Liquid Optically Clear Adhesive for Display Applications

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Technical Director
Henkel Corporation
LOCTITE® Liquid Optically Clear Adhesives (LOCA)

LOCA used to laminate various layers of a display

Cover lens

Touch sensor

LOCA

LCD
Benefits of LOCA

- Improving the viewing experience
- Increasing the display ruggedness
- Extending the battery life
- Extending the display product life
Henkel Light Curing Technology

- +40 year experience
- Large global business growing at 15-20% per year
- Broadest portfolio of light curing chemistries
  - Acrylated urethanes
  - Epoxies
  - Silicones
  - Cyanoacrylates
  - Anaerobics
  - PSAs
- Total solution provider
  - Best in class technical service
  - Technology leader in light curing adhesives
  - Technology leader in dispensing and curing equipment
- LOCA specifics
  - Key Product Development centers:
    - Shanghai, China
    - Isogo, Japan
    - Rocky Hill, CT
    - Manufacturing – Yantai, China
Typical LOCA Process Flow

1. **Apply LOCA onto a substrate**
2. **Bond two parts together under ambient or vacuum**
3. **Pre-Cure: spot curing or side cure**
4. **Inspection & Rework**
5. **Final Cure**
Typical Requirements for LOCAs

- **Processing**
  - Fast flow and fast curing
  - Control overflow
- **Optical Performance**
  - Optically clear and particle free
  - Refractive index
  - Optical property: Transmittance >99%; Haze <0.5%; Yellowness (b*<1)
- **Mechanical property**
  - Low shrinkage, low modulus, low hardness, high elongation
- **Reliability**
  - No degradation of performance after:
    - HTHH (65C/90%RH, 85C/85%RH)
    - high temp aging (85C or 95C)
    - Low temp aging
    - UV aging
    - Thermal cycling or thermal shock
Henkel LOCA Chemistries

- **Acrylate Chemistry (319X)**
  - Relatively fast curing
  - Maintain good optical performance under display reliability conditions
  - Desirable RI (1.48-1.52)
  - Strong adhesion to various substrates
  - Shadow cure with heat or primer

Radicals I. could be generated via:

1) Light; 2) Thermal; 3) Oxidation-Reduction…
**Henkel LOCA Chemistries**

- **Silicone Chemistry (519X)**
  - Good optical performance
  - Can potentially maintain good optical performance under harsher condition
  - **Very low curing shrinkage (<1%)**
  - Non-thermal shadow curing capability (moisture curing)
# Loctite® LOCA Technical Data

<table>
<thead>
<tr>
<th></th>
<th>Loctite® 3192</th>
<th>Loctite® 3193*</th>
<th>Loctite® 3195</th>
<th>Loctite® 3195DM</th>
<th>Loctite® 3196</th>
<th>Loctite® 5192</th>
<th>Loctite® 5192DM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Chemistry</strong></td>
<td>Acrylic</td>
<td>Acrylic</td>
<td>Acrylic</td>
<td>Acrylic</td>
<td>Acrylic</td>
<td>Silicone</td>
<td>Silicone</td>
</tr>
<tr>
<td><strong>Curing Method</strong></td>
<td>UV + heat</td>
<td>UV</td>
<td>UV</td>
<td>UV</td>
<td>UV</td>
<td>UV / Moisture</td>
<td>UV</td>
</tr>
<tr>
<td><strong>Viscosity (cPs @ 25°C)</strong></td>
<td>4,500</td>
<td>3,000</td>
<td>3,500</td>
<td>40,000</td>
<td>3,600</td>
<td>4000</td>
<td>47,000</td>
</tr>
<tr>
<td><strong>Shore Hardness</strong></td>
<td>oo50</td>
<td>oo60</td>
<td>oo25</td>
<td>oo50</td>
<td>oo11</td>
<td>oo71</td>
<td>oo30</td>
</tr>
<tr>
<td><strong>Elongation</strong></td>
<td>&gt; 70%</td>
<td>&gt; 800%</td>
<td>&gt; 150%</td>
<td>&gt; 100%</td>
<td>&gt; 200%</td>
<td>&gt; 135%</td>
<td>&gt; 150%</td>
</tr>
<tr>
<td><strong>Refractive Index</strong></td>
<td>1.49</td>
<td>1.48</td>
<td>1.51</td>
<td>1.51</td>
<td>1.51</td>
<td>1.41</td>
<td>1.41</td>
</tr>
<tr>
<td><strong>Transmittance (%)</strong></td>
<td>99.00</td>
<td>99.10</td>
<td>98.90</td>
<td>98.90</td>
<td>99.70</td>
<td>99.00</td>
<td>99.30</td>
</tr>
<tr>
<td><strong>Shrinkage (% by Volume)</strong></td>
<td>&lt;3</td>
<td>&lt;3</td>
<td>1.6</td>
<td>1.6</td>
<td>1.6</td>
<td>0.55</td>
<td>&lt;2</td>
</tr>
<tr>
<td><strong>Adhesion on Glass (MPa)</strong></td>
<td>1.0</td>
<td>1.0</td>
<td>1.22</td>
<td>0.91</td>
<td>0.55</td>
<td>0.4</td>
<td>0.64</td>
</tr>
<tr>
<td><em><em>Yellowness (b</em>)</em>*</td>
<td>0.3</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.2</td>
<td>0.19</td>
<td>0.33</td>
</tr>
<tr>
<td><strong>Haze (%)</strong></td>
<td>0.10</td>
<td>0.10</td>
<td>0.07</td>
<td>0.13</td>
<td>0.07</td>
<td>0.04</td>
<td>0.17</td>
</tr>
</tbody>
</table>

