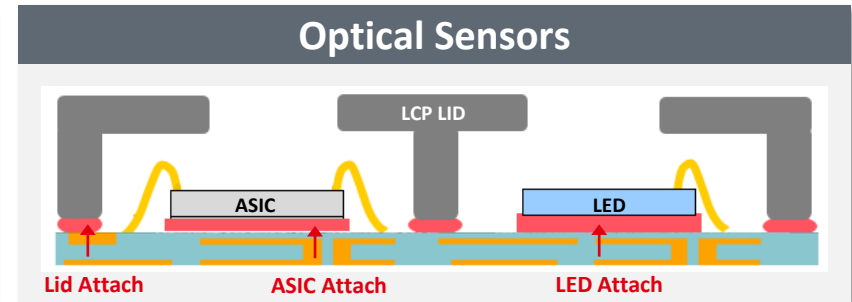
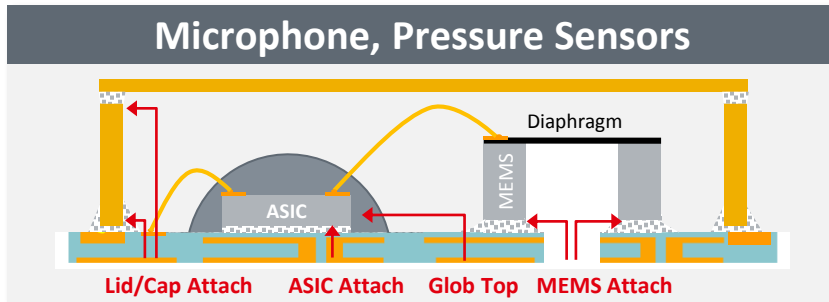
- Compression Molding for „FAN-OUT“ (eWLB)



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

| Adhesives for MEMS & Sensors

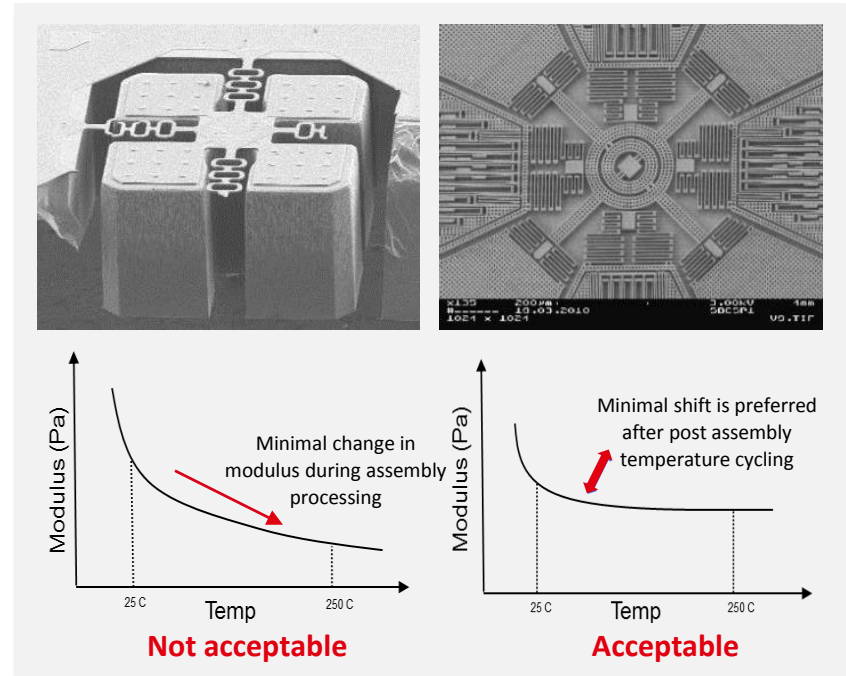
Typical Applications Running in High Volume



