Enabling advanced automotive lighting applications with moldable optical silicones

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Dow Performance Silicones – Lighting
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Advanced lighting for automotive
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Dark or low-lighting conditions increase likelihood of a collision\(^1\)

- Dark driving – 25% of automotive travel
  - 52% of driver fatalities
  - 71% of pedestrian deaths
- Largest contributing factors
  - Limited forward illumination – efficacy of US compliant headlamps
  - Speed of travel – low beam usage adequate for only 39-52 mph

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2. FHWA Lighting Handbook: https://safety.fhwa.dot.gov/roadway_dept/night_visib/lighting_handbook/#a1

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**Figure 1:** Fatal crash rates per VMT for Day and Night (2009 FARS and NHTS data)\(^2\)
## Transportation Lighting: Potential Solutions

<table>
<thead>
<tr>
<th>Potential solution</th>
<th>Limitations¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Increase roadway illumination</td>
<td>Glare and reflections, infrastructure needed</td>
</tr>
<tr>
<td>Increase high beam usage by drivers</td>
<td>Glare and concern for oncoming drivers</td>
</tr>
</tbody>
</table>

**Adaptative driving beam (ADB) implementation:**
Long range visibility without causing discomfort, distraction or glare

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Dow is the world leader in Silicone technology with 10+ years of optical silicone experience and five years of use in production ADB systems.

Moldable silicones are high performance materials that provide:

- Improved design flexibility (form factor, undercuts, optical features)
- Strong optical performance
- Superior environmental stability
THE NEW Dow

Back integrated feedstocks

Building blocks

Material platforms

Building blocks

Product development

Technology capabilities

Target markets

Building blocks

Ethylene

Propylene

Silicones

Building blocks

Cellulosics

Acrylics

Propylene Oxide

Ethylene Oxide

Polyolefins & elast.

Silicones

Various others

High-throughput research

Catalyst discovery & ligand synthesis

Polymer science

Material science

Formulation sciences

Process engineering

High-performance computer modeling

Application development

Target markets

Packaging

Infrastructure

Consumer
DOW SILICONES: FROM SAND TO FUNCTIONALITY

Sand (SiO₂) → Silicon (Si) → Methylchlorosilanes → Silicones

Energy → Reaction(s) → Reaction(s)

Low cost integration and focus on process innovation

Materials for key applications

Focus on product and application innovation

Functional silicones

Organic functionality

Copolymers

Silicone fluid

Silicone elastomer

Silicone resin

Fillers additives

Polymerization & purification
A NEW MATERIAL: MOLDABLE OPTICAL SILICONES

An enabling technology that is both **clear and tough**

- Excellent environmental stability, optical performance and design flexibility

LIQUID SILICONE RUBBER (LSR):
Silica particle reinforced: *hazy material*

MOLDABLE OPTICAL SILICONES (MS):
Siloxane resin reinforced: *clear material*

- Molds like LSR
- Transmits light like glass
A NEW MATERIAL: MOLDABLE OPTICAL SILICONES

Moldable silicones *are:*

- Injection moldable optical silicone materials for unique applications, including lenses, light guides, diffusers, reflectors, etc.

Moldable silicones *can:*

- Precisely control light, ‘bend’ light, replicate nano-scale optical features, uniformly diffuse or reflect light, be used in harsh environments/applications, and more...
## How Chemistry Relates to End-Use Properties

What unique capabilities do these properties **enable**?

<table>
<thead>
<tr>
<th>Property</th>
<th>SILASTIC™ Moldable Silicone</th>
<th>PC</th>
<th>PMMA</th>
<th>Glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light transmission</td>
<td>94%</td>
<td>88-90%</td>
<td>93%</td>
<td>95%</td>
</tr>
<tr>
<td>Refractive index</td>
<td>1.42</td>
<td>1.58</td>
<td>1.49</td>
<td>1.52</td>
</tr>
<tr>
<td>UV resistance</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Chemical resistance</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Service temperature maximum (°C)</td>
<td>&gt;150</td>
<td>120</td>
<td>90</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Yellowing*</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Micro detail replication</td>
<td>High</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td>Ability to mold large and thick parts</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
</tr>
<tr>
<td>Maximum thickness</td>
<td>&lt;0.5 mm</td>
<td>2 mm</td>
<td>2 mm</td>
<td>–</td>
</tr>
<tr>
<td>Draft angle (manufacturing)**</td>
<td>&lt;0°</td>
<td>1 to 2°</td>
<td>1 to 2°</td>
<td>–</td>
</tr>
<tr>
<td>Weight</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Flexible material – Integration</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
MOLDABLE SILICONE ENABLED DESIGN: REFERENCES