*Loctite® 3193 has high peel strength on various plastic substrates [N/mm]: PMMA: 2.4, PC: 2.45, PET: 2.77
LOCAs for Vacuum Assembly

• **Why vacuum assembly**
  • Driven by cycle time reduction for high yield of bubble-free laminations

• **Why is low weight loss of LOCA important?**
  • Better adhesive thickness control
  • Shorter cycle time
  • More consistent performance
Performance Vacuum Bonding

- Weight loss under vacuum

Henkel LOCAs are compatible with ambient and vacuum bonding
Technology Development Highlights

• Shadow Cure
• Improved Reworkability
• LCD Direct Bonding
Shadow Curing Solutions

- Shadow Curing:
  - UV adhesive cannot be cured under shadow area
  - Critical issue for LCD direct bonding

- Solutions:
  - UV-heat
  - UV-moisture
  - UV-primer
  - Side UV curing
UV-heat Dual Curing

<table>
<thead>
<tr>
<th></th>
<th>Loctite 3192</th>
<th>A-2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry</td>
<td>Acrylic</td>
<td>Acrylic</td>
</tr>
<tr>
<td>Curing condition</td>
<td>UV + 1 hr @ 80°C</td>
<td>UV + 1-2 hr @ 60°C</td>
</tr>
<tr>
<td>Storage</td>
<td>2-8°C</td>
<td>-10 ~ -15°C</td>
</tr>
</tbody>
</table>

Apply LOCA

Bond the substrates

UV cure viewable area

Heat cure the shadow area

Percent Cure vs. Total Cure Energy

Henkel offers both 60°C and 80°C heat curable LOCAs
UV-Moisture
Henkel’s Unique Solution

Apply LOCA

Bond the substrates

UV cure viewable area

Moisture cure the shadow area
UV-Moisture: Henkel’s Unique Solution

- Loctite 5192: UV + moisture
- Unique RT shadow curing solution
- Good adhesion on glass or plastic

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<td><strong>Curing condition</strong></td>
</tr>
<tr>
<td><strong>Storage</strong></td>
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Depth of Cure (Moisture)
The depth of cure by moisture depends on temperature and humidity. The graph below shows the increase in depth of cure with time at 23 ± 2°C / 50 ± 5% RH.
Side-Curing of Ultra-low Energy LOCA

Test Set up

- UV curing equipment: LED line cure
- LOCA: A-1
- Substrates: glass with ink
- Process:
  - Laminate two substrates with ink
  - Side curing through the LOCA layer
  - Take apart the substrates
  - Measure the cured width

LED Line Cure

- Edge curing
  - 365 nm Line, P/N 1449337
  - Controller, P/N 1447728
  - Cable, P/N 1483215
Side-Curing of Ultra-low Energy LOCA

