Dow Corning Solution in Lamp and Luminaire Assembly

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Application Engineer
Dow Corning do Brasil
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- Lamp and Luminaire market overview
- Introduction to Silicones
- Silicone opportunity in LED lighting market
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  - Adhesive / Sealant
  - Conformal Coating
  - Optical Materials
Guiding vision: We are innovative leaders unleashing the power of silicon to benefit everyone, everywhere

Equally owned by The Dow Chemical Company and Corning Incorporated
Dow Corning ... a B2B Specialty Materials Company

Dow Corning was established in 1943 specifically to explore and develop the potential of the silicon atom.

Today:

- $6.22 billion USD in sales (2014)
- 7,000 products and services; over 5,300 active patents
- 25,000 customers; 11,000 employees
- 4-5% investment of sales in R&D
- 15-20% of our products and services are less than five years old
- 17 Science & Technology Centers; 45 manufacturing & warehouse locations
- Beyond products ... solutions
Helping industries worldwide
‘invent the future’

Beauty & Personal Care
Chemical Manufacturing
Solar Energy
Electronics
Food & Beverage

Healthcare
High Performance Building
Household & Cleaning
Imaging
Industrial Assembly & Maintenance

Lighting
Oil & Gas
Packaging
Paints & Coatings
Plastics & Composites

Power & Utilities
Rubber Fabrication
Semiconductor
Textiles
Transportation

We help you invent the future.™
LED lighting Market Overview

LED market share by sector (Value based)

LED Lamp Average Price (2011-2020)

LED lighting penetration Rate

LED lamp ASP trend

(Data source: Mckinsey ‘Lighting the way 2012 report)
LED Lighting Segmentation

**LED Lighting**

- **Replacement Lamp**
  - Bulb/ Candle
  - Spot lighting
    - PAR
    - AR
    - MR
  - Tube

- **Luminaries**
  - Architecture
  - Entertainment
  - Retail display
  - Residential
  - Commercial /industry
  - Consumer Portable
  - Safety/ security
  - Outdoor
  - Off-grid ( solar powered)

**LED lighting market fcst 2011-2020**

Source: Strategy Unlimited 2012

Source: Mckinsey- Lighting the way 2012 / IMS-world L&L
What Are Silicones?

Quartz → Reduction (T ~ 1500 °C) → Silicon Metal → Reaction with CH₃Cl → Chlorosilanes → Hydrolysis (H⁺) → Silicones
Why Use Silicones?

<table>
<thead>
<tr>
<th>Main difference between Silicones and Organics?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bond Energy Kcal/mol</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Si-O</th>
<th>C-C</th>
</tr>
</thead>
<tbody>
<tr>
<td>108</td>
<td>87</td>
</tr>
</tbody>
</table>

DOW CORNING

We help you invent the future.
Silicones – A New Material for Lighting

Glasses are:
- Thermally stable
- Optically clear
- Complex to process

Organic polymers are:
- Easier to process
- Range of properties
- Less thermally stable

Silicones have properties that combine glass and organic polymers
Why silicones excel in electronics/LED lighting

1. Electrically conducting or non-conducting
2. Thermal management capabilities
3. Optical clarity and light transmittance
4. Adhesion, flexibility, and resilience
5. Resist heat and cold, thermal shock, oxidation, moisture, chemicals, and ultraviolet radiation; perform reliably under harsh conditions
6. More durable than many organic materials; perform longer
7. Flowing, wetting, adhesion, and cure properties that speed and simplify processing; repairable
## Silicone versus Organic

### Time & Reliability versus Money

<table>
<thead>
<tr>
<th>Rating: 1 (highest) to 4</th>
<th>Acrylic</th>
<th>PU</th>
<th>Epoxy</th>
<th>Silicone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humidity Resistance</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Extended periods</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Resistance</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Temperature Resistance</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Abrasion Resistance</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Mechanical Strength</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Solvent Resistance (organic)</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Electrical Resistance</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>After salt fog exposure</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UV Resistance</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Silicone Material Opportunity in LED Lighting

**Lamp**

**Pottants**

*Application:* Driver protection

*Key requirements*
- High reliability
- Fast production
- EMI
- UL 94 (V0)
- UL746 (RTI)

**Thermal Interface Materials**

*Application:* TIM between PCB and heat sink

*Key requirements*
- High reliability
- Easy process
- UL 94V0

**Adhesives / Sealants**

*Key application:* Structure sealing

*Key requirements*
- Reliability
- Fast room temperature cure
- Transparent / white
- No color change
- UL 94V0

**Luminaires**

*Application:* Driver protection

*Key requirements*
- High reliability
- Fast production
- EMI
- UL 94 (V0)
- UL746 (RTI)
Dow Corning Thermal Pottant

Dow Corning Silicone Product Line
To protect the LED driver from environmental facts (moisture, dust) and dissipate the heat from LED driver.

