OPTICAL SILICONES IN TRANSPORTATION

INTELLIGENT AUTOMOTIVE LIGHTING 2019

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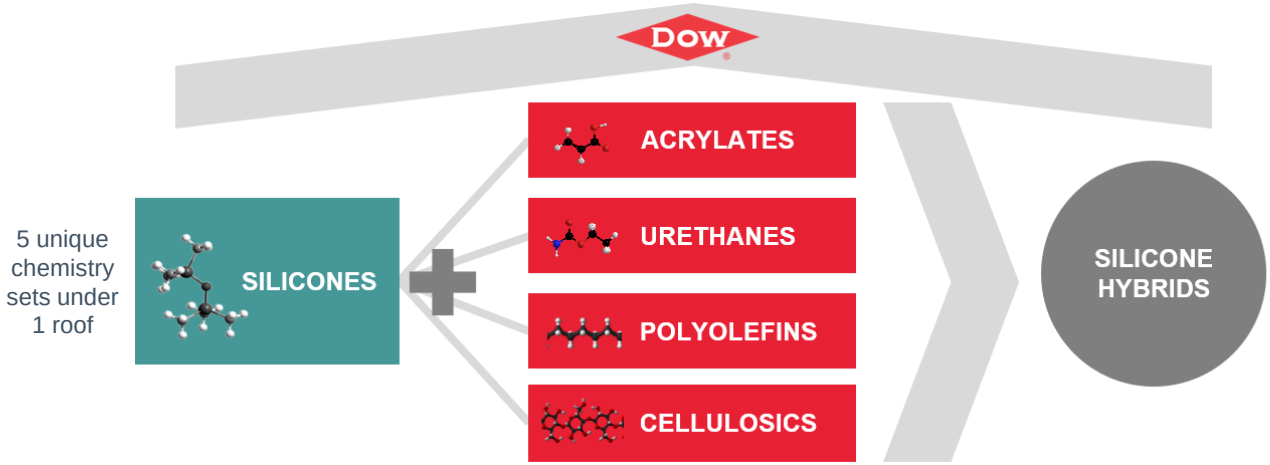
DOW INNOVATION ENGINE

Combining 75 years of silicones expertise with exceptional innovation to deliver new offerings to the market



Silicone hybrids provide improved material properties such as enhanced thermal stability, adhesion, sealing, and durability that reduce processing time and increase speed to finished product

DOW CONSUMER SOLUTIONS: AT A GLANCE

High Performance Building

Transportation

Si Elastomers

Pressure Sensitive

Personal Care

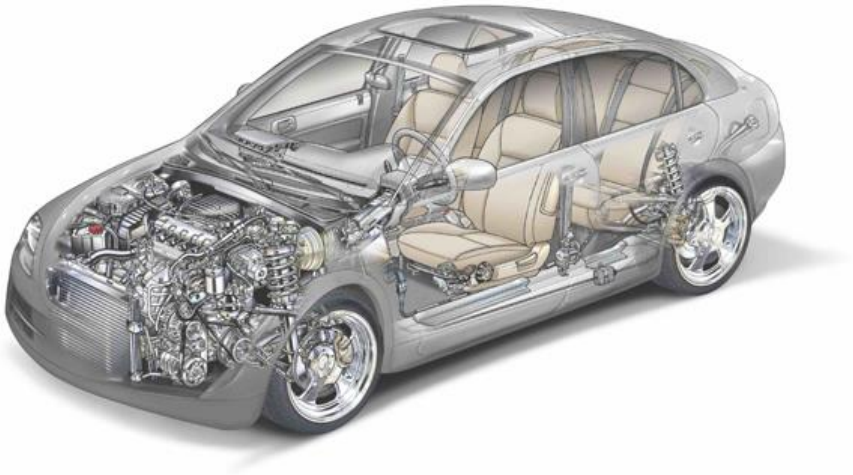
Home Care

TRANSPORTATION SOLUTIONS

Adhesives and sealants		Bonding
Conformal coatings		Sealing
Encapsulants		Protection
Dielectric gels		Stress relief
Thermally conductive		Heat dissipation
Electrically conductive		Processing
Optical moldable silicones		Lighting

TRANSPORTATION APPLICATIONS

- Battery pack assembly
- Under-the-hood gasketing
- Boards and assemblies
- Sensors
- Displays
- Housings
- Head / rear lamps



