Liquid Optically Clear Adhesive for Display Applications

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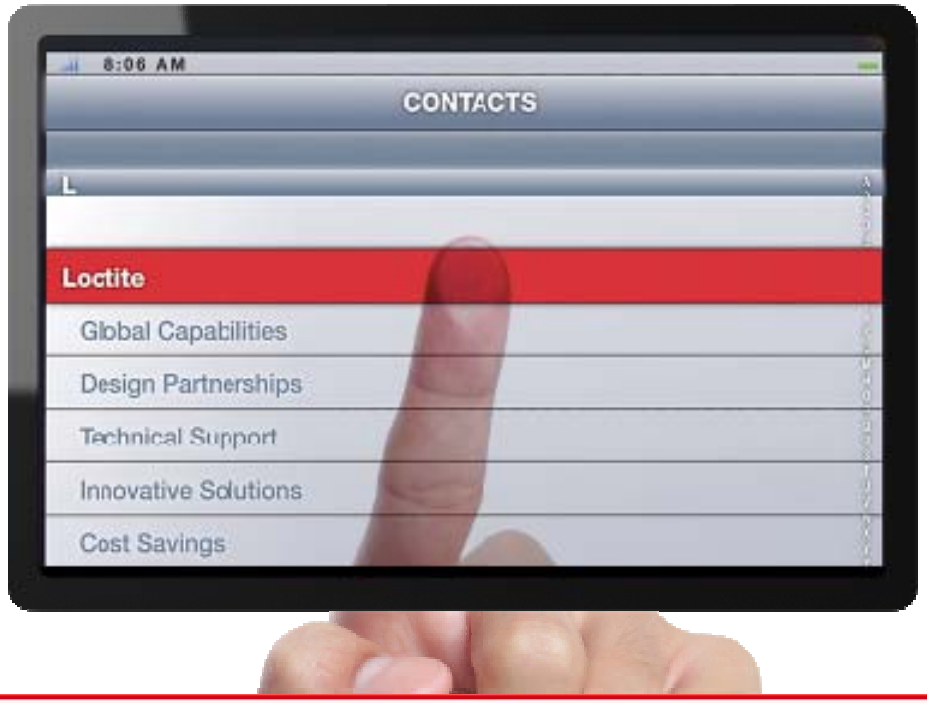
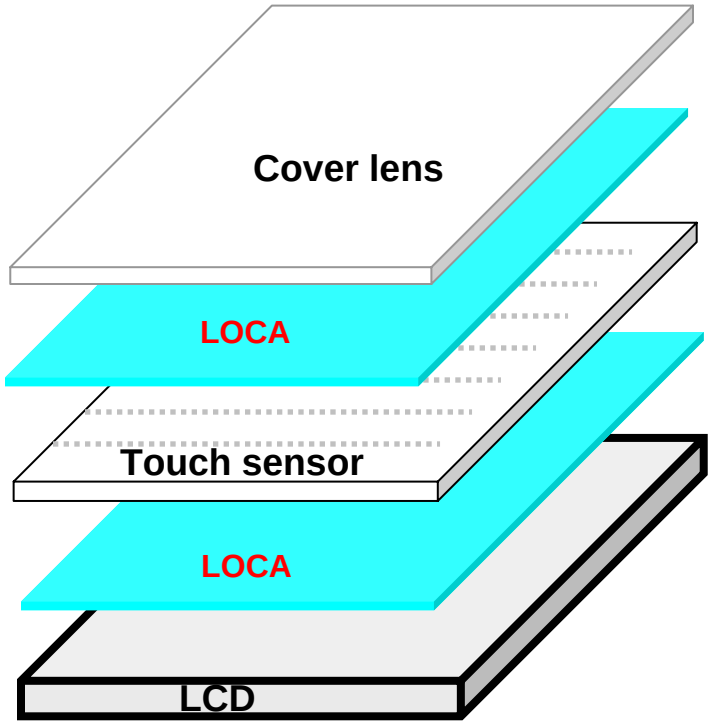
Technical Director

Henkel Corporation



Henkel Excellence is our Passion

LOCTITE® Liquid Optically Clear Adhesives (LOCA)



LOCA used to laminate various layers of a display

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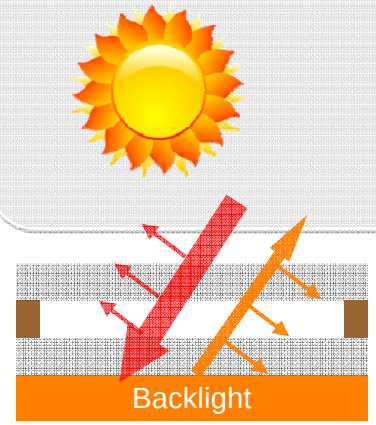
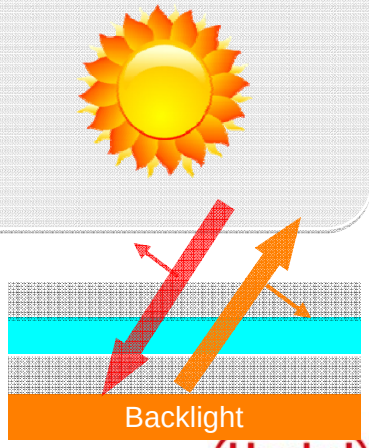
Benefits of LOCA

- Improving the viewing experience
- Increasing the display ruggedness
- Extending the battery life
- Extending the display product life

without LOCA

with LOCA





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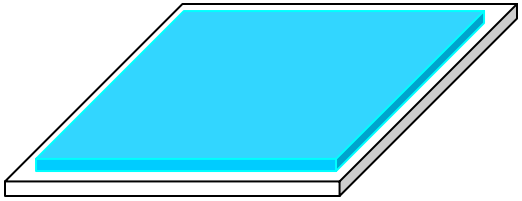
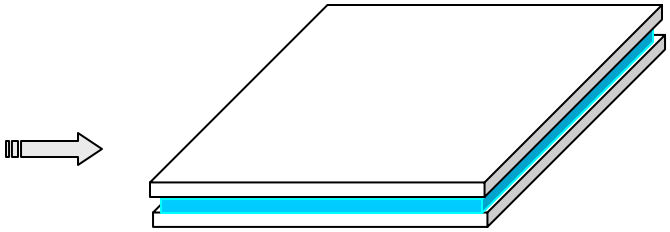
Henkel Light Curing Technology