ADAPTIVE DRIVING BEAM: LIGHT ENGINE
high-power LED matrix w/\textit{silicone} primary lens

REAR LAMP/INDICATOR: LIGHT GUIDE
LED linear w/\textit{silicone} coupler and guide

*Designs are for reference only and are not meant to duplicate or infringe on any other design
Moldable optical silicones: Material performance
Heat influences viscosity of moldable silicone – very sensitive to temperature

**Pros:**
- Ease of fabrication through liquid injection molding
- Good flow allows for complex part geometry
- Excellent reproduction of mold features

**Cons:**
- Easily turbulent
- Higher potential for flash in tooling
**Moldable Silicones: Cure**

Cure properties *tuned* for optic and mold design

- Cure profile allows for fill of complex geometry in liquid state
- Reduced gelation period can reduce cycle time and defects
- Quick to cured and handle-able part

Moldflow analysis in place to help better understand and predict material behavior
**MATERIAL PERFORMANCE**

- Good flow in complex parts
- Cure profile allows for fill in liquid state

- Excellent reproduction of mold features

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**Tooling**

**Molded silicone**
Moldable optical silicones: Mechanical and optical performance
**Moldable Silicones: Mechanical Properties**

**Soft & pliable or firm and tough**
- High elongation and Shore A durometer → impact and scratch resistance
- Range of hardness’ and material toughness → accurate part fixation, high IP rating

**Light weight optics**
- Silicones are less dense than incumbent material → less weight in auto lighting
- Optics lighter than with alternatives for a given volume
**MECHANICAL PERFORMANCE**

- Impact and scratch resistant

- Minimal compression set and accurate part fixation

- Optics lighter than with alternatives for a given volume

Volume: ~3.5 cc
Silicone: 3.7g
PMMA/PC: 4.2g

Volume: ~173 cc
Silicone: 185g
PMMA/PC: 206g
**Moldable Silicones: Optical Properties**

**Excellent optical performance**
- High light transmittance
- Low haze and scatter

*Reliable* in extreme conditions
- Robust to thermal and hydrothermal aging

**Optics for many applications**
- Freeform collimators; secondary lenses, micro-lens arrays; light guides
OPTICAL PERFORMANCE

- High light transmittance
- Low haze and scatter

Robust thermal and hydrothermal aging

<table>
<thead>
<tr>
<th>Weathering conditions:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial non-aged lenses</td>
</tr>
<tr>
<td>UV/65°C 6000 hrs</td>
</tr>
<tr>
<td>130°C 6000 hrs</td>
</tr>
<tr>
<td>85% rh/ 85°C 8 weeks</td>
</tr>
</tbody>
</table>

(*) PC and PMMA were NON-STABALIZED grades against UV
Moldable optical silicones: In-application performance
MOLDABLE SILICONES: IN APPLICATION

Industry tested

- Weathering: FMVSS 108 Appendix H
  - *AMECA Certified Materials*
- Impact: SAE J400
- Abrasion: FMVSS 108 Appendix J
- Chemical resistance: GMW 14334
- Flammability: FMVSS 302
- and more...

FMVSS 108 Appendix H

SILASTIC™ MS-1002 Moldable Silicone

PC-coated

GMW 14334
MOLDABLE SILICONES: APPLICATION EXAMPLES

- Interior: Light guides
- Interior: Branding
- Exterior: A-Side
- Image projection
- Optical sensors
- Color mixing (white reflector)
- Co-molding
- Over-molding
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