Dow Corning Solution in Lamp and Luminaire Assembly

We help you invent the future."
Dow Corning Solutions for Lighting Assembly

With more than 70 years of experience developing silicone-based solutions for cutting-edge applications, Dow Corning offers today’s LED industry unmatched experience and know-how for LED lamp and Luminaire assembly. We bring more than just an industry-leading portfolio of assembly materials - such as thermal pottants, thermal interface materials, adhesives & sealants and conformal coatings. As a innovation leader, we also bring proven process and application expertise, a reliable global supply base and world-class customer service. If your application involves the manufacture, assembly, protection or enhancement of LED lighting devices, then you will likely find with Dow Corning a materials or process solution tailored to your needs.
Contents

- Lamp and Luminaire market overview
- Introduction to Silicones
- Silicone opportunity in LED lighting market
- Dow Corning Solutions
  - Thermal Pottant
  - Thermal Interface Material
  - Adhesive / Sealant
  - Conformal Coating
Fast grow in next 3-5 yrs. L&L market growth will lead by lamp replacement which forecast to grow 38% CAGR (2013-2017) and then slowly decline 2% CAGR to 2020.

‘Cost of lighting’ is the key drive for LED company to be success. LED lighting company is not only competing in LED market but also traditional lighting market.

Lighting market becoming more fragmented than before. The market structure has been disrupted by many new players who are not in the lighting business before (such as Samsung, LG). Need to build portfolio to deal with market dynamics.

(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
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

We help you invent the future.
Silicones Polymer Properties

<table>
<thead>
<tr>
<th>Chemical Property</th>
<th>Physical Property</th>
<th>Application/Design Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Si-O bond distance</td>
<td>Facile bond rotation</td>
<td>Low modulus</td>
</tr>
<tr>
<td>Wide bond angle</td>
<td>Stable bonds</td>
<td>Heat resistance</td>
</tr>
<tr>
<td>High bond energy</td>
<td>Low temperature dependence</td>
<td>Wide working range</td>
</tr>
<tr>
<td>Weak van der Waals’ force</td>
<td>Low viscosity</td>
<td>Good workability</td>
</tr>
<tr>
<td>Organic exterior</td>
<td>Hydrophobicity</td>
<td>Low moisture absorption</td>
</tr>
</tbody>
</table>

A unique combination of properties among polymeric materials
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>Visible Light</td>
<td>8%</td>
<td>21%</td>
<td>27%</td>
<td>20-30%</td>
</tr>
<tr>
<td>IR</td>
<td>73%</td>
<td>37%</td>
<td>17%</td>
<td>~0%</td>
</tr>
<tr>
<td>UV</td>
<td>0%</td>
<td>0%</td>
<td>19%</td>
<td>0%</td>
</tr>
<tr>
<td>Heat Convection and Conduction</td>
<td>19%</td>
<td>42%</td>
<td>37%</td>
<td>70-80%</td>
</tr>
<tr>
<td>Total</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.
## 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></td>
<td>Extended periods</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></td>
<td>After salt fog exposure</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**

1. **Pottants**
   - **Application:** Driver protection
   - **Key requirements**
     - High reliability
     - Fast production
     - EMI
     - UL 94 (V0)
     - UL 746 (RTI)

2. **Thermal Interface Materials**
   - **Application:** TIM between PCB and heat sink
   - **Key requirements**
     - High reliability
     - Easy process
     - UL 94V0

3. **Adhesives / Sealants**
   - **Key application:** Structure sealing
   - **Key requirements**
     - Reliability
     - Fast room temperature cure
     - Transparent / white
     - No color change
     - UL 94V0