- **+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

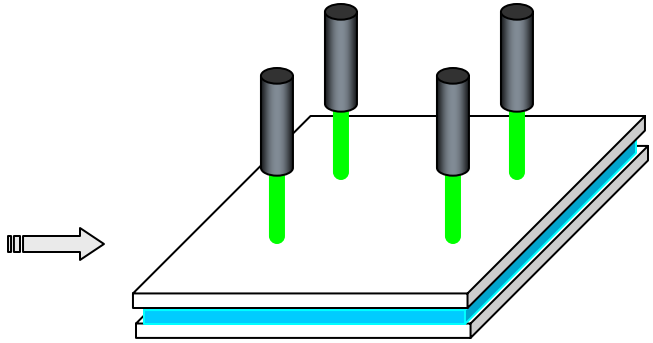
Typical LOCA Process Flow



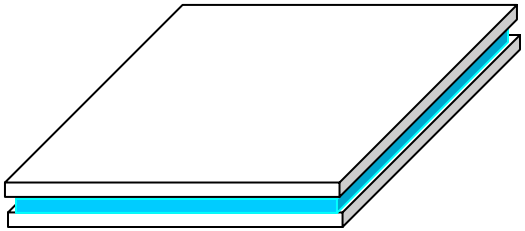
Apply LOCA
onto a substrate



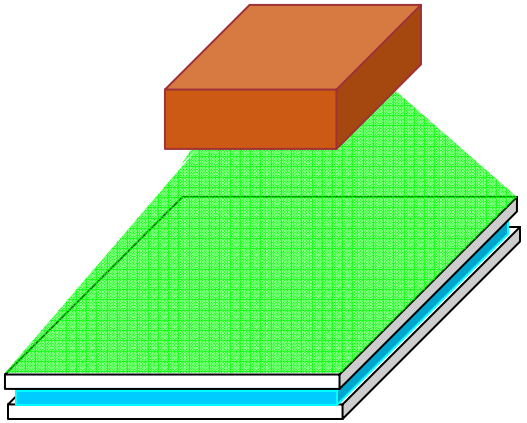
Bond two parts together
under ambient or vacuum



Pre-Cure: spot
curing or side cure



Inspection & Rework



Final Cure

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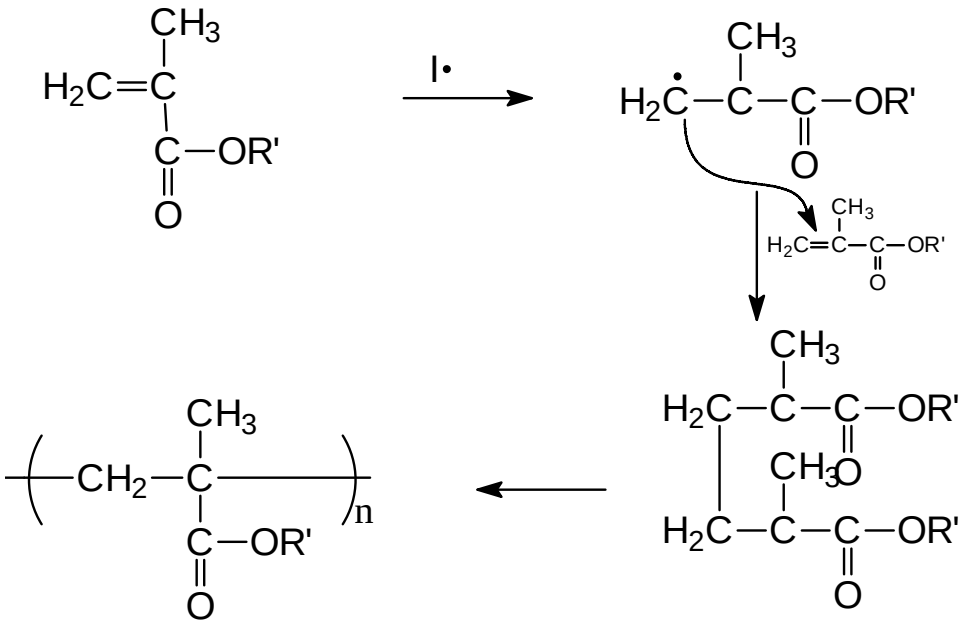
Typical Requirements for LOCAs

- **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



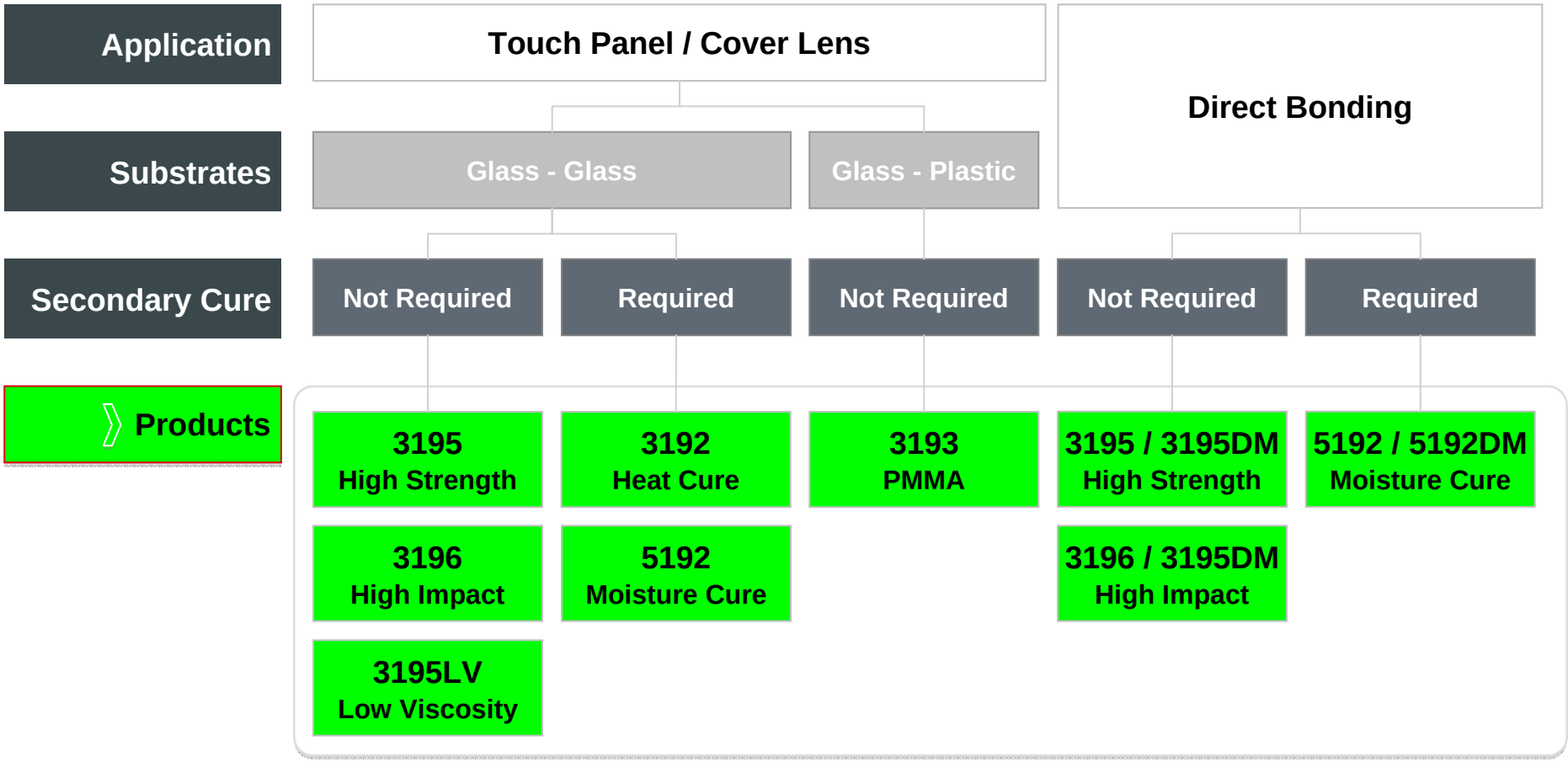
Radicals I. could be generated via:

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



Loctite® LOCA Technical Data

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

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

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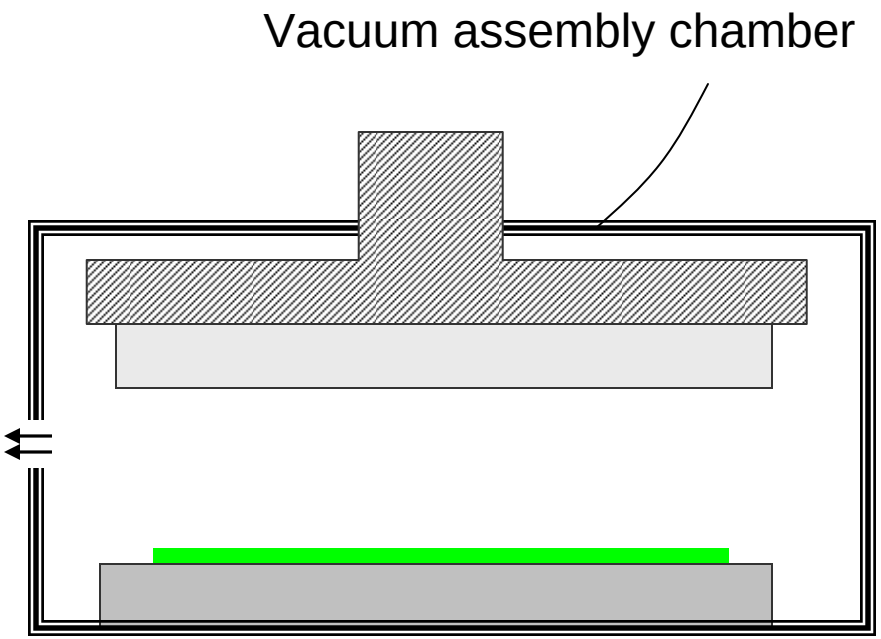
LOCAs for Vacuum Assembly

- **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



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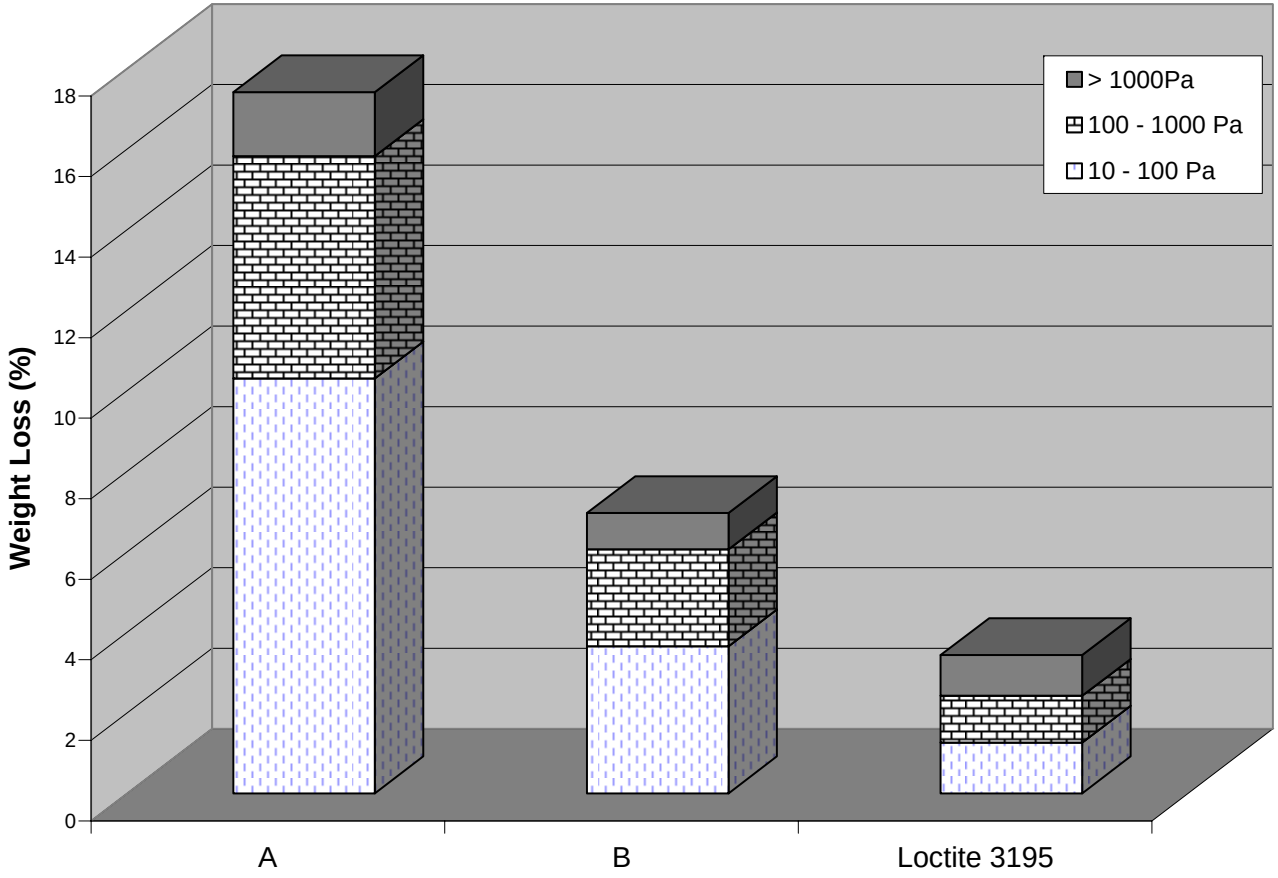
Performance Vacuum Bonding