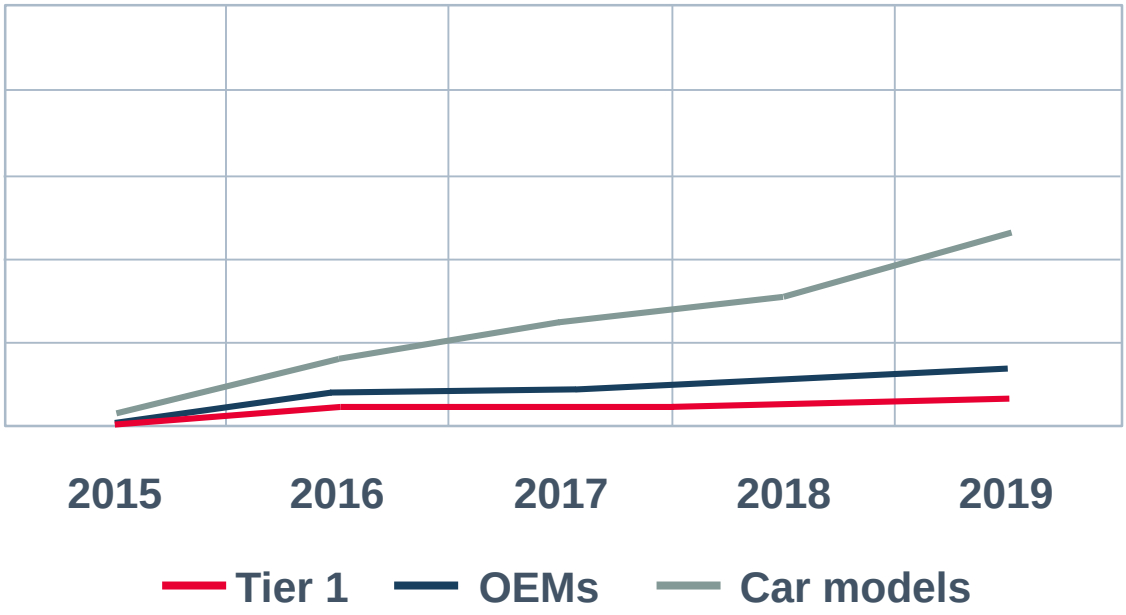
WHY SILICONE FOR OPTICS?

Flexible and soft material

High precision and heat stability

Bendable light guides

European adoption of moldable optical silicones in automotive lighting



MOLDABLE OPTICAL SILICONES FROM DOW

HELLA KGaA Hueck & Co.

Adaptive headlamps

Consumer Solutions

DOWSIL™ Brand Moldable Optical Silicones Help Pave the Way to a Groundbreaking LED Headlamp Design from Hella KGaA Hueck & Co.

Case Study: Hella KGaA Hueck & Co.

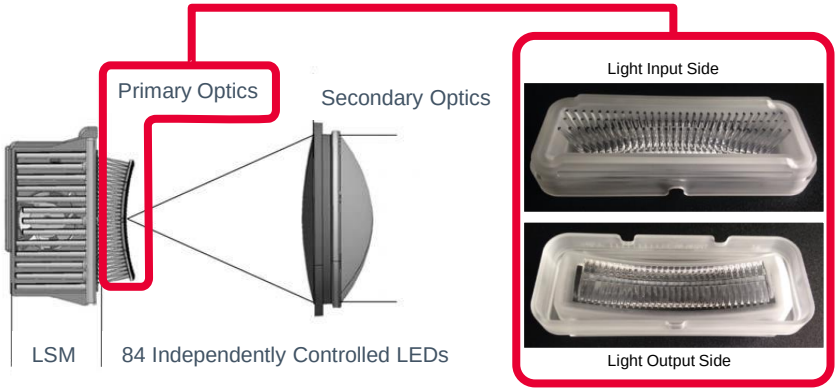
The Challenge

For years, the conventional approach to automotive LED headlamp design relied on mechanical actuators to position the beams of a single, controllable LED row. Hella KGaA Hueck & Co., a leading manufacturer of innovative automotive lighting components, envisioned a more dynamically adaptive solution that needn't rely on mechatronic components.

That vision became the award-winning MULTIBEAM LED headlamp. Developed in partnership with Daimler AG, the MULTIBEAM module incorporates 84 individually controllable LED pixels arrayed in three rows, enabling the headlamp to dynamically distribute light in real time based on changing traffic, weather and road conditions. Hella's groundbreaking headlamp module further ensures that the high beam function can be used more frequently, therefore offering greater safety and comfort.

Such innovation did not come without challenges, however. Distributing light evenly from the MULTIBEAM module's 84 LEDs required design of a complicated primary lens structure that incorporated 84 light guides. Most of these optics needed to be placed at an angle that, in turn, required them to incorporate a strong undercut that would have been impractical to impossible to achieve with glass or transparent plastics, as demolding the proposed lens design would require a highly flexible material.