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



Adhesives for MEMS & Sensors

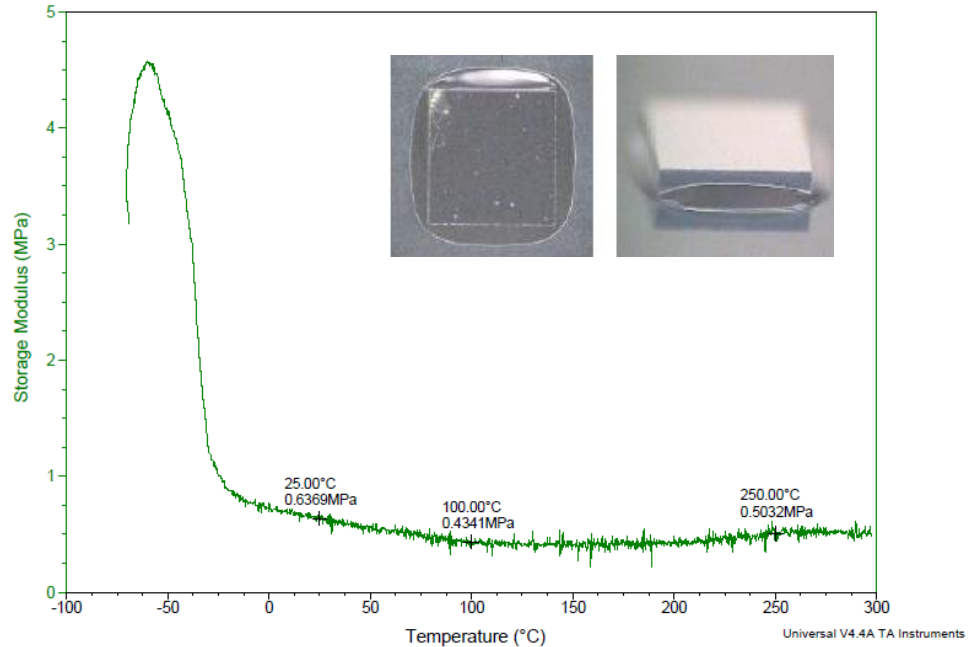
Ultra Low & Constant Modulus below 1 MPa

- **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*)

Sample: SDA20081-4-3A
Size: 12.0150 x 4.6200 x 0.7500 mm
Method: Temperature Ramp

DMA

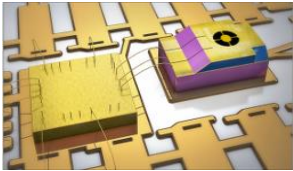
File: C:\V4 MEMS\test\DMA\SDA20081-4-3A.001
Operator: jyc
Run Date: 14-May-2014 16:29
Instrument: DMA Q800 V7.5 Build 127



| Adhesives for MEMS & Sensors

Application Examples of Non Conductive SIL Series

MEMS Microphone



MEMS Attach

- 2.8 MPa @ RT
- 3.0 MPa @ 250°C
- TI = 3.3
- No slumping
- Black color

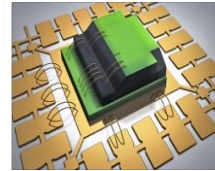
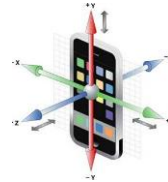
Automotive Speed Sensor



Magnet Attach + Encapsulant

- 25 MPa @ RT
- 20 MPa @ 250°C
- TI = 3.5
- Black color

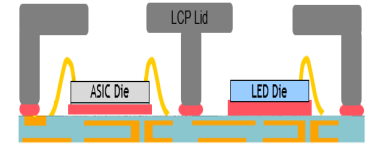
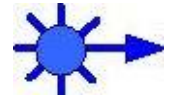
Accelerometer



ASIC to MEMS

- 100 MPa @ RT
- Z-direction stable modulus
- 0.8 W/mK (Al₂O₃)
- White color

Ambient Light Sensor



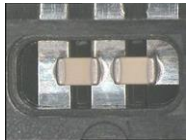
LED Attach

- 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)