- Weight loss under vacuum



Henkel LOCAs are compatible with ambient and vacuum bonding

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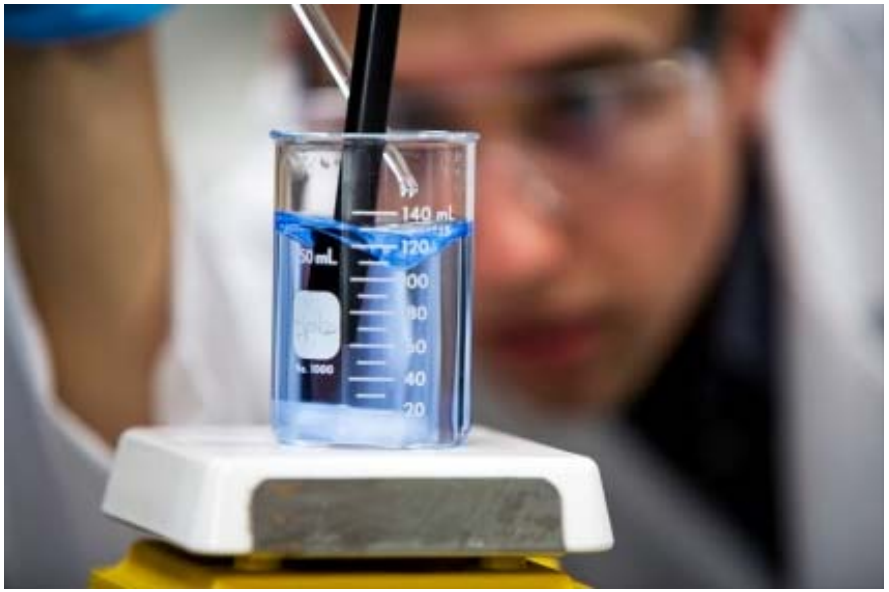
Technology Development Highlights

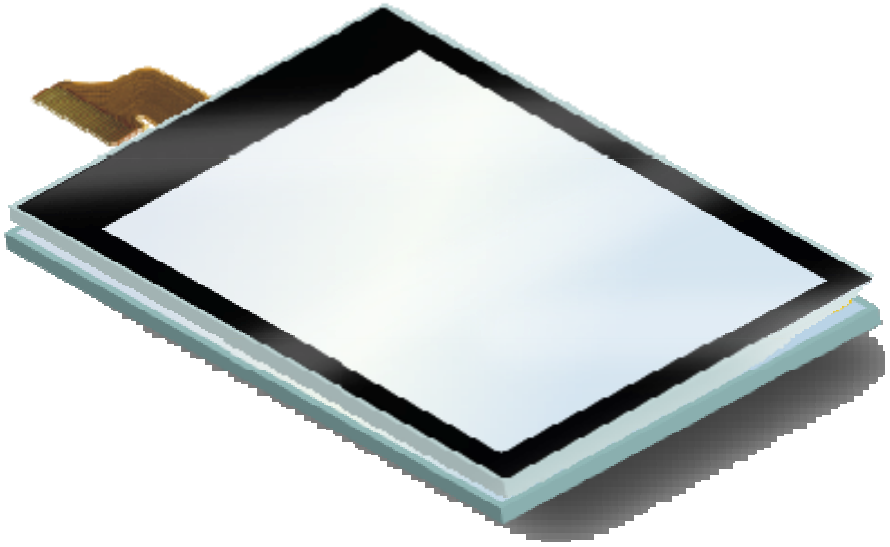
- Shadow Cure
- Improved Reworkability
- LCD Direct Bonding



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**



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UV-heat Dual Curing

	Loctite 3192	A-2
Chemistry	Acrylic	Acrylic
Curing condition	UV + 1hr @ 80C	UV + 1-2hr @ 60C
Storage	2-8C	-10 ~ -15C