Lastly, in order to optimize optical efficiency, the MULTIBEAM's light guides are positioned in close proximity to its high-power LED dies. Consequently, the primary lens material would need to perform reliably despite long exposure to high temperature and photodensity – organic plastics such as PMMA and PC would darken and turn brown within a relatively short time.



High complexity headlamp module

- Silicone light guides
- Acrylic lens

Benefits of SILASTIC™ MS-1002 Moldable Optical Silicone

- Highly flexible material allows demolding with undercuts
- Stable mechanical and optical properties against high power LEDs

Emergency vehicle light

Consumer Solutions

Emergency Vehicle LED Lighting Gets More Visible — and More Rugged — with Co-molded Silicones from Dow

DOWSIL™

Case Study: SoundOff Signal

The Challenge

One rainy night, a motorist calls 9-1-1 for help after getting into a "fender bender" accident with another vehicle. An unmarked police cruiser is the first to arrive on the scene at the dark intersection of two country roads. Suddenly, the plain-looking police vehicle lights up the night. Its previously "invisible" lights send bright warning lights far down the road to alert other motorists of the hazard ahead. The lighting also helps the officer see the accident scene and helps other motorists see the officer.

SoundOff Signal takes its job of manufacturing emergency vehicle lighting and warning electronics seriously. Already a global leader in this type of lighting, the company wanted to create a new, next-generation design to add to their popular lighting options for law enforcement, emergency and amber vehicles.

This employee-owned company in Hudsonville, Michigan, set out to create a new light with a smaller footprint, intense lighting, high quality and long life. The light would need the overall durability to withstand dirt, wet and extreme weather, gravel impacts and other road conditions. In addition to being rugged, the light's materials must offer good photothermal stability to avoid yellowing from intense UV exposure.

SoundOff Signal turned to the team of LED lighting silicone experts at Dow for recommendations and support for their new design ideas.

The Solution

SoundOff Signal created its first-generation optical design called ClearDuty™ technology. This technology and moldable silicone materials allow for the optic (lens) design and the housing to be molded — all in one piece. SoundOff Signal branded this new light as the mPOWER™ Fascia Light. It is the first extremely compact, tri-color line of lighting on the market.

When compared with a traditional polycarbonate lens, the new mPOWER™ Fascia Light has several advantages:

- A small footprint with maximized candela output
- Greater resistance to damage, such as gravel pitting, scratching or cracking
- Improved sealing performance to prevent water from entering the light
- Higher UV and photothermal stability to prevent lens yellowing over time

Smaller and lighter weight, the mPOWER™ Fascia Light can be mounted multiple ways and almost anywhere on a vehicle, including in grills and along tight areas on the sides of vehicles. The size, low profile and flat front make it easy to "disappear" and be unobtrusive.

The three- and four-inch lights have the ability to provide bright head-on and off-angle coverage with configurations of six to 18 LEDs — and up to three colors of LEDs from the same unit.

Video courtesy of SoundOff Signal

Benefits of SILASTIC™ MS-1002 Moldable Optical Silicone

- Over-molding SILASTIC™ MS-1002 with SILASTIC™ MS-0002
- Fewer parts for ease of assembly
- Small footprint with maximized candela output
- Improved sealing performance to prevent water ingress
- Greater resistance to gravel pitting, scratching, or cracking
- Higher UV and photo-thermal stability to prevent lens yellowing

SILASTIC™ MOLDABLE OPTICAL SILICONES PORTFOLIO

Designed for many applications

- Freeform collimators
- Secondary lenses
- Micro-lens arrays
- Light guides

Expanded material properties

- Hardness
- Viscosity

Enhanced optical performance

- High light transmittance
- Accurate control of surface light scattering

Diverse properties enable unique designs

Property	SILASTIC™ MS-1003 Silicone	SILASTIC™ MS-1002 Silicone	SILASTIC™ MS-4007 Silicone	SILASTIC™ MS-4002 Silicone
Viscosity, Part A (Pa-sec)	52	40	28	47
Viscosity, Part B (Pa-sec)	37.5	18	9.5	20
Viscosity, Mixed (Pa-sec)	42.3	26.3	10.5	25
Specific Gravity	1.05	1.07	1.08	1.08
Durometer (Shore A)	51	72	70	84
Tensile Strength (MPa)	5.5	11.2	11.7	11.7
Elongation at Break (%)	325	80	100	60
Linear CTE (by TMA) (ppm/˚C)	325	275	270	250

