Enhanced design freedom and superior performance – Dow Optical Silicones

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Intelligent Automotive Lighting 2018

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Dow Performance Silicones - Lighting

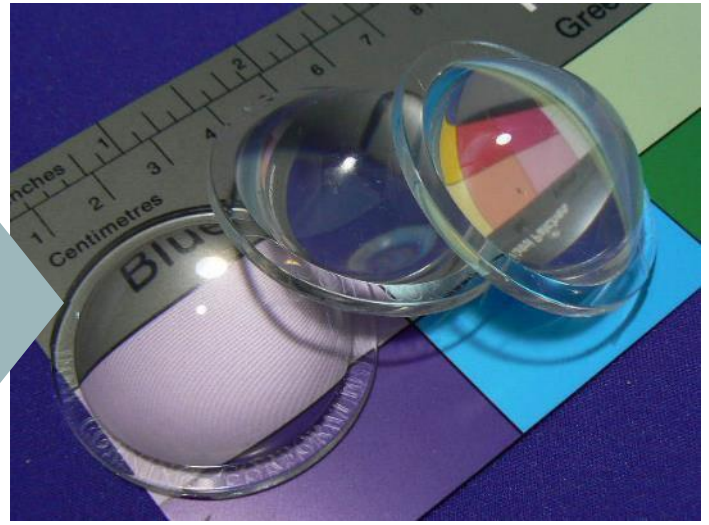
Outline

- **What are Silicones?**
  - Compare to Different Optical Materials
- **Quick Look**
  - Dow Product Portfolio for Transportation Lighting
- **Case Studies**
  - Enabling Performance & Design

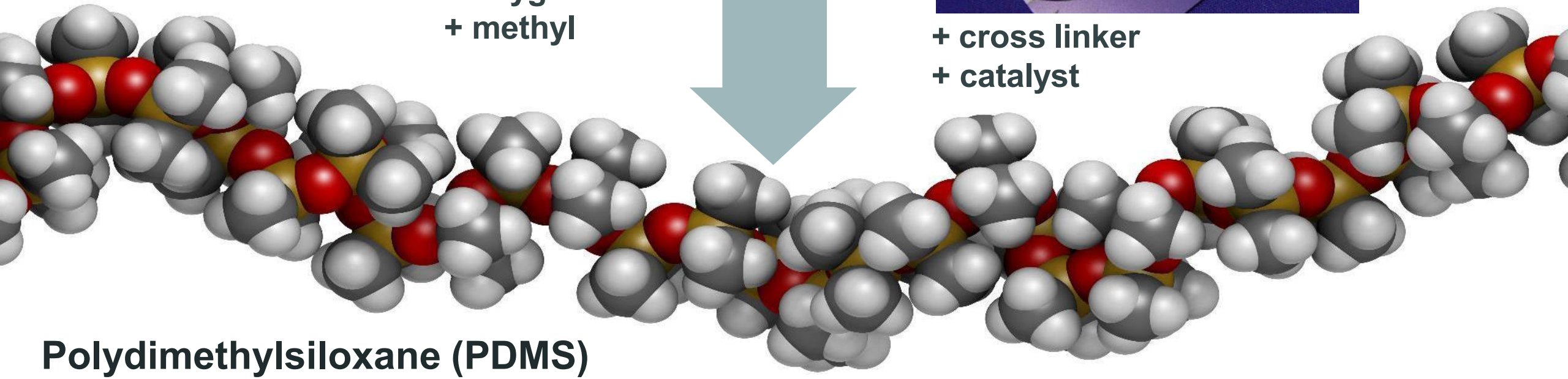
Silicones

Si

+ oxygen
+ methyl



+ cross linker
+ catalyst



Polydimethylsiloxane (PDMS)

Silicones Versus Glass and Plastic

	Dow Moldable Optical Silicone	Glass	PC	PMMA
Initial Physical Form (@ 25°C)	Liquid	Solid	Solid	Solid
Processing Temperature (°C)	15 - 25	1500	280-320	250
Molding Temperature (°C)	125 - 180	600 (tin bath)	90 - 120	60 - 80
Refractive Index (n @ 633nm)	1.42	1.52	1.58	1.49
Thermo-Optical Coefficient (dn/dT)	-3.2×10^{-4}	ca. 2×10^{-6}	-1.07×10^{-4}	-1.1×10^{-4}
Light Transmission (%)	94	91	89	93
Abbe number	ca. 50		ca. 30	ca. 57
Max Service T (°C)	150	>200	120	90
Glass Transition Temperature, Tg (°C)	ca. -104	ca. +600	ca. +145	ca. +120
Specific Gravity (g/cm^3)	1.02 – 1.08	2.5	1.2	1.2
CTE (ppm/°C)	250-325	10	65	72

What unique capabilities do these properties enable?