Apply LOCA

⇩

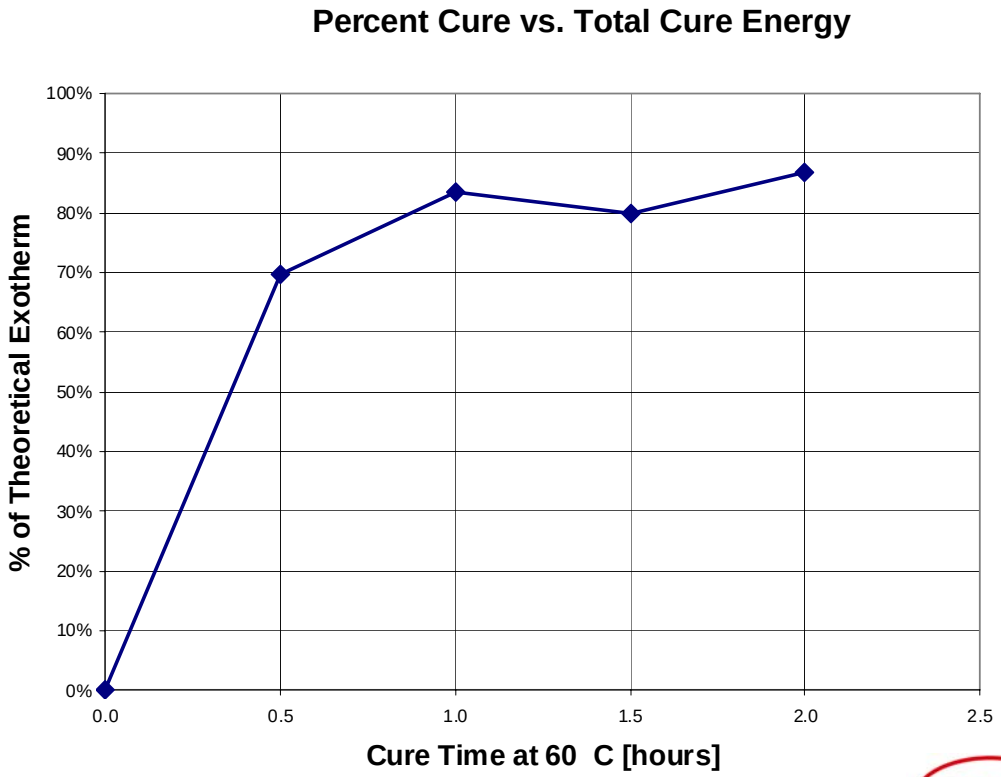
Bond the substrates

⇩

UV cure viewable area

⇩

Heat cure the shadow area



Henkel offers both 60C and 80C heat curable LOCAs

UV-Moisture

Henkel's Unique Solution

Apply LOCA

⇩

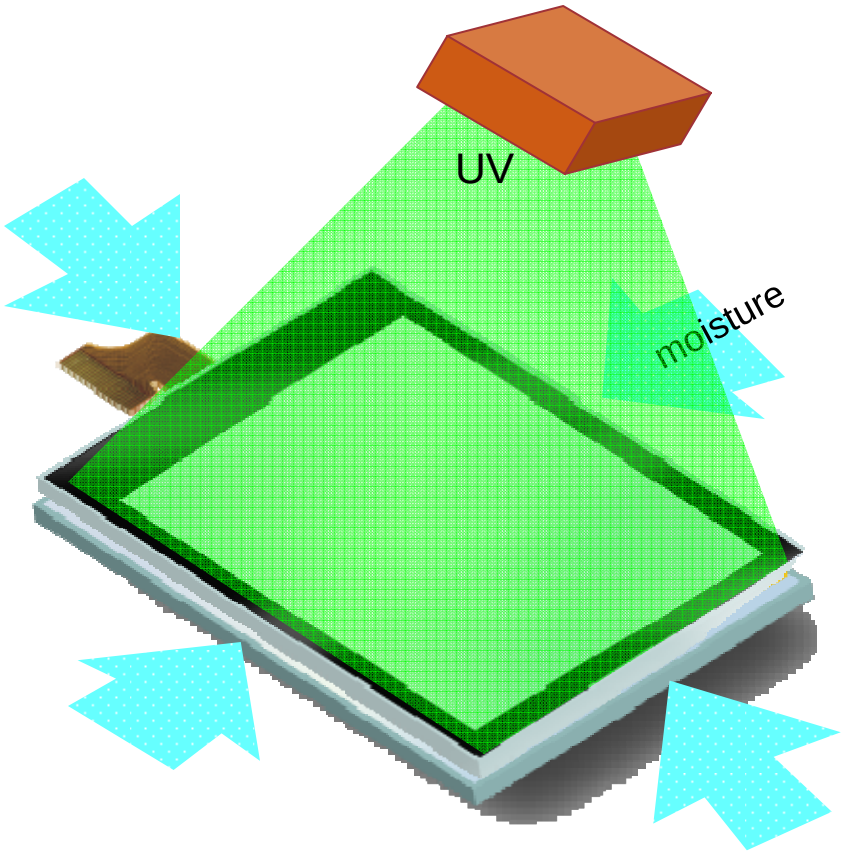
Bond the substrates

⇩

UV cure viewable area

⇩

Moisture cure the shadow area



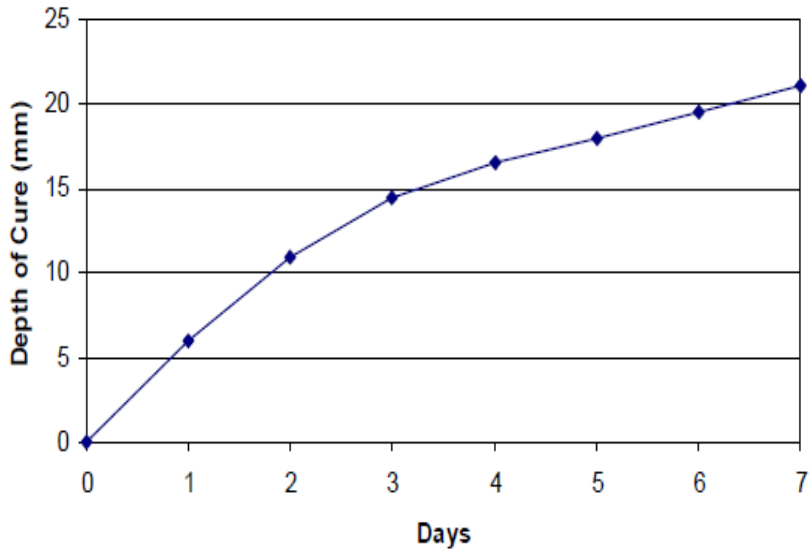
UV-Moisture: Henkel's Unique Solution

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

	Loctite 5192
Chemistry	**Silicone**
Curing condition	**UV + moisture**
Storage	**RT**

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

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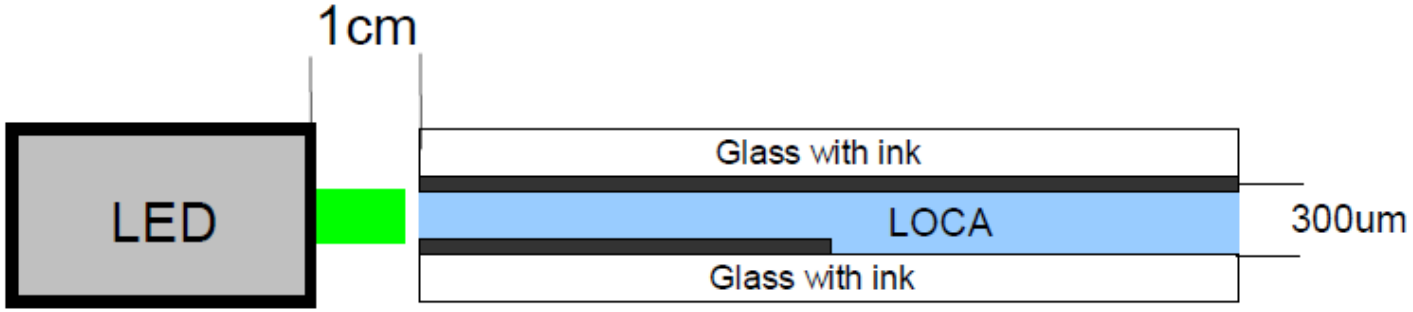
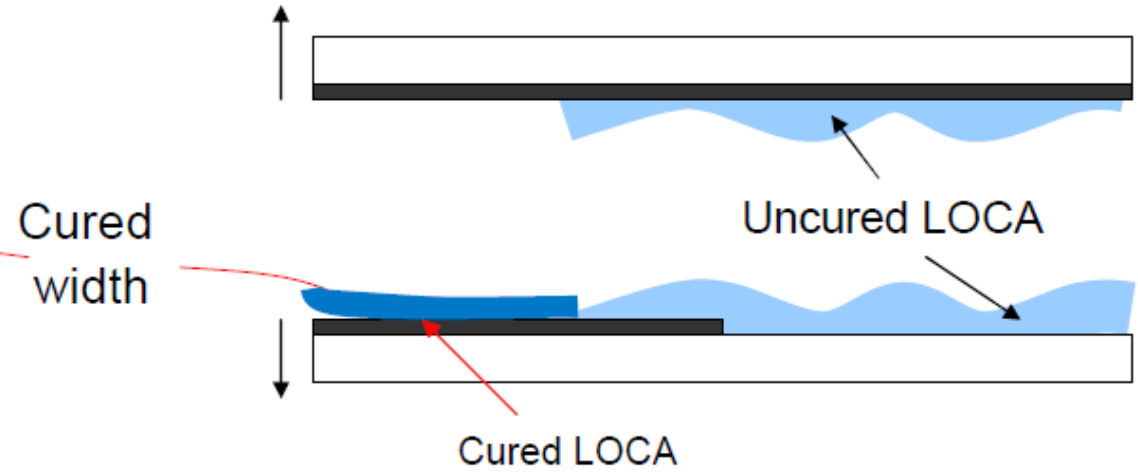
Side-Curing of Ultra-low Energy LOCA