For complete data sheet, visit consumer.dow.com

SILASTIC™ MS-40XX Moldable Optical Silicone Elastomers

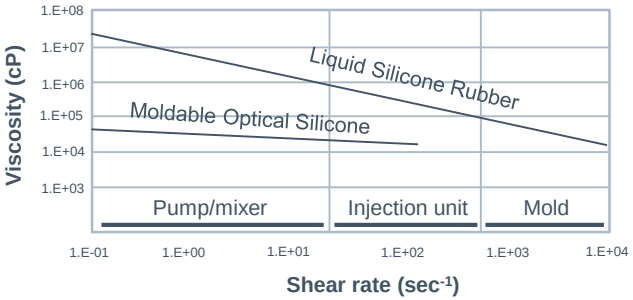
SSL Enabling Technologies – Optics

https://sapphireawards.secure-platform.com/a/page/2019finalists

MOLDABLE AND MECHANICAL PROPERTIES

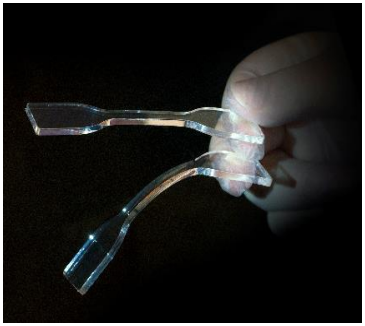
Efficient injection molding

- Ease of fabrication by liquid injection molding
- No secondary polishing of molded optics required

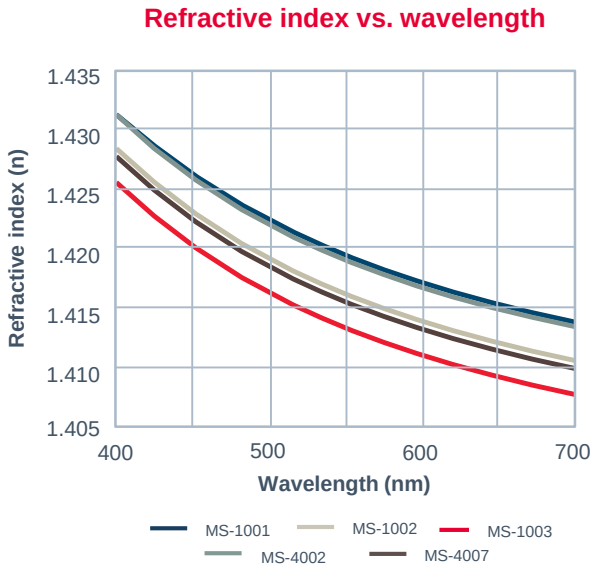


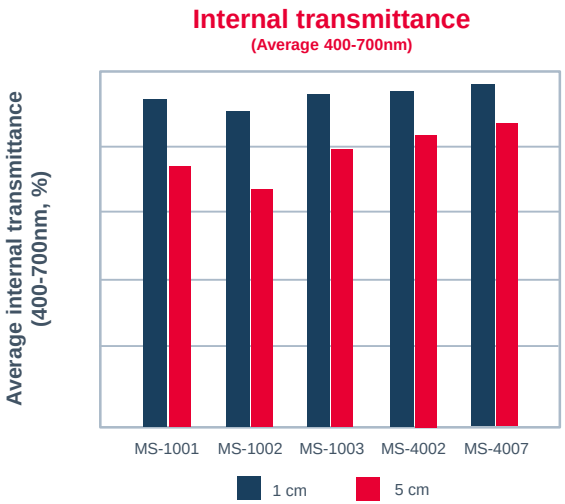
Soft and pliable, or firm and tough

- Impact and scratch resistant when hit or dropped
- High IP and IK ratings luminaries



OPTICAL PROPERTIES

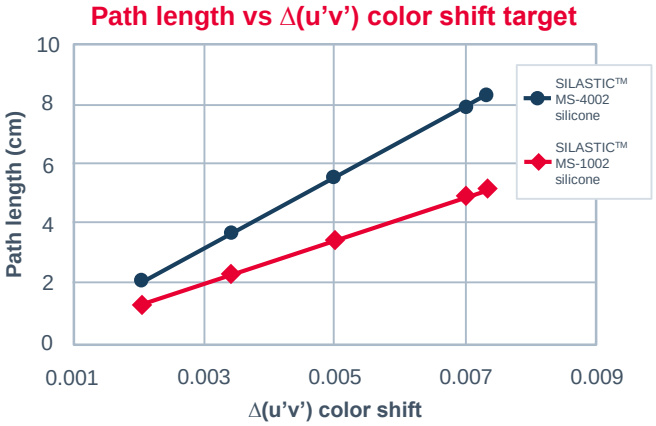




Property	SILASTIC™ MS-1001 Silicone	SILASTIC™ MS-1002 Silicone	SILASTIC™ MS-1003 Silicone	SILASTIC™ MS-4002 Silicone	SILASTIC™ MS-4007 Silicone
Refractive Index (633 nm)	1.42	1.41	1.41	1.42	1.41
Abbe Number	48.7	50.4	50.1	52.0	48.0