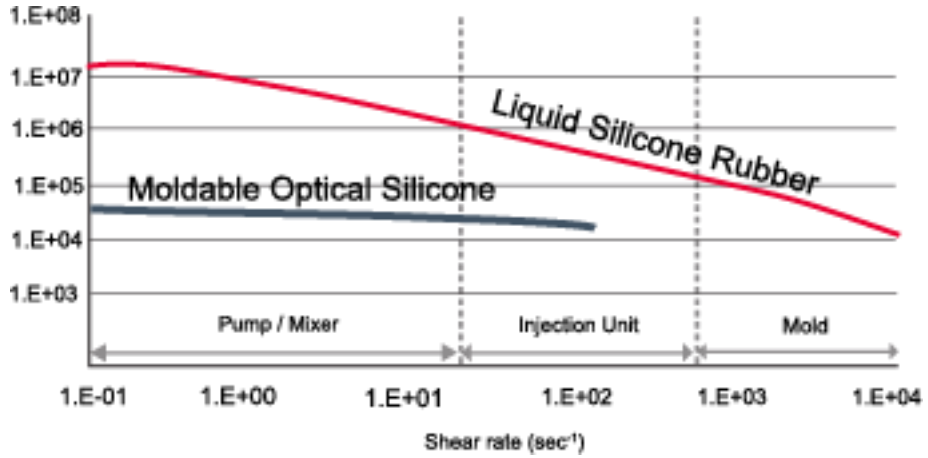
Molding and Mechanical Properties

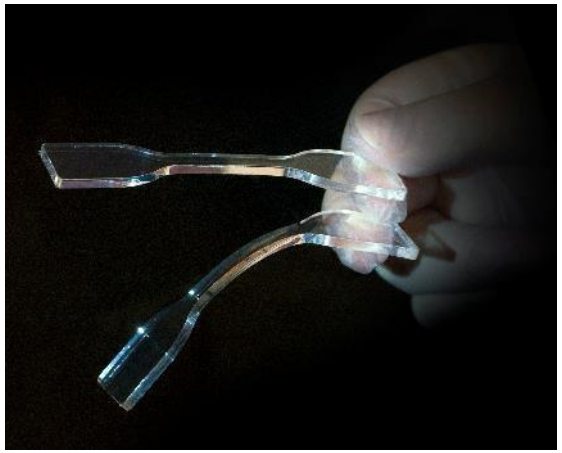
Efficient Injection Molding

- 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
- Minimal compression set → high IP ratings luminaires





Optical Properties and Reliability

Excellent Optical Clarity

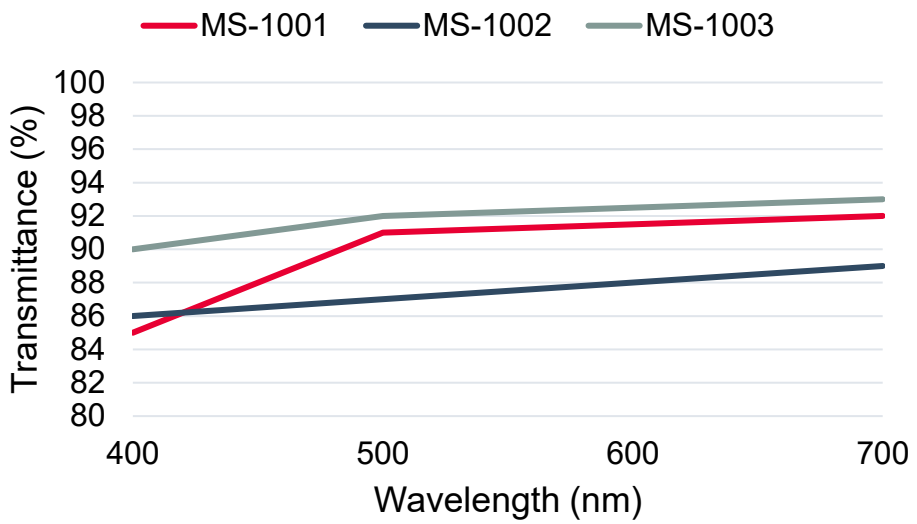
- Select optical grade to meet application requirements