Linear LED intensity 534mW/cm2 (tested by Loctite Radiometer Dosimeter)



Side-Curing of Ultra-low Energy LOCA

Shadow Curing Data

Bondline: 300um

	Cured Width (mm) with irradiation time			
Sample	**20s**	**30s**	**40s**	**60s**
A-1	5	6	7	7
Competition A	2.5	4.5	5	5.5
Competition B	2.5	4	5	5

A-1 achieves up to 7mm side curing depth

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UV + Primer Curing

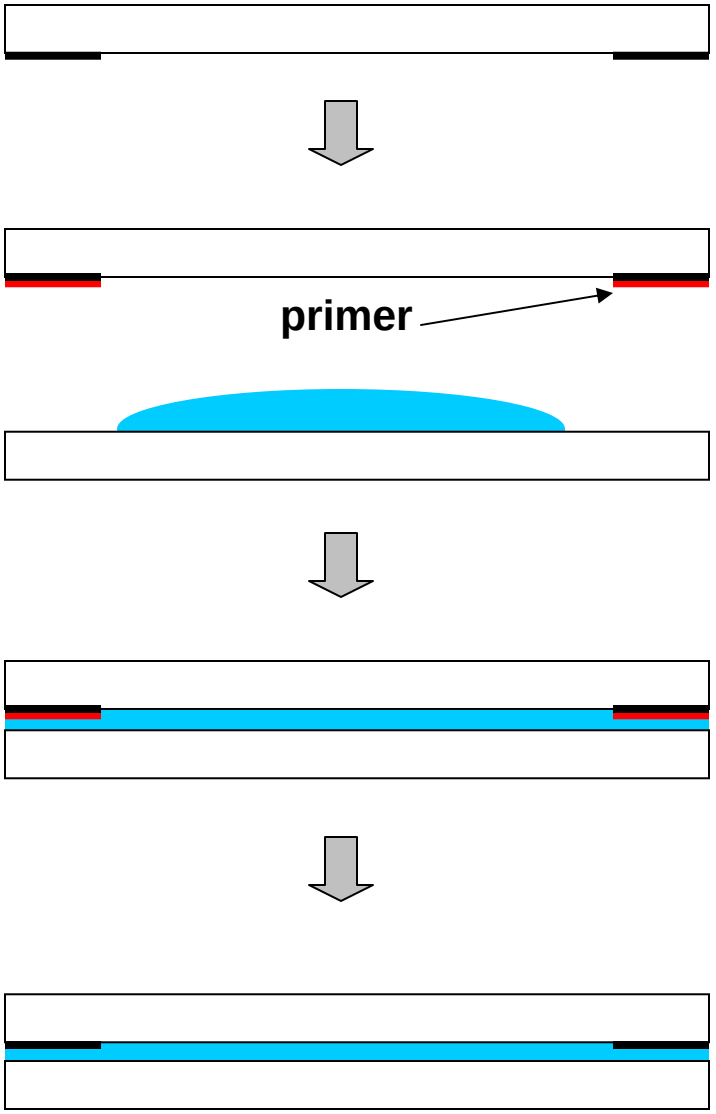
Apply primer on shadow area

Apply LOCA

Bond the substrates

UV cure viewable area

Primer cure the shadow area



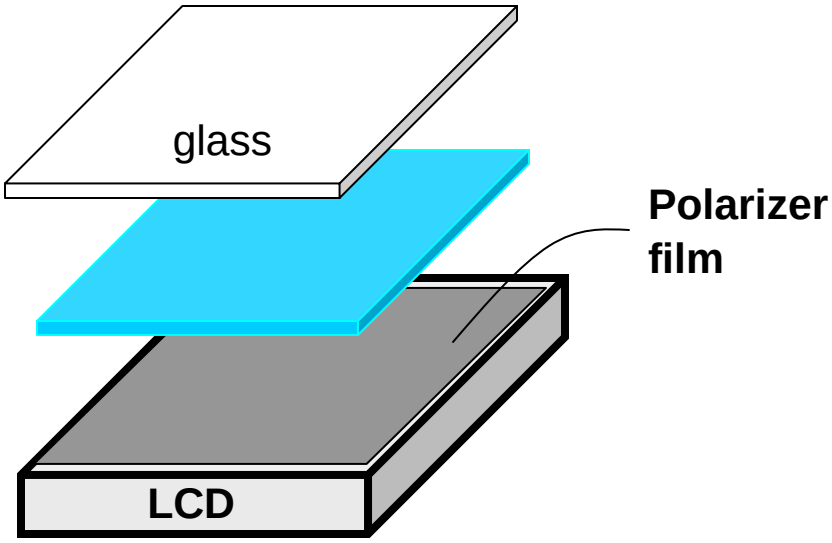
UV + Primer Curing

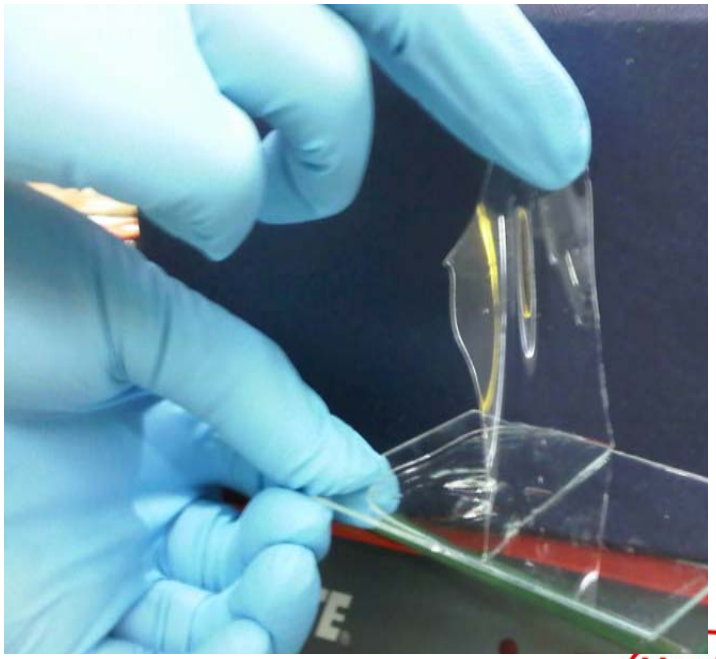
- Adhesive spreads to contact primer in the shadow and gets cured
- Primers can cure some acrylic LOCAs in 10-30 min