Dow Corning Thermal Pottant

Thermal Pottants

Our high-flow thermal silicone pottants protect LED drivers from moisture and dust, while dissipating damaging heat and absorbing component noise. With high thermal conductivity and RTI reaching as high as 150°C, these materials help ensure long-term reliability and lower lifetime costs for your LED lamp and Luminaire design. Their room-temperature cure process can be accelerated with mild heat to expand manufacturing flexibility and reduce processing cost.
# Dow Corning Thermal Pottant

<table>
<thead>
<tr>
<th>Pottants</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Hardness (Shore A)</th>
<th>Mixed Viscosity (cP)</th>
<th>Curing</th>
<th>Agency list</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sylgard® 160 Silicone Elastomer</td>
<td>0.62</td>
<td>56</td>
<td>6025</td>
<td>24 hours/RT; 4min/100°C</td>
<td>UL94 V0 (1.5, 3.0mm) RTI=105 °C</td>
<td>Gray</td>
</tr>
<tr>
<td>Dow Corning® CN-8760 G</td>
<td>0.67</td>
<td>45</td>
<td>3200</td>
<td>24hrs/RT; 30min/60 °C</td>
<td>UL94 V0 (2.5mm) RTI=150 °C</td>
<td>Gray</td>
</tr>
<tr>
<td>Dow Corning® CN-8760</td>
<td>0.65</td>
<td>49</td>
<td>2850</td>
<td>24hrs/RT; 45min/50 °C</td>
<td>UL94 V0 (5.0mm) RTI=105 °C</td>
<td>Gray</td>
</tr>
<tr>
<td>Sylgard® 170 Silicone Elastomer</td>
<td>0.48</td>
<td>50</td>
<td>2050</td>
<td>24hrs/RT; 10min/100 °C</td>
<td>UL94 V0 (5.6mm) RTI=170 °C</td>
<td>Black</td>
</tr>
</tbody>
</table>

**RTI=Relative Température Index (UL746)**
Maximum service temperature for a material where specific properties are not unacceptably compromised

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**Dow Corning**

*We help you invent the future.*
CN-8760G / CN-8760 Aging 130C/150C

Thermal Conductivity Aging at 150°C

Hardness 130C/150C aging

Tensile Strength (psi)

Dielectric strength

We help you invent the future.
Dow Corning Thermal Interface Material

Dow Corning Silicone Product Line
Dow Corning Thermal Interface Material

To be applied between PCB and heat sink to **dissipate the heat** from the lighting source and **reduce junction temperature**.

**Thermal Interface Materials**

Our broad portfolio of thermal interface materials offers versatile heat management options for virtually every LED lamp and Luminaire design.

- **Thermal Adhesives** form strong thermally stable bonds to most LED printed circuit board substrates (e.g. Ceramic, MCPCB and FR4), and deliver excellent thermal conductivity. Our materials cure at room temperature, with accelerated heat cure options for flexible processing. Their low volatility means no adverse impact to light output.

- **Dispensable Thermal Pads** enable quick and precise printing of thermally conductive silicone pads in controllable thicknesses on complex substrate shapes. They can enhance thermal performance, accelerate production and reduce system costs compared to fabricated pads. Plus, they may offer longer reliability compared to conventional thermal greases.