**Luminaires**
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.

### 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>Sylgard® 164 Silicone Elastomer</td>
<td>0.64</td>
<td>61</td>
<td>-</td>
<td>36min/25 ° C</td>
<td>UL94 V0 (5.9mm) 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)
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.
# 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-5625 Thermally Conductive Compound</td>
<td>2.5</td>
<td>0.096</td>
<td>95,000</td>
<td>Gray, low thermal resistance, with medium thermal conductivity</td>
</tr>
<tr>
<td>Dow Corning® TC-5080 Thermally Conductive Compound</td>
<td>1.0</td>
<td>0.25</td>
<td>76,200</td>
<td>Gray, ultrathin bondlines, Lowest thermal resistance</td>
</tr>
<tr>
<td>Dow Corning® SC 102 Compound</td>
<td>0.8</td>
<td>0.62</td>
<td>&lt;100,000</td>
<td>White color</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</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>RTV 120 hrs @ RT*</td>
</tr>
<tr>
<td>Dow Corning® SE 4485 L</td>
<td>2.2</td>
<td>-</td>
<td>1 part, white</td>
<td>RTV 72 hrs @ RT*</td>
</tr>
<tr>
<td>Dow Corning® SE 4486</td>
<td>1.59</td>
<td>-</td>
<td>1 part, white</td>
<td>RTV 72 hrs @ RT*</td>
</tr>
<tr>
<td>Dow Corning® SE 4420</td>
<td>0.92</td>
<td>-</td>
<td>1 part, white</td>
<td>RTV 48 hrs @ RT* (Fast TFT)</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></td>
</tr>
<tr>
<td>Dow Corning® SE 9184 White RTV</td>
<td>0.84</td>
<td>UL 94 V-0</td>
<td>1 part, white</td>
<td>RTV 48 hrs @ 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

![Graph 1: Thermal Resistance vs. Pressure](image1)

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

![Graph 2: Thermal Resistance vs. RTV Exposure Time](image2)

- Pressure 36 psi
- Pressure 3.6 psi

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## Dow Corning EA-9189H Thermal Adhesive

### Thermal Aging:
150°C

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

<table>
<thead>
<tr>
<th>Properties</th>
<th>Initial</th>
<th>Aged 168 hrs</th>
<th>Aged 500 hrs</th>
<th>Aged 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>Al</td>
<td>292</td>
<td>252</td>
<td>243</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>275</td>
<td>231</td>
<td>239</td>
</tr>
<tr>
<td></td>
<td>FR-4</td>
<td>346</td>
<td>285</td>
<td>286</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>

<table>
<thead>
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<td>24</td>
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<td>72</td>
</tr>
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<td>Al</td>
<td>292</td>
<td>292</td>
</tr>
<tr>
<td></td>
<td>Cu</td>
<td>275</td>
<td>246</td>
</tr>
<tr>
<td></td>
<td>FR-4</td>
<td>346</td>
<td>287</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>191</td>
<td>125</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</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>▪ 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></td>
<td></td>
<td></td>
<td></td>
<td>▪ Glass beads added to control the thickness</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</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>▪ 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)

Stencil template opening ~50mm

ATMA AT-25 semi-auto printer
Application method #2: Automatic Dispensing with Static Mixer

Automated dispensing with metering pump

We help you invent the future.
Dow Corning Adhesive / Coating

Dow Corning Silicone Product Line
Dow Corning Adhesive / Sealant

- 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.

We help you invent the future.
## Adhesive/Sealant

<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>Non-flow</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 Paste</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>
<tr>
<td>Dow Corning® 3145 RTV MIL-A-46146 Adhesive/Sealant-Gray and -Clear</td>
<td>Paste</td>
<td>Mil Spec</td>
<td>1 part, gray or translucent</td>
<td>Tack-free time at 25°C: 78 min (gray) or 64 min (clear)</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

We help you invent the future.
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
- Protection from abrasion and solvents
- Elastomeric coatings provide stress relief
- Protect the insulation resistance of the circuit board
## Conformal Coating

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 °C:6mins</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 °C:5 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 @ 100°C</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 °C:8mins</td>
</tr>
</tbody>
</table>
Top reasons to choose Dow Corning® Protection, Assembly & Thermally Conductive materials:

- Greases
- Gels
- Pads
- Encapsulants
- Pastes
- Pottants
- Adhesives

“One-Stop Shop”
Thank You

http://www.dowcorning.com/content/etronics/
What are the key features?

High Tc, Low Tr

• High temperature stability

• Low stress during thermal cycling

• Environmental stability

Higher TR

Lower TR

Bulk conductivity and contact resistance being equal, a thinner bond line will result in lower thermal resistance.
Product Thermal Testing – Hitachi Hotplate

Hitachi Guarded Hotplate (ASTM # D5470).

- Measures thermal resistance through TIM at different bond lines and pressure loads

Thermal resistance testing critical for TIM characterization:
- Steady state method
- Handles complex materials
- Load or Thickness can be controlled
- Measurable at 40~140C
- Probe: precision-machined 1 cm X 1 cm Cu blocks.

\[
R_{TM} = \frac{BLT}{k_{TM}} + R_{c1} + R_{c2}
\]

BLT = Bond Line Thickness
\(k_{TM}\) = Thermal Conductivity
\(R_{c1}, R_{c2}\) = Contact Resistance between the TIM and the two surfaces.
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