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”**





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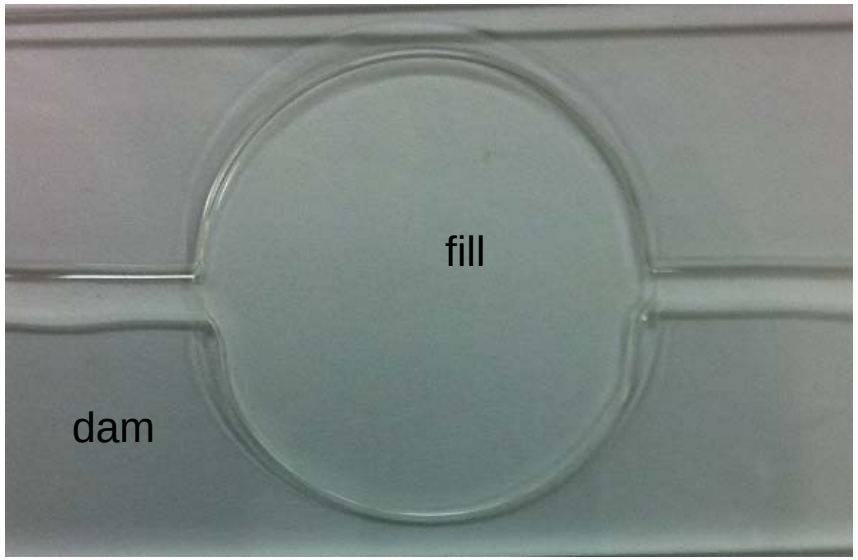
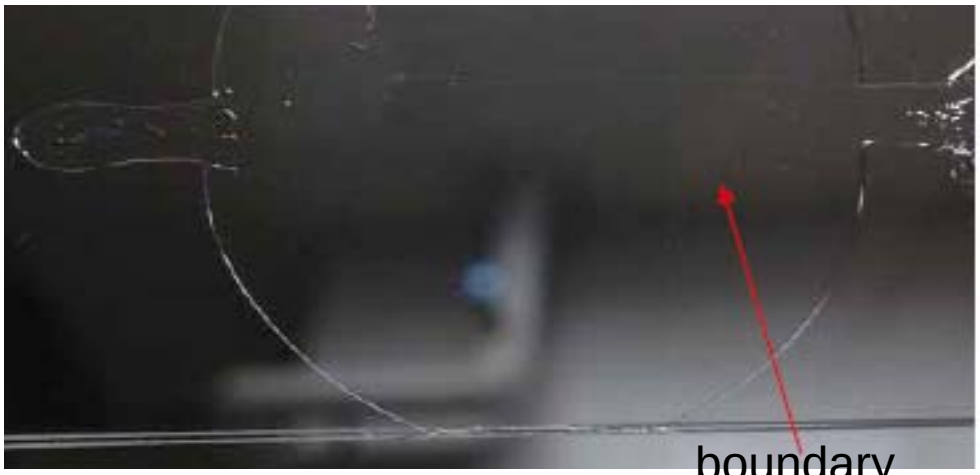
LCD Direct Bonding: Considerations

Processing:

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





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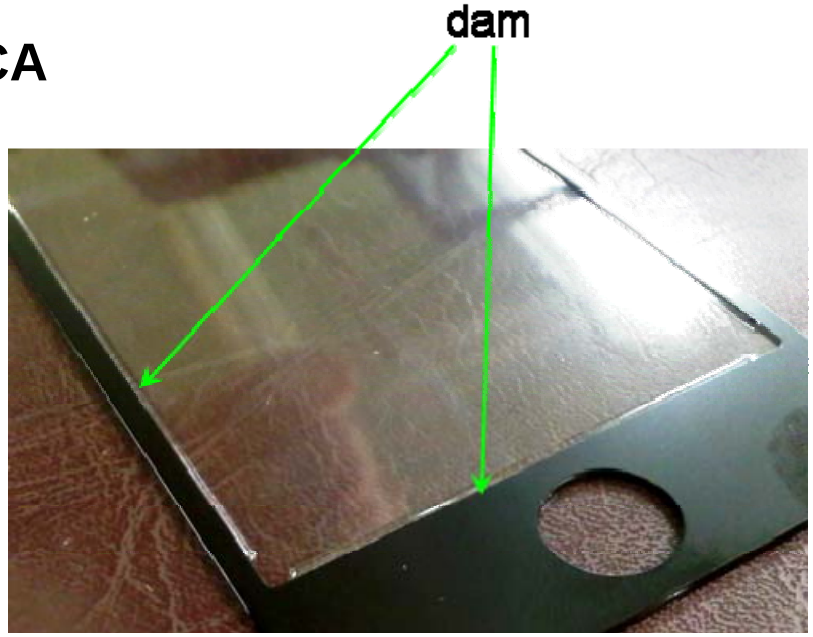
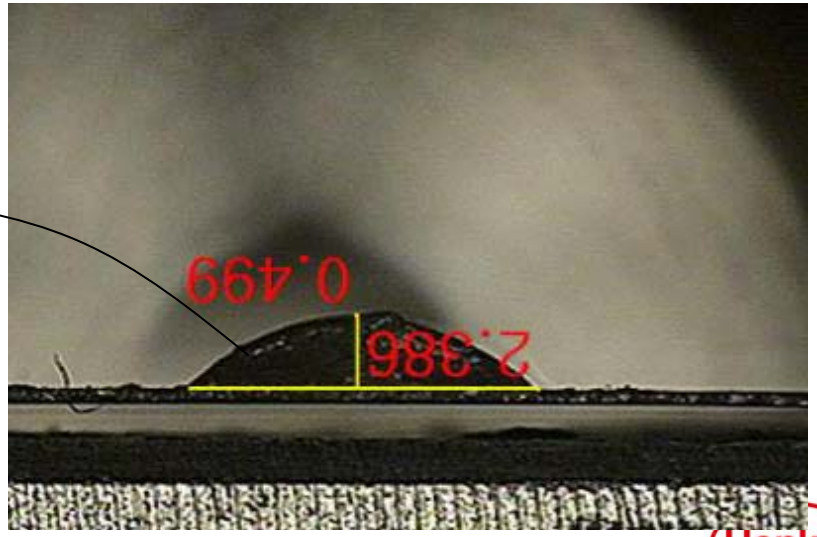
LCD Direct Bonding: Overflow Control

- **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



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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

sample	Shrinkage (linear) (%)	Modulus (x 10^4 Pa)
3196	0.69	2.9
5192	0.38	1.3
A-1	1.5	1.9
A-3	0.69	1.22

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LCD Direct Bonding (TP2): Mura-free

Optically Clear Gel

	Optically Clear Gel
Type	Acrylate
Application	TP1, TP2
Curing condition (Metal halide lamp)	3,000mJ/cm^2
Viscosity (mPa· s)	3,000
Hardness	oo 0(E0)
Elongation (%)	900
Elastic modulus (Pa)	Off the register
RI	1.53
shrinkage	0.5%
Transmittance	99%
b*	0.07