Full optical data sets available upon request for simulation

SILICONE OPTIC: LONG LIGHT PATH



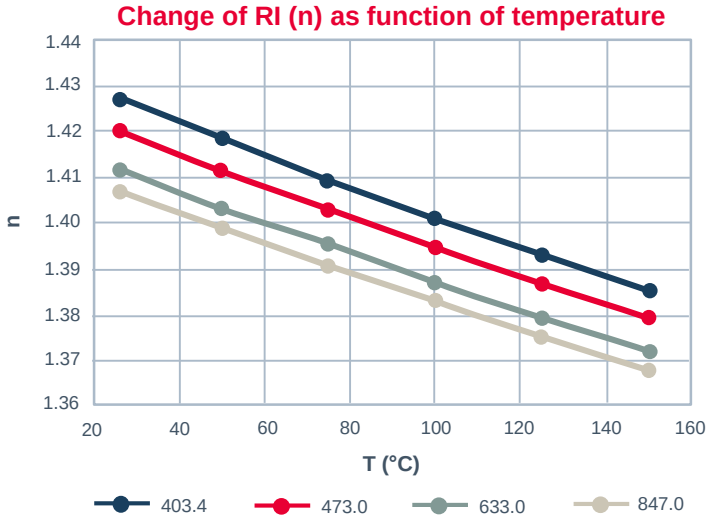
D65 white light source

- Significant color shift
  Δ(u'v') = 0.007
  (average on 400-800 nm)
- Light loss <5% up to 10 cm path length
  (SILASTIC™ MS-4002 Silicone and
  SILASTIC™ MS-4007 Silicone)

Monochromatic light source

- No color shift concern
- Light loss dependent on wavelength

THERMAL EFFECTS IN SILICONE OPTICS

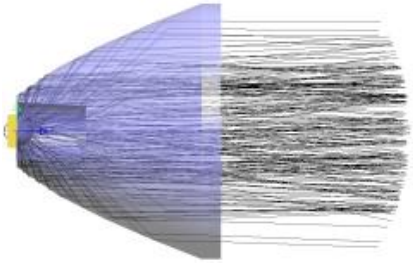


Material	CTE (ppm)	TOC (10^{-4}) dn/dT
Silicone	275	-3.2
PMMA	72	-1.1
PC	65	-1.07

CTE = Coefficient of Thermal Expansion
TOC = Thermo-Optical Coefficient

Refractive index measured with Metricon 2010/M Prism Coupler at four laser wavelengths, from room temperature up to 150ºC.

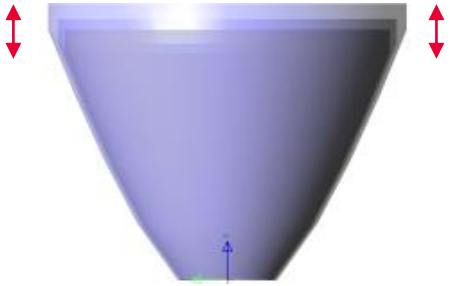
SILICONE OPTIC: NARROW BEAM ANGLE COLLIMATOR



Temperature	Volume (cm^3) Narrow collimator
25ºC	5.58
75ºC	5.81
150ºC	6.18

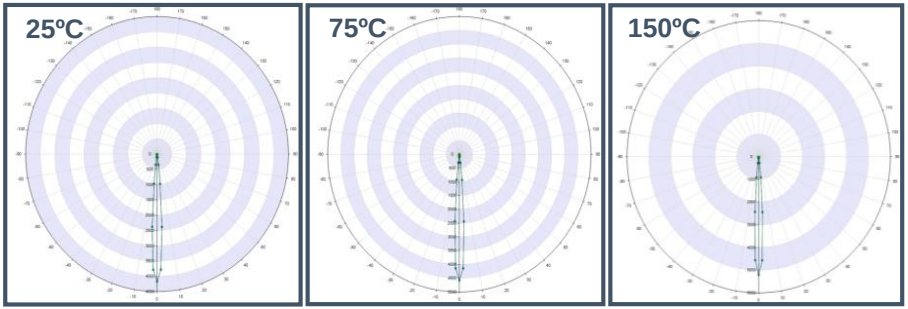
Simulation parameters

- Light source: CREE XPG-2 LED
- Narrow beam angle collimator: 9°
- Volume increase due to CTE effect – from 25°C up to 150°C
- Collimator un-constraint