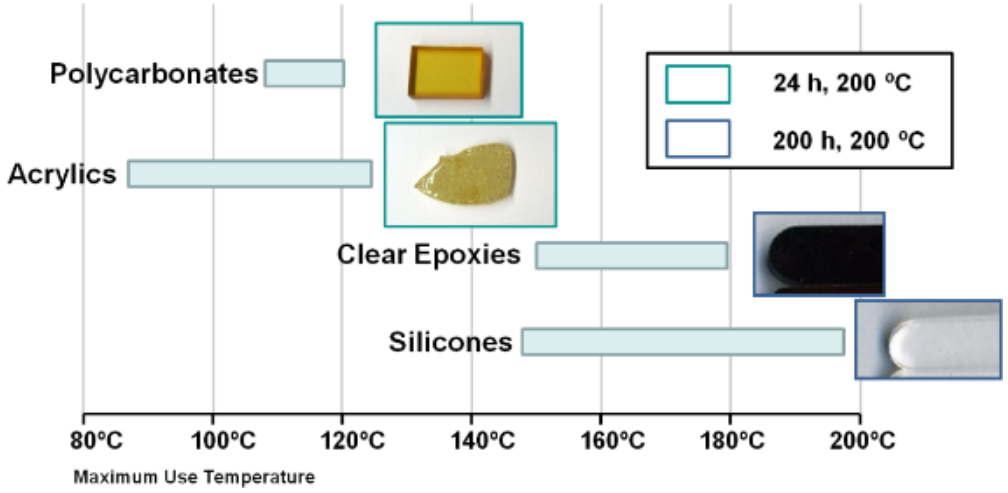
Also, High Optical Reflectivity

- Diffuse and specular reflectivity

Reliable in Extreme Conditions

- Robust to thermal and hydrothermal aging





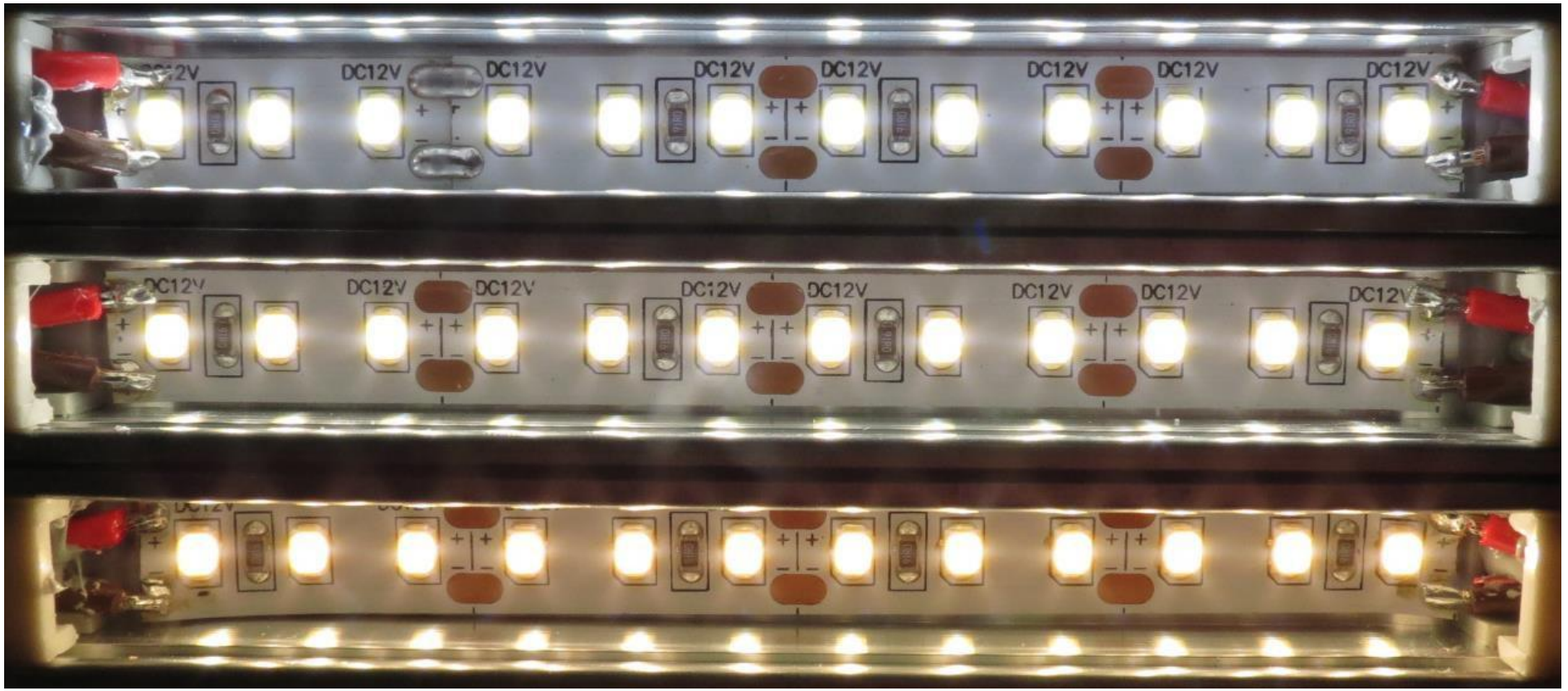
Performance and Design Impact

- Encapsulation of LEDs for protection
- Moldable Optical silicones for design freedom
- Thin and flexible light guide for new illumination concepts