- **Thermal Greases** enable very thin bond lines and fill tight gaps to ensure durable thermal management and long-term reliability of LED devices.
Lamp & Luminaire – Thermal Applications

<table>
<thead>
<tr>
<th>Energy</th>
<th>Incandescent (60 W)</th>
<th>Fluorescent (Typical linear CW)</th>
<th>Metal Halide</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Visible Light</strong></td>
<td>8%</td>
<td>21%</td>
<td>27%</td>
<td>20-30%</td>
</tr>
<tr>
<td><strong>IR</strong></td>
<td>73%</td>
<td>37%</td>
<td>17%</td>
<td>~0%</td>
</tr>
<tr>
<td><strong>UV</strong></td>
<td>0%</td>
<td>0%</td>
<td>19%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Convection and Conduction</strong></td>
<td>19%</td>
<td>42%</td>
<td>37%</td>
<td>70-80%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

• In LED lamp, most of electricity energy is converted into heat w/o IR thermal radiation path like in conventional incandescent bulb.
## Dow Corning Thermal Greases

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Thermal Resistance at 40Psi (°C.cm²/W)</th>
<th>Viscosity cP</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Corning® TC-5121 Thermally Conductive Compound</td>
<td>3.2</td>
<td>0.1</td>
<td>85,000</td>
<td>Gray, low thermal resistance, high thermal conductivity</td>
</tr>
<tr>
<td>Dow Corning® TC-5080 Thermally Conductive Compound</td>
<td>1.0</td>
<td>0.25</td>
<td>836,000</td>
<td>Gray, ultrathin bondlines, Low thermal resistance</td>
</tr>
<tr>
<td>Dow Corning® SC 102 Compound</td>
<td>0.8</td>
<td>0.62</td>
<td>29,000</td>
<td>White color, low viscosity</td>
</tr>
<tr>
<td>Dow Corning® 340 Heat sink compound</td>
<td>0.68</td>
<td>0.6</td>
<td>542,000</td>
<td>White color, less volatile</td>
</tr>
</tbody>
</table>
TC5080 stability: Thermal Resistance

- Typical properties
  - Viscosity: 836 Pa-s
  - Thermal conductivity: 1.0 W/mK
  - Density: 2.16 g/cm³
  - Dielectric strength: 9 kV/mm
  - Volume resistivity: 2.9E+15 ohm.cm
# Thermal Conductive Adhesives

<table>
<thead>
<tr>
<th>Product</th>
<th>Thermal Conductivity (W/m-K)</th>
<th>Agency Listing</th>
<th>Form/Color</th>
<th>Cure Conditions (tack Free time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Corning® SE 4485</td>
<td>2.8</td>
<td>UL 94 V-0</td>
<td>1 part, white</td>
<td>10 min @ RT*</td>
</tr>
<tr>
<td>Dow Corning® SE 4485 L</td>
<td>2.2</td>
<td>-</td>
<td>1 part, white</td>
<td>8 min @ RT*</td>
</tr>
<tr>
<td>Dow Corning® SE 4486</td>
<td>1.59</td>
<td>-</td>
<td>1 part, white</td>
<td>4 min @ RT*</td>
</tr>
<tr>
<td>Dow Corning® SE 4422</td>
<td>0.90</td>
<td>-</td>
<td>1 part, white</td>
<td>11 min @ RT*</td>
</tr>
<tr>
<td>Dow Corning® EA-9189 H White</td>
<td>0.88</td>
<td>UL 94 V-0</td>
<td>1 part, white</td>
<td>5 min @ RT</td>
</tr>
</tbody>
</table>

* Cure time for moisture cure adhesives depends on many factors, including ambient temperature, material thickness and relative humidity of cure environment.
Dow Corning SE 4485 Thermal Adhesive

Thermal Resistance vs. Pressure

- RTV Exposure Time 3 mins
- RTV Exposure Time 12 mins

Thermal Resistance (°C cm²/W)

Pressure (psi)
Dow Corning EA-9189H Thermal Adhesive

**Thermal Aging:** 150°C

<table>
<thead>
<tr>
<th>Properties</th>
<th>Initial</th>
<th>168 hrs</th>
<th>500 hrs</th>
<th>1,000 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, psi</td>
<td>644</td>
<td>557</td>
<td>531</td>
<td>638</td>
</tr>
<tr>
<td>Elongation, %</td>
<td>32</td>
<td>30</td>
<td>20</td>
<td>26</td>
</tr>
<tr>
<td>Hardness, Shore A</td>
<td>78</td>
<td>76</td>
<td>72</td>
<td>79</td>
</tr>
<tr>
<td>Lap Shear Adhesion, psi</td>
<td>292</td>
<td>252</td>
<td>243</td>
<td>282</td>
</tr>
<tr>
<td>Al</td>
<td>275</td>
<td>231</td>
<td>239</td>
<td>273</td>
</tr>
<tr>
<td>Cu</td>
<td>346</td>
<td>285</td>
<td>286</td>
<td>323</td>
</tr>
<tr>
<td>FR-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Volume Resistivity, Ω·cm</td>
<td>3.23 X 10^16</td>
<td>2.64 X 10^16</td>
<td>3.99 X 10^16</td>
<td>2.53 X 10^16</td>
</tr>
<tr>
<td>Dielectric Strength, KV/mm</td>
<td>24</td>
<td>22</td>
<td>26</td>
<td>26</td>
</tr>
</tbody>
</table>