Linear LED intensity 534mW/cm² (tested by Loctite Radiometer Dosimeter)
Side-Curing of Ultra-low Energy LOCA

Shadow Curing Data

Bondline: 300um

<table>
<thead>
<tr>
<th>Sample</th>
<th>Cured Width (mm) with irradiation time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20s</td>
</tr>
<tr>
<td>A-1</td>
<td>5</td>
</tr>
<tr>
<td>Competition A</td>
<td>2.5</td>
</tr>
<tr>
<td>Competition B</td>
<td>2.5</td>
</tr>
</tbody>
</table>

A-1 achieves up to 7mm side curing depth
UV + Primer Curing

Apply primer on shadow area

Apply LOCA

Bond the substrates

UV cure viewable area

Primer cure the shadow area
UV + Primer Curing

- Adhesive spreads to contact primer in the shadow and gets cured
- Primers can cure some acrylic LOCAs in 10-30 min

**Primer can cure acrylate LOCAs under shadow area within 30min**
Reworkability

- Solutions:
  - Wire cut + solvent cleaning
  - Preferential release: after wire cut, the adhesive residue stays on
    - Glass
    - Polarizer film
  - Film-forming LOCA: Adhesive can peeled off as “film”
LCD Direct Bonding: Considerations

**Processing:**
- Overflow control:
  - Dam:
    - RI match: Very close RI match of dam and fill to ensure no bondline
    - **Curing process affects RI**

![Diagram of dam and fill](image1)

**Boundary**
LCD Direct Bonding: Overflow Control

Overflow control: use of dam LOCA

- Types of Dam:
  - High viscosity dam

- Same material for fill and dam

Dam was created by:
Dispensing + LED curing
200mJ/cm²
LCD Direct Bonding (TP2): Mura-free

Mura-free

- Reduce the stress imposed on LCD by LOCA
  - Low modulus / low hardness
  - Low curing shrinkage

An example of Mura
**LCD Direct Bonding (TP2): Mura-free**

**Cured Properties - Photorheometry**

<table>
<thead>
<tr>
<th>sample</th>
<th>Shrinkage (linear) (%)</th>
<th>Modulus (x 10⁴ Pa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3196</td>
<td>0.69</td>
<td>2.9</td>
</tr>
<tr>
<td>5192</td>
<td>0.38</td>
<td>1.3</td>
</tr>
<tr>
<td>A-1</td>
<td>1.5</td>
<td>1.9</td>
</tr>
<tr>
<td>A-3</td>
<td>0.69</td>
<td>1.22</td>
</tr>
</tbody>
</table>
## LCD Direct Bonding (TP2): Mura-free Optically Clear Gel

<table>
<thead>
<tr>
<th>Type</th>
<th>Acrylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td>TP1, TP2</td>
</tr>
<tr>
<td>Curing condition (Metal halide lamp)</td>
<td>3,000mJ/cm²</td>
</tr>
<tr>
<td>Viscosity (mPa·s)</td>
<td>3,000</td>
</tr>
<tr>
<td>Hardness</td>
<td>oo 0(E0)</td>
</tr>
<tr>
<td>Elongation (%)</td>
<td>900</td>
</tr>
<tr>
<td>Elastic modulus (Pa)</td>
<td>Off the register</td>
</tr>
<tr>
<td>RI</td>
<td>1.53</td>
</tr>
<tr>
<td>shrinkage</td>
<td>0.5%</td>
</tr>
<tr>
<td>Transmittance</td>
<td>99%</td>
</tr>
<tr>
<td>b*</td>
<td>0.07</td>
</tr>
</tbody>
</table>

**Low Shrinkage and low hardness → MURA free**
Summary

• Henkel offers both acrylate and silicone based LOCAs to display markets

• Henkel offers various solutions to address shadow curing, reworkability, and mura-free LCD bonding for next generation display applications
Thank you!
Typical LOCA Process Flow
Henkel Silicones

Curing

UV curing

Moisture curing

acetoxy silane

H₂O

CH₃COH + ≡Si−OH

silanol

≡Si−O−Si≡ + H₂O

siloxane