SILICONE OPTIC: NARROW BEAM ANGLE COLLIMATOR

Temperature of Lens	Optical Efficiency	Δ	CBCP (cd)	Δ	Beam Angle / FWHM	Δ
25ºC	90.70%	-	4,179	-	8.9°	-
75ºC	91.07%	↑0.4%	4,336	↑3.8%	8.6°	↓0.3°
150ºC	91.54%	↑0.9%	4,540	↑8.6%	8.3°	↓0.6°



Simulation results

- Optical efficiency and light intensity at the center of the light beam increasing
- Light distribution slightly more narrow

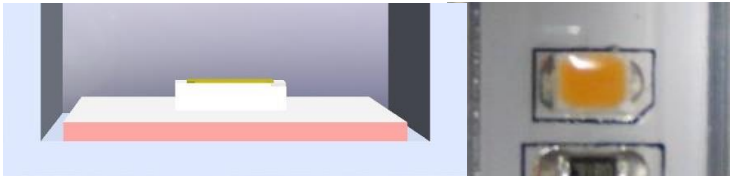
PROTECTIVE MATERIALS OVER LEDS

AND ASSOCIATED OPTICAL EFFECTS



PROTECTION OPTIONS

4000K Test part, no material (Optical simulation)



Conformal coating: Silicone, acrylic, urethane

- Thin layer provides little impact on light quality

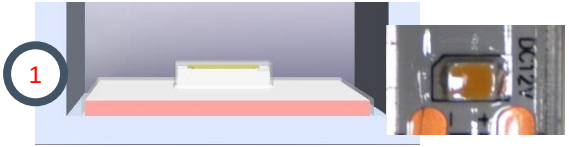
Encapsulant: Silicone, acrylic, urethane

- Impact protection in challenging environments

Molded lens: Silicone, PC, PMMA

- Impact protection with little impact on light quality

4000K Test part with DOWSIL™ 1-2577 Low VOC Conformal Coating



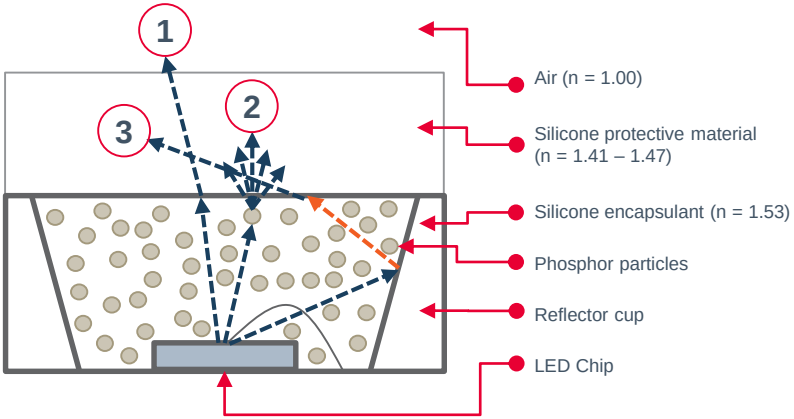
4000K Test part with DOWSIL™ EI-1184 Optical Encapsulant

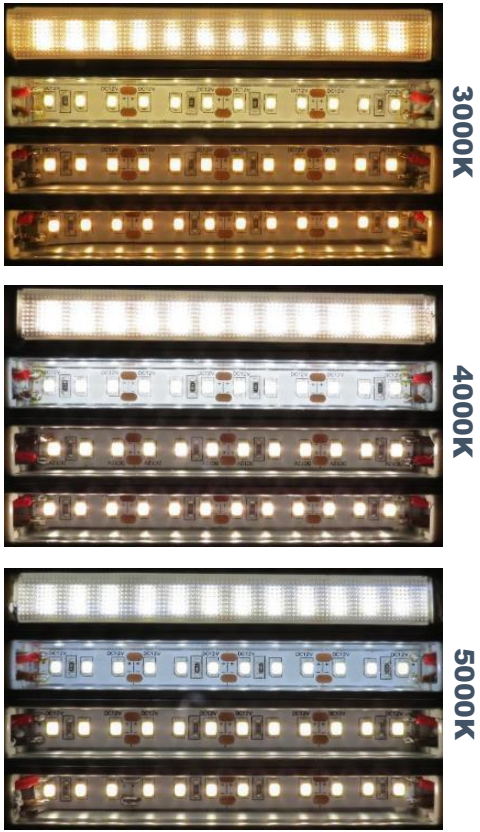
4000K Test part with SILASTIC™ MS-1002 Moldable Optical Silicone

Lens design courtesy of: LumenFlow Corp. Photonics Engineering & Manufacturing

OPTICAL INFLUENCE

Lumen output? Color temperature?