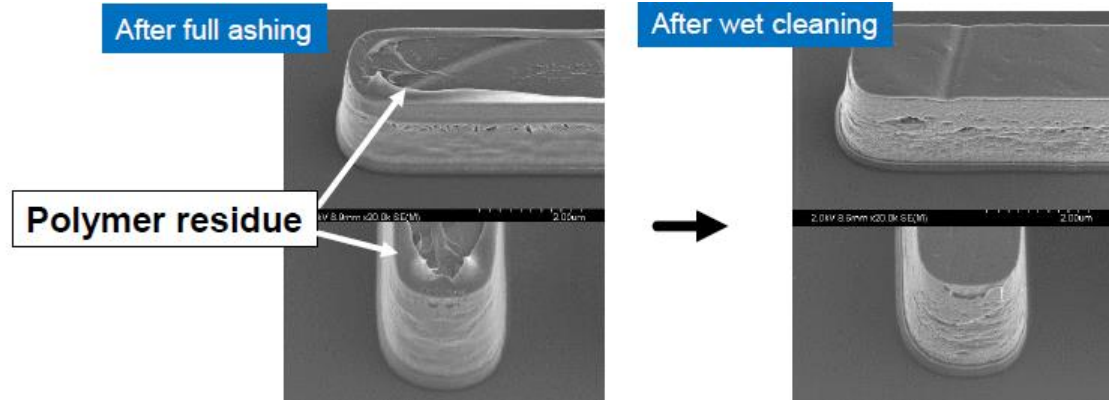
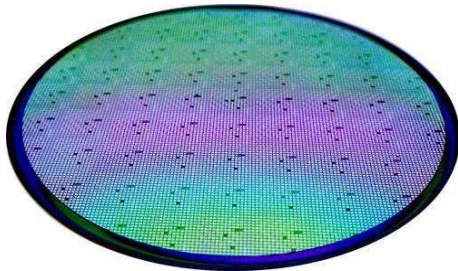


| LOCTITE ABLESTIK | ICP 4000 | ICP 4001 | ICP 4015 |
|--------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| Chemistry | Silicone | Silicone | Silicone |
| Appearance | Silver | Silver | Silver |
| Viscosity @ 25°C | 25-40 Pa.s (@ 15s ⁻¹) | 30-50 Pa.s (@ 15s ⁻¹) | 18-25 Pa.s (@ 15s ⁻¹) |
| Worklife | 2 days, change of viscosity < 50% | 1 day, change of viscosity < 50% | 2 days, change of viscosity < 50% |
| Cure Schedule | 35 min 140°C or 60 min 130°C | 35 min 140°C | 60 min 80°C or 35 min 140°C |
| Thermal Expansion | 330 +/- 30ppm | 365 +/- 70ppm | NA |
| Elongation | > 20% | > 20% | > 20% |
| Volume Resistivity | 5x10 ⁻⁵ Ohm cm | 5x10 ⁻⁴ Ohm cm | 5x10 ⁻⁵ Ohm cm |
| Hardness Shore A | NA | 73 - 85 | NA |
| Die Shear Strength | > 400gr | > 1500gr | > 350gr |