Protect Materials Over LEDs

and Associated Optical Effects

Protection and Performance

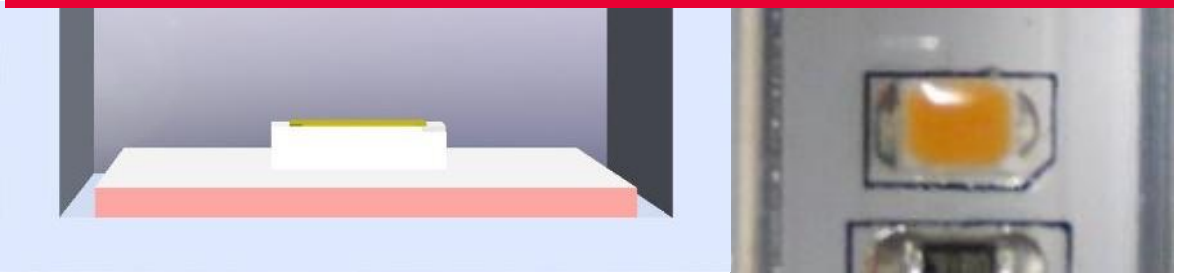


Can we protect LEDs and preserve optical performance?

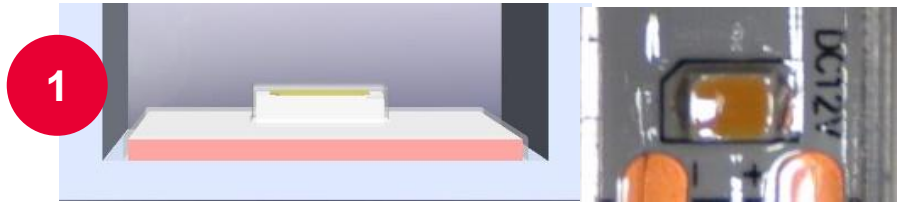
Protection Options

- **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

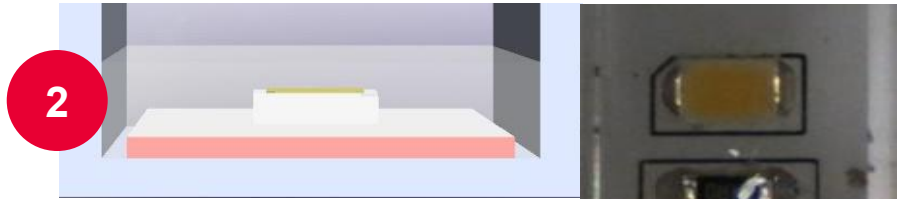
4000K Test part, no material (Optical simulation)