Protective material can

- Change Fresnel reflection
- Change color converted light
- Change total internal reflection

SILASTIC™ MS-1002
Moldable Silicone

DOWSIL™ EI-1184
Encapsulant

DOWSIL™ 1-2577
Low VOC Conformal Coating

No Protection

INNOVATIVE TECHNOLOGY FROM DOW

New DOWSIL™ EI-2888 primerless silicone encapsulant

- Patented technology
- 100% silicone product

DOWSIL™ EI-2888 Encapsulant	
Light transmission	
Aging resistance	
Low viscosity	
Rapid RT cure	
Self adhesion	
Health concern	
Shrinkage/Exotherm	
Cure robustness	
Cost	

DOWSIL™ EI-2888 ENCAPSULANT: SELF ADHESIVE

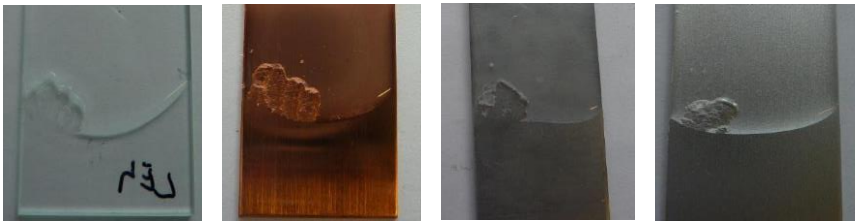
Cohesive failure on

- Anodized aluminum
- Glass
- FR4
- Stainless steel
- Steel
- Polycarbonate
- PBT
- Copper