AI Polymer Stripper for MEMS Wafer Processing

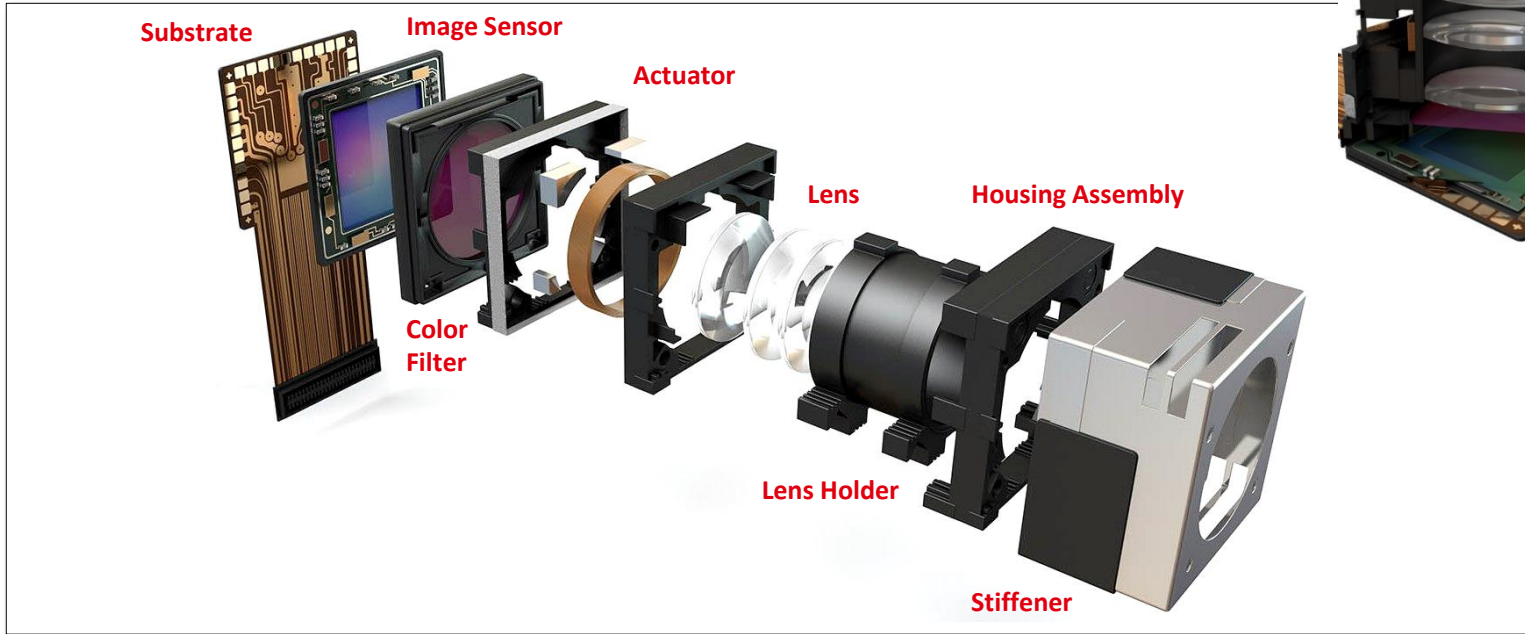
Qualified by European Foundry

- 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
 - **65°C for 20 minutes**