**Thermal & Humidity Aging:** 60°C; 90% RH

<table>
<thead>
<tr>
<th>Properties</th>
<th>Initial</th>
<th>168 hrs</th>
<th>500 hrs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile Strength, psi</td>
<td>644</td>
<td>655</td>
<td>599</td>
</tr>
<tr>
<td>Elongation, %</td>
<td>32</td>
<td>27</td>
<td>24</td>
</tr>
<tr>
<td>Hardness, Shore A</td>
<td>78</td>
<td>77</td>
<td>72</td>
</tr>
<tr>
<td>Lap Shear Adhesion, psi</td>
<td>292</td>
<td>292</td>
<td>293</td>
</tr>
<tr>
<td>Al</td>
<td>275</td>
<td>246</td>
<td>315</td>
</tr>
<tr>
<td>Cu</td>
<td>346</td>
<td>287</td>
<td>280</td>
</tr>
<tr>
<td>FR-4</td>
<td>191</td>
<td>125</td>
<td>119</td>
</tr>
<tr>
<td>Volume Resistivity, Ω·cm</td>
<td>3.23 X 10^16</td>
<td>3.33 X 10^16</td>
<td>5.41 X 10^16</td>
</tr>
<tr>
<td>Dielectric Strength, KV/mm</td>
<td>24</td>
<td>29</td>
<td>28</td>
</tr>
</tbody>
</table>
# Dow Corning® Dispensable Thermal Pad

<table>
<thead>
<tr>
<th>Products</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Mixed Viscosity (cP)</th>
<th>Hardness (Shore 00)</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Corning® TC-4015</td>
<td>1.7</td>
<td>103,000</td>
<td>50</td>
<td>Two part, 1:1 mixing, soft and suitable for stress-relieving</td>
</tr>
<tr>
<td>Dow Corning® TC-4016</td>
<td>1.7</td>
<td>103,000</td>
<td>50</td>
<td>Two part, 1:1 mixing, soft and suitable for stress-relieving, Glass beads added to control the thickness</td>
</tr>
<tr>
<td>Dow Corning® TC-4025</td>
<td>2.5</td>
<td>70,000</td>
<td>50</td>
<td>Two part, 1:1 mixing, soft and suitable for stress-relieving</td>
</tr>
<tr>
<td>Dow Corning® TC-4026</td>
<td>2.5</td>
<td>70,000</td>
<td>50</td>
<td>Two part, 1:1 mixing, soft and suitable for stress-relieving, Glass beads added to control the thickness</td>
</tr>
</tbody>
</table>
Reliability Test of TC-4025

- Samples are cured into thin sheets 0.25-1mm thick and then brought for reliability tests: 85 °C/85%, thermal shock -40~125 °C.
- Thermal resistance after reliability test (500, 1000, 2000 hrs/cycles) obtained based on ASTM 5470 standard and compared with time 0 testing.
Dow Corning® Dispensable Thermal Pad

**Thermal Resistance vs. Thickness**

- TC-4015
- TC-4025

**Thermal Resistance vs. Pressure @1mm**

- TC-4015
- TC-4025

**Thickness vs. Pressure**

- TC-4015
- TC-4025

**Thermal Resistance vs. Thickness**

- TC-4015, 1.7 W/mK
- TC-4025, 2.5 W/mK
- Competitor 1 Pad, 1.2 w/mK
- Competitor 1 Pad, 3.0 W/mK
- Competitor 2 Pad, 1.5 W/mK
Application Method #1: Manual or Automatic printing

Typical working mode:
- Manual (manual mix + manual printing)
- Semi-automatic (manual mix + programmable printing)
- Printing modes: Screen/Stencil printing (thickness, design)
Application method #2: Automatic Dispensing with Static Mixer