Reliable adhesion after 2000 hours

- 150°C
- 85°C/85% RH
- -40/+150°C thermal shock
- Sunlight UV

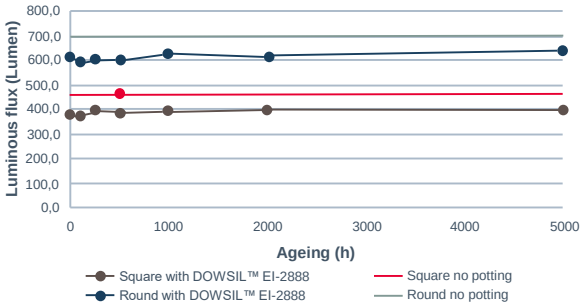
Limitation: PMMA, die-cast aluminum



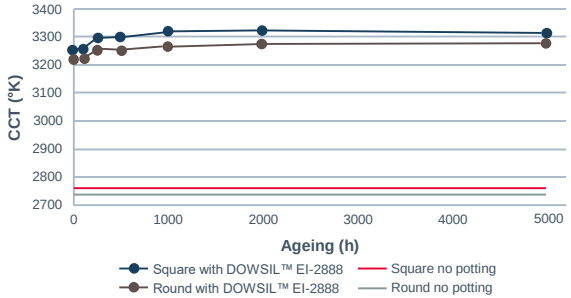
DOWSIL™ EI-2888 ENCAPSULANT: PROVEN RESULTS

Two rigid, high-power LED modules using DOWSIL™ EI-2888 encapsulant

Luminous flux evolution



Correlated color temperature stability



Round & square cross section design

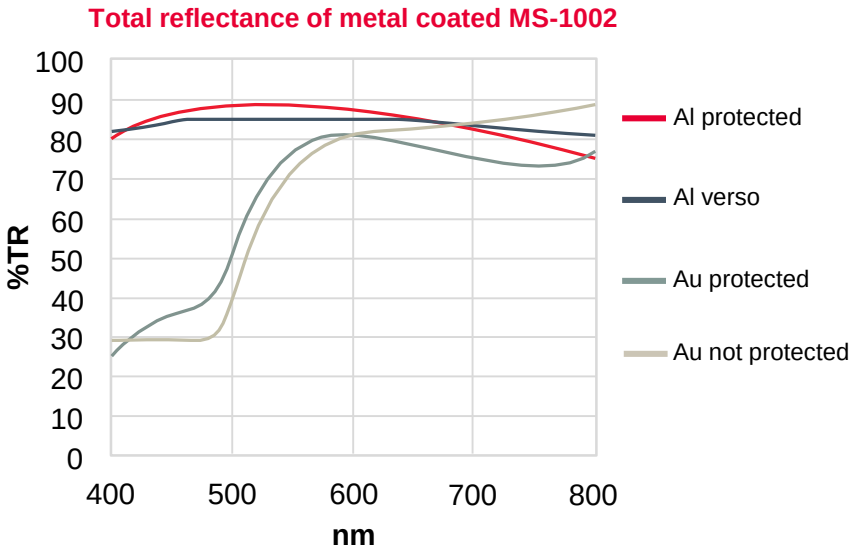
Driven 12V, 1.42A up to 5000 hrs

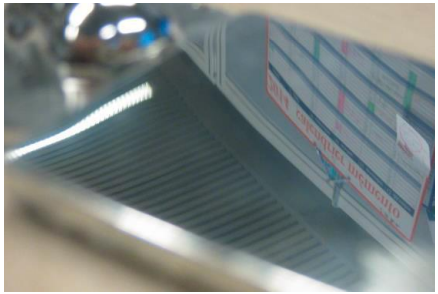
All details on the market release and technical performances available from LEDs Magazine webinar of February 21, 2019 on «***Stick to the clear advantage: new patented DOWSIL™ EI-2888 PrimerlessSilicone Encapsulant for LED Lighting***»
by Julien Renaud, Thierry Cooremans, Konstantin Sobolev

Reflective materials

Specular vs. lambertian

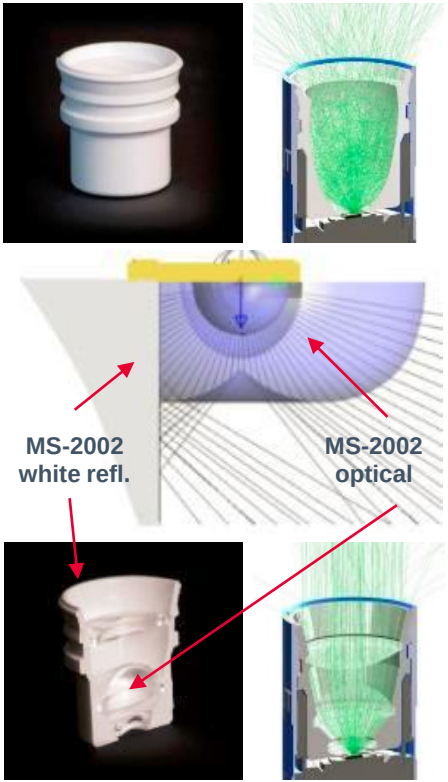
METAL COATING ON SILASTIC™ MS-1002 MOLDABLE SILICONE

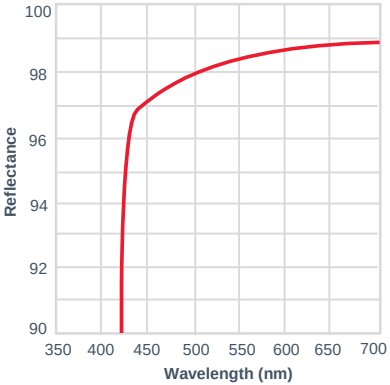


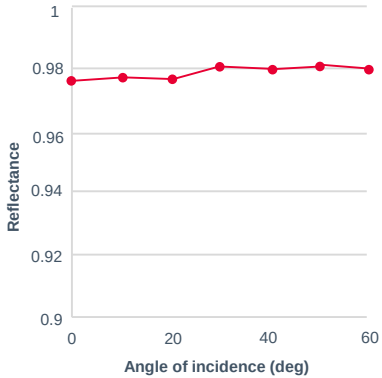


- ***PE-CVD deposition of SiO2 layer + magnetron sputtering of metal layer (Al, Au)*** **-**Surcotec, Geneva, Switzerland
- ***Total reflectance*** of Al and Au coating on optical moldable silicone are quite closely matching pure metal spectra

SILASTIC™ MS-2002 WHITE REFLECTING MOLDABLE SILICONE







SILASTIC™ MS-2002	
Mixing ratio	1:1
Viscosity mix A+B (1 sec^{-1} ; 25°C, mPa*s)	650,000
SG (g/ml)	1.44
Refractive index (@633 nm)	NA
Abbe number	NA
Light reflectance (thick.=3mm)	97%R (450 nm) 99%R (630 nm)
Hardness (Shore A)	**84**
Tensile strength (Mpa)	8.6
Elongation (%)	86
CTE (ppm/°C)	210
Pot life (hrs, 2X viscosity @25°C)	48

CONCLUSIONS

- Moldable optical silicones and optical encapsulants from Dow continue to enable innovation in exterior and interior automotive lighting
- A dedicated multi-expertise's technical and commercial team continue to serve customers in the field
- Your new design ideas are continuously welcome to challenge our curiosity and leadership in developing new solutions

DOWSIL™

SILASTIC™
silicone elastomers by DOW

THANK YOU

S2D 93535/E27541 Form No. 11-3976-01 A

Seek

Together™