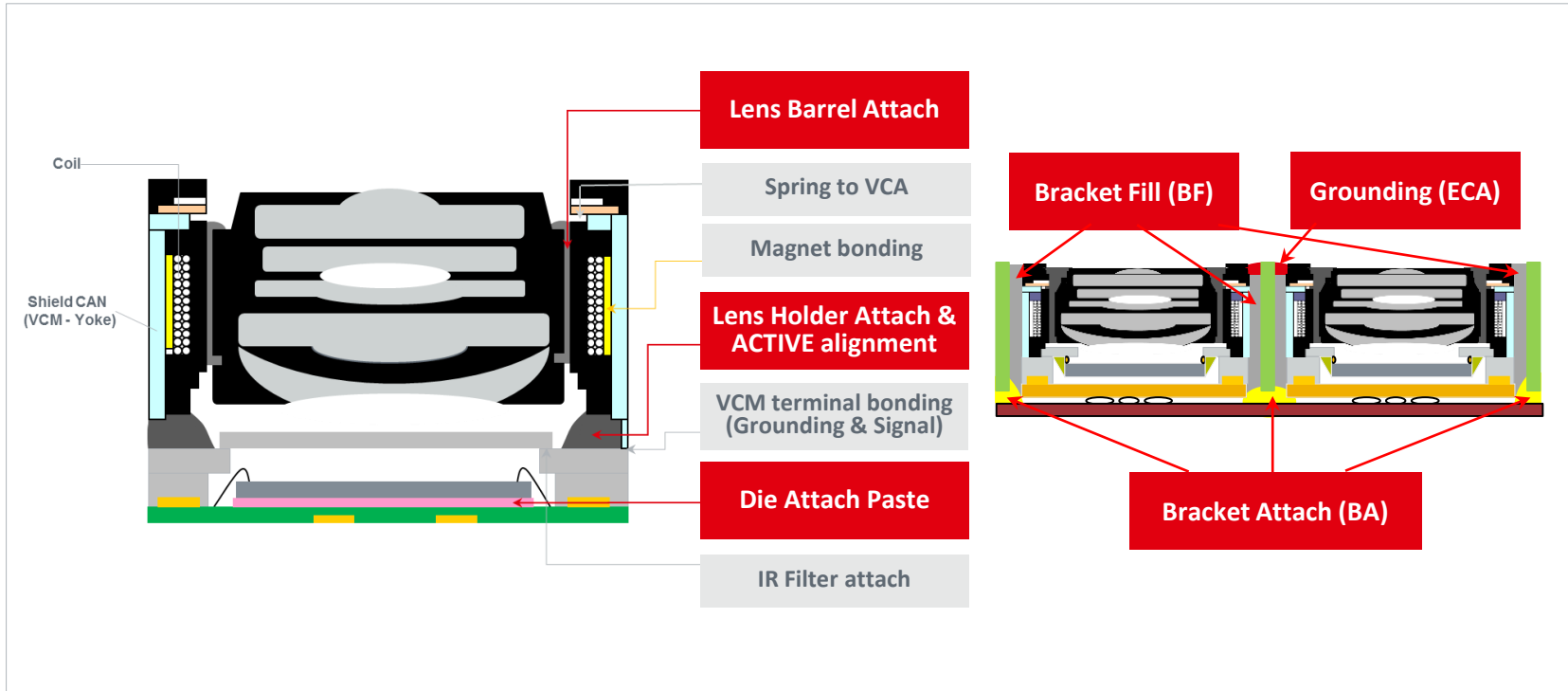
| Adhesives for CMOS Image Sensors

Typical Compact Camera Module (CCM) Design



Adhesives for CMOS Image Sensors

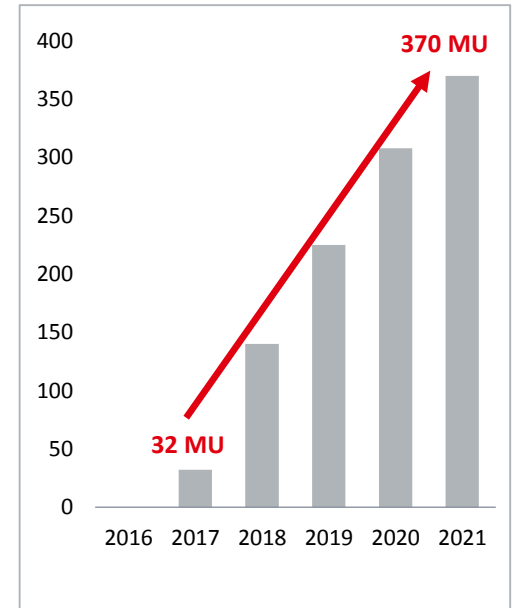
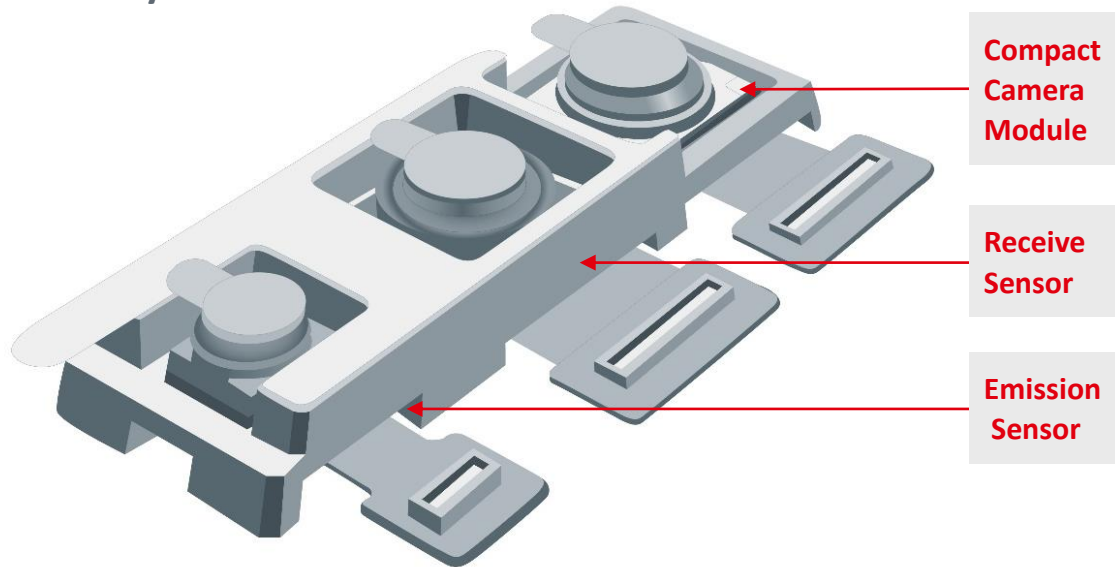
Multiple Bonding & Other Applications in CCM