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



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

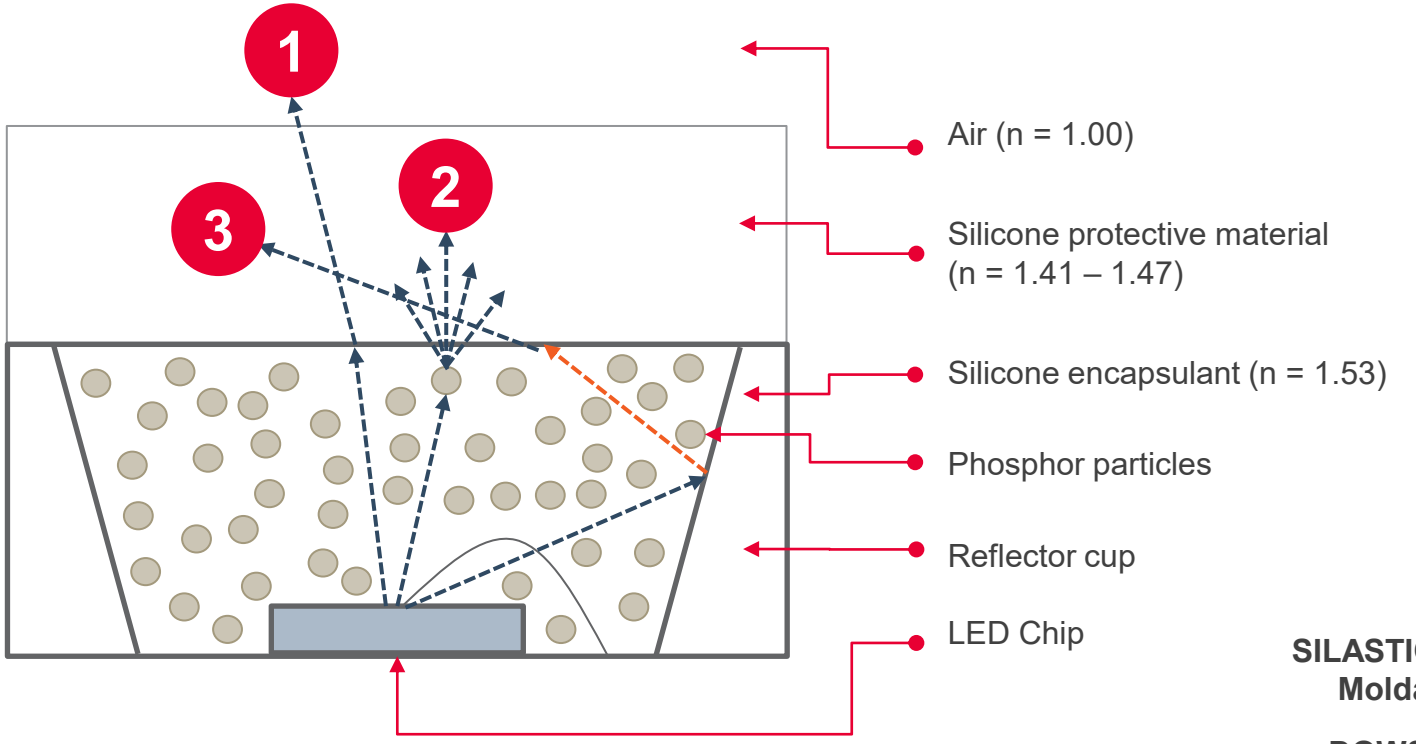


4000K Test part with SILASTIC™ MS-1002 Moldable Optical Silicone

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

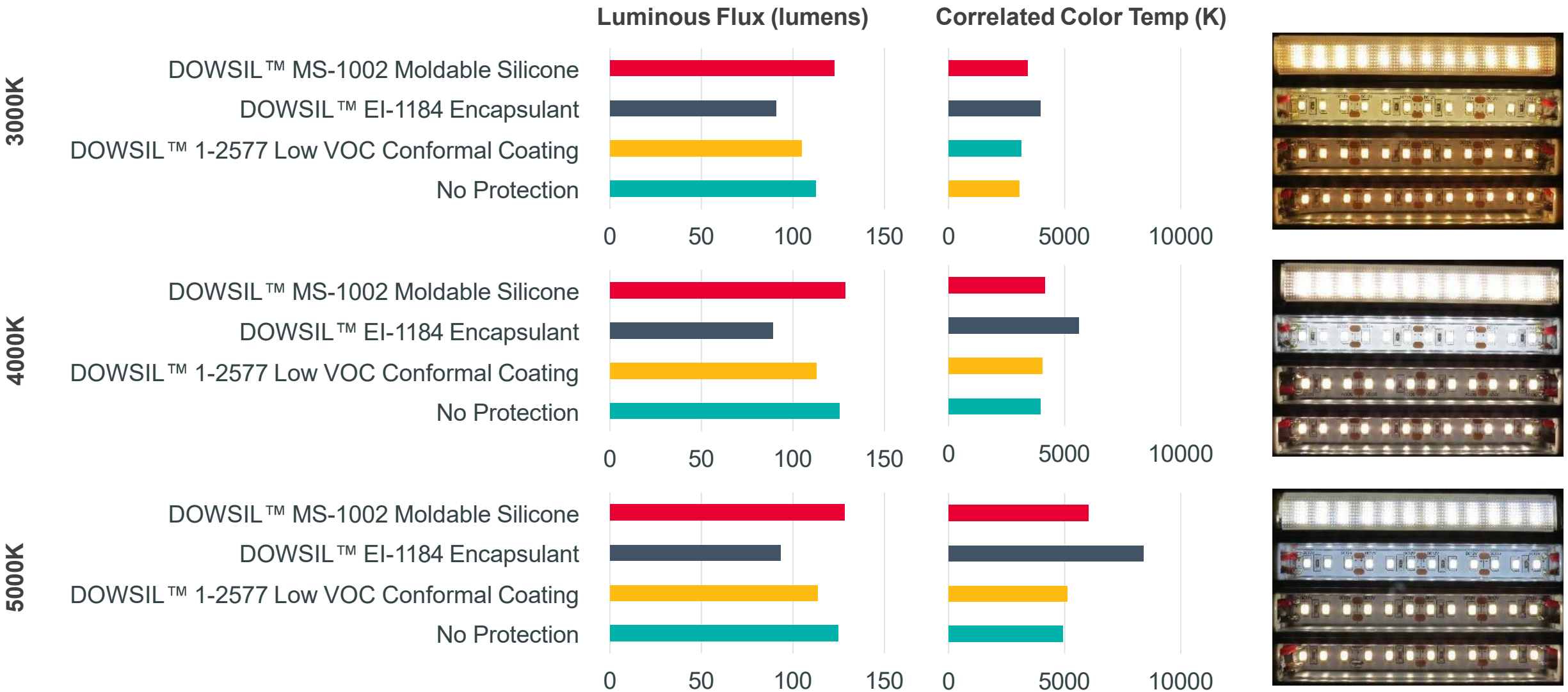
SILASTIC™ MS-1002
Moldable Silicone

DOWSIL™ EI-1184
Encapsulant

DOWSIL™ 1-2577
Low VOC Conformal Coating

No Protection

Optical Influence



Protective Material

- **DOWSIL™ 1-2577 Low VOC Conformal Coating**
  - Minimally effects Luminous Flux and CCT
    - But, provides the least amount of protection above bare components
- **DOWSIL™ EI-1184 Optical Encapsulant**
  - Provides significant protection above bare components
    - But, reduces Luminous Flux and increases CCT
- **DOWSIL™ MS-1002 Moldable Silicone**
  - Slightly increases Luminous Flux and CCT
    - And, provides significant protection above bare components

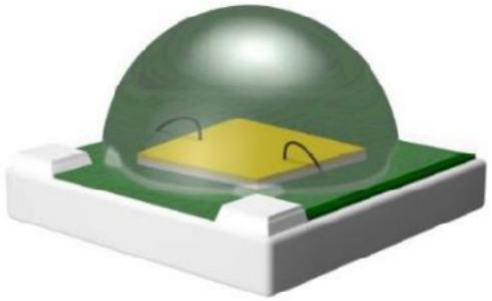
Moldable Optical Silicones

and Design Freedom

Moldable Optical Silicones Trends and Opportunities

Incandescent
ca. 1900-2000 AD

A Lighting Revolution



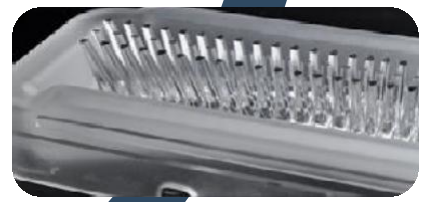
Modern LED
ca. 2000-Today

Performance Silicones Opportunities

Specialty Applications
PHILIPS Deep UV Disinfection

Outdoor Lighting VS Lighting
M-Class Outdoor Lighting Module

Headlamp Assembly
HELLA KGaA Hueck & Co.
Matrix LED Module



Market Trends

- High Power, High Efficiency
- LED Roadway Lighting
- Adaptive Headlights

Product Trends

- High Photo/Thermal Stability
- Environmental Stability
- Design Flexibility

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
- Low haze and scatter