Automated dispensing with metering pump
Sealing exterior edges in the assembly

Adhesives & Sealants
Thermal silicone adhesives & sealants from Dow Corning form excellent bonds and seals with a variety of common LED lamp and Luminaire materials, and ensure reliable long-term performance at temperatures exceeding 120°C. These solventless materials cure at room temperature to greatly simplify processing, and their low volatility (<300 ppm) helps maintain lumen output over the lifetime of your device.
<table>
<thead>
<tr>
<th>Products</th>
<th>Viscosity (cP)</th>
<th>Agency Listing</th>
<th>Form/Color</th>
<th>Cure Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Corning® 3165 Fast Tack RTV Adhesive Sealant</td>
<td>Paste</td>
<td>UL94 V-0 (@ 5.4 mm)</td>
<td>1 part, gray</td>
<td>Tack-free time at 25°C: 5 min</td>
</tr>
<tr>
<td>Dow Corning® EA-4900 White RTV Adhesive</td>
<td>Paste</td>
<td>UL 94 V-0</td>
<td>1 part, white</td>
<td>Tack-free time at 25°C: 5 min</td>
</tr>
<tr>
<td>Dow Corning® 3-1944</td>
<td>64,000</td>
<td>UL 94 V-0 Mil Spec</td>
<td>1 part, translucent</td>
<td>Tack-free time at 25°C: 14 min</td>
</tr>
</tbody>
</table>
Secondary optics fixation

Key requirements for the adhesives:
- Low out gassing
- Reliable fixation
- Lens positioning
- Protection
- Resistance against thermal shock
- Compatible with LED light source

Recommended materials (CREE listed):
- Dow Corning 3-1944
- Dow Corning 744
- Dow Corning 3145
Conformal Coating

- Conformal coatings protect electronic printed circuit boards from moisture and contaminants, to prevent:
  - short circuits
  - corrosion of conductors and solder joints
  - dendritic growth and the electromigration of metal between conductors
- Elastomeric coatings provide stress relief
- Protect the insulation resistance of the circuit board
Conformal Coatings

Our silicone conformal coatings protect delicate LED electronics from humidity, moisture and thermal stress, and deliver excellent insulation against high voltages and short circuits. Dow Corning conformal coatings are available in a variety of viscosities and cure chemistries, they provide excellent unprimed adhesion to many common LED materials.

<table>
<thead>
<tr>
<th>Products</th>
<th>Viscosity (cp)</th>
<th>Agency list</th>
<th>Form</th>
<th>Cure condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dow Corning® 1-2577LV</td>
<td>1050</td>
<td>UL 94V-0</td>
<td>1 part, transparent</td>
<td>Tack free time (min) 25 ºc:15 mins</td>
</tr>
<tr>
<td>Dow Corning® 1-2620LV</td>
<td>350</td>
<td>UL 94V-0</td>
<td>1 part, transparent</td>
<td>Tack free time (min) 25 ºc:15 mins</td>
</tr>
<tr>
<td>Dow Corning® 1-4105</td>
<td>450</td>
<td>UL 94V-1</td>
<td>1 part, clear</td>
<td>5 mins @ 100ºC</td>
</tr>
<tr>
<td>Dow Corning® 3-1953</td>
<td>350</td>
<td>UL 94V-0</td>
<td>1 part, translucent</td>
<td>Tack free time (min) 25 ºc:8mins</td>
</tr>
</tbody>
</table>
Optical Silicones for Secondary Optics
Silicone applications in LED Package
Example of Applications (Lamps)

Remote Phosphor technology has many patents from different companies, Dow Corning is not responsible for the use of this technology, or any IP related subject.
Example of Applications (LED Luminaires)
Optical Materials for Lamps and Luminaires

Moldable Optical lenses

Remote Phosphor; Diffuser

Light Guides

White Reflector

Silicones benefits across the entire lighting value chain
- Thermal stability
- Transparency
- Photo stability
- Enhanced light output efficiency
- Easy processability
- Lower cost of ownership
- Enhanced Protection
- Enhanced reliability and lifetime
Features/Benefits of Silicones

FEATURES
• Good transparency
• Medium viscosity for **injection molding**
• Good mold flow for excellent feature reproduction
• Easy mixing of additives