| 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



Global 3D Face Sensor Shipments in Mobile Handsets (Millions of Units)

Source: IHS Markit 2018

Adhesives for CMOS Image Sensors

Dual Cure Adhesive Comparison (UV + Thermal)

| Product Name | OGR-150HTG | LOCTITE 3217 | LOCTITE 3707 |
|--------------------------------------|---|--|---|
| Resin type | Acrylate | Acrylated Epoxy | Cationic Epoxy |
| Recommended cure conditions | 100mW/cm ² 365nm + 1h @ 100°C / 2h @ 85°C | 100mW/cm ² 220-260nm + 20min @ 80°C / 30min @ 60°C | 100mW/cm ² 220-260nm + 2min @ 130°C |
| Color | Colorless (amber) | Colorless (amber) | Opaque (white) |
| Basic properties | | | |
| Viscosity @ 25°C (mPa.s) | 1,000 (@ 10rpm) | 38,000 (@ 20rpm) | 10,000 (@ 20rpm) |
| Thixotropic index @ 25°C, 0.5/5.0rpm | NA | 2.9 | NA |
| Work life @ 25°C (days) | >90 | >14 | >7 |
| Physical properties | | | |
| Tg (°C), by TMA | 145 | 82 | 53 |
| CTE (ppm/°C), by TMA | Below Tg | 61 | 53 |
| | Above Tg | 157 | 178 |
| Modulus @ 25°C (GPa), by DMA | 1.3 | 0.33 | 4.4 |
| Hardness, Shore D | 76 | 86 | NA |

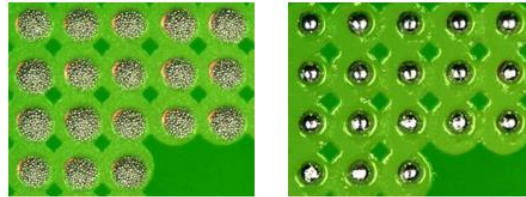
Medical Sensing in Smart Wearables (“Health Patches”)

Multiple Printing, Bonding & Other Applications

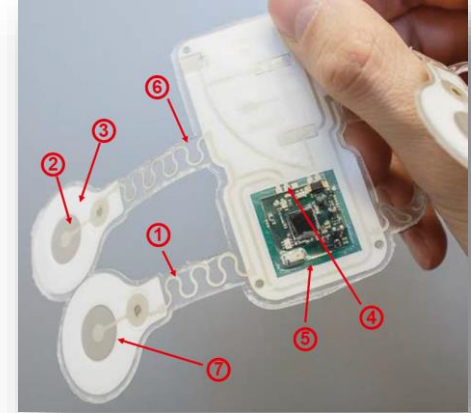
- Printed Electronics
 - Highly conductive inks with Sheet Resistance $<0.005 \text{ ohm/sq}/25\mu\text{m}$



- 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

Continued
Miniaturization

Thinner
Packages

Thermal
Management

Application
Specific Packages

Automotive
Reliability

Many Thanks !

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