Low Shrinkage and low hardness → MURA free

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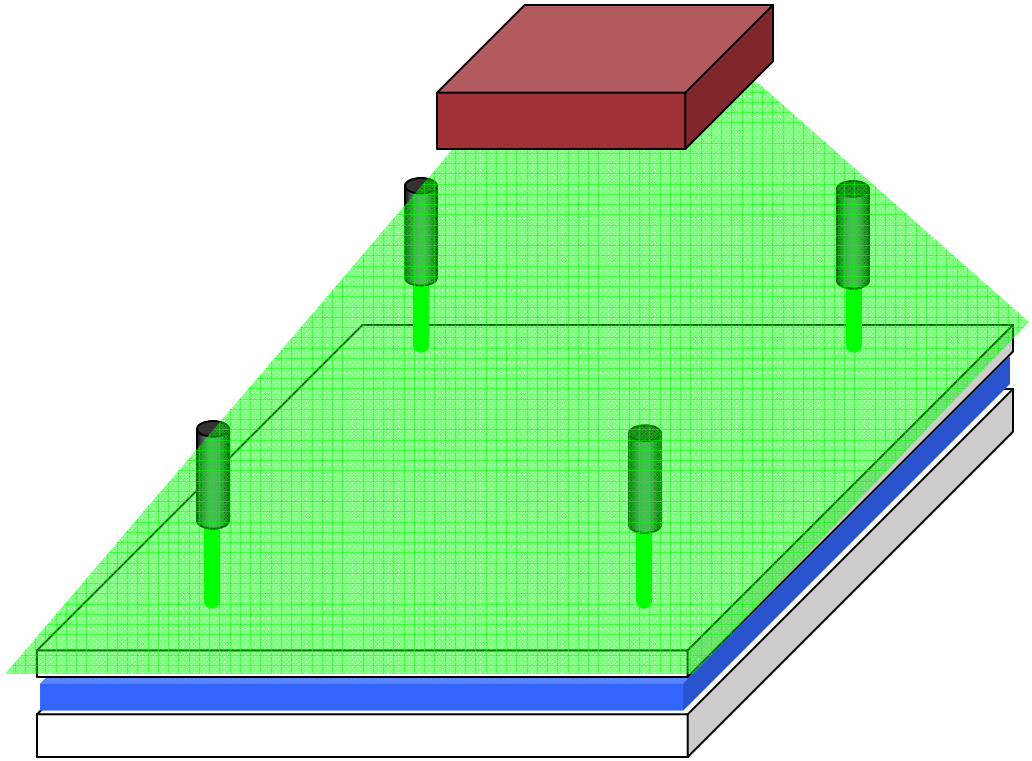
Summary

- 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!

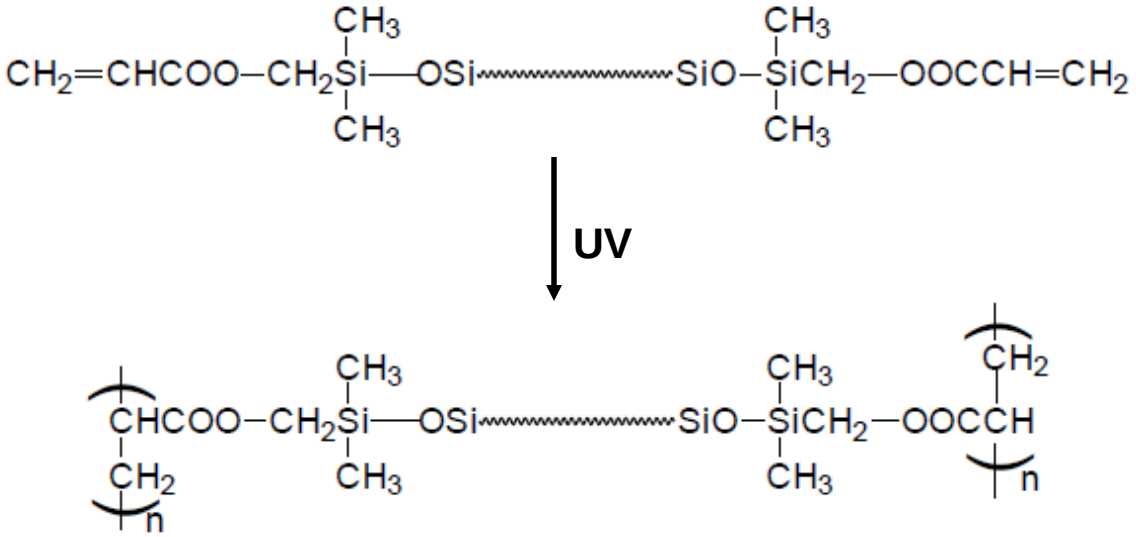
Typical LOCA Process Flow



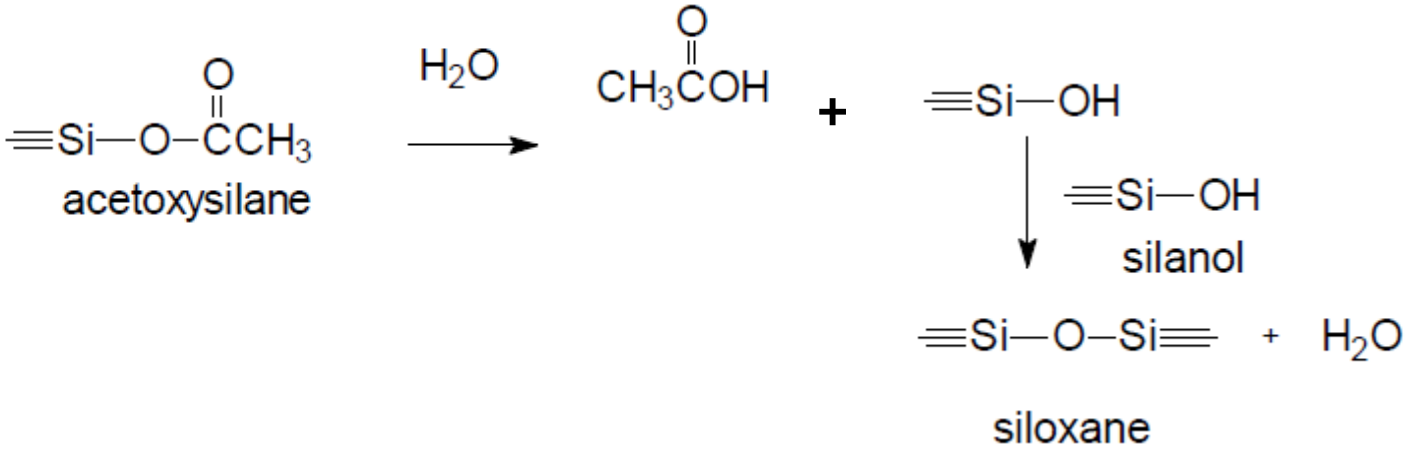
Henkel Silicones

❑ Curing

UV curing



Moisture curing



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