BENEFITS
• Lighter than glass
• Easily molded into complex and big shapes
• Allow very detailed shapes unlike other optical materials
• Better heat resistance than plastic
• Less yellowing than some plastic

POTENTIAL USES
• Primary or secondary lenses
• Light pipes
• Light guides
• Other optic devices
• Remote phosphor designs

Dow Corning® MS-1002 Moldable Silicone
Dow Corning® MS-1003 Moldable Silicone
Typical Organic materials used for optical systems in lamps and luminaires, and Silicone resin aged at 200°C for 24 hours.
Thermal & UV Stability in optically clear materials

PMMA and PC have many grades that could have different results

Optical design by Gaggione
Injection Molding Optical Parts - Benefits

- Injection molding is the recommended method of manufacture for these materials
- Benefits of injection molding with Silicones:
  - Precision applications
    - Micrometer-sized features
  - Complex shapes
    - Undercuts, precise optical lens features, etc.
  - Short cycle times
    (specially in big parts, enables faster production)
  - Less steps in production
    e.g. No melting process, easier to release from mold allowing faster production that might lead to cost reduction.
  - No waste (liquid materials)
  - Possibility of overmold
    Friendly to use with other materials in an overmold Process (e.g. Glass overmolded on top)
Injection Molding Optical Parts – Ideal Process

- Parts A and B are fed through static mixer and into barrel
  - Low pressure, thorough mixing of parts
- Feed screw transfers material into plunger chamber
  - Friction in the screw warms material slightly, lowering viscosity somewhat
- Material fed from the screw fills the plunger chamber
  - Material forces plunger backward in its stroke path
- When plunger chamber is filled, the plunger is driven forward injecting material into the mold
  - Injection speeds and pressures are typically low as compared to LSR and thermoplastic
- Material cures in the heated mold
  - Cure profile is mold dependant and can range from 10 sec to 5 min depending on mold design and temp.

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- Third stream enables the input of precise amounts of additives into the base material
  - Computer control ensures mix ratio is always correct (e.g. Phosphors, diffusing materials)
# Typical Optical Properties

## Dow Corning® MS-1002

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission (350nm, 750nm)</td>
<td>%</td>
<td>90.44, 94.02</td>
</tr>
<tr>
<td>Reflection (350nm, 750nm)</td>
<td>%</td>
<td>6.56, 5.78</td>
</tr>
<tr>
<td>Haze (350nm, 750nm)</td>
<td>%</td>
<td>1.87, 0.77</td>
</tr>
<tr>
<td>Refractive Index (350nm, 750nm)</td>
<td></td>
<td>1.44, 1.42</td>
</tr>
</tbody>
</table>

*3mm thick unaged sample

## Dow Corning® MS-1003

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission (350nm, 750nm)</td>
<td>%</td>
<td>91.04, 94.50</td>
</tr>
<tr>
<td>Reflection (350nm, 750nm)</td>
<td>%</td>
<td>6.35, 5.68</td>
</tr>
<tr>
<td>Haze (350nm, 750nm)</td>
<td>%</td>
<td>1.81, 0.76</td>
</tr>
<tr>
<td>Refractive Index (350nm, 750nm)</td>
<td></td>
<td>1.43, 1.41</td>
</tr>
</tbody>
</table>

*3mm thick unaged sample
Transmission

- No changes in optical properties after 10000 hours under 150°C
- No change in mechanical properties after 10000 hours under 150°C
## Materials properties

<table>
<thead>
<tr>
<th>Properties</th>
<th>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 (Methyl) 1.53(Phenyl)</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>High</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Service temperature max(C°)</td>
<td>&gt;150</td>
<td>120</td>
<td>90</td>
<td>&gt;200</td>
</tr>
<tr>
<td>Dust collection</td>
<td>Medium-High</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</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>Large and Thick parts</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Minimal thickness**</td>
<td>&lt; 0.5mm</td>
<td>2mm</td>
<td>2mm</td>
<td>-</td>
</tr>
<tr>
<td>Draft angle (manufacturing)**</td>
<td>-2 to 0°</td>
<td>1 to 2°</td>
<td>1 to 2°</td>
<td>-</td>
</tr>
<tr>
<td>Weight</td>
<td>Low</td>
<td>Low</td>
<td>Low</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>

* Yellowing due to high temperature, high lumen density or UV exposure / ** Injection molding process
Questions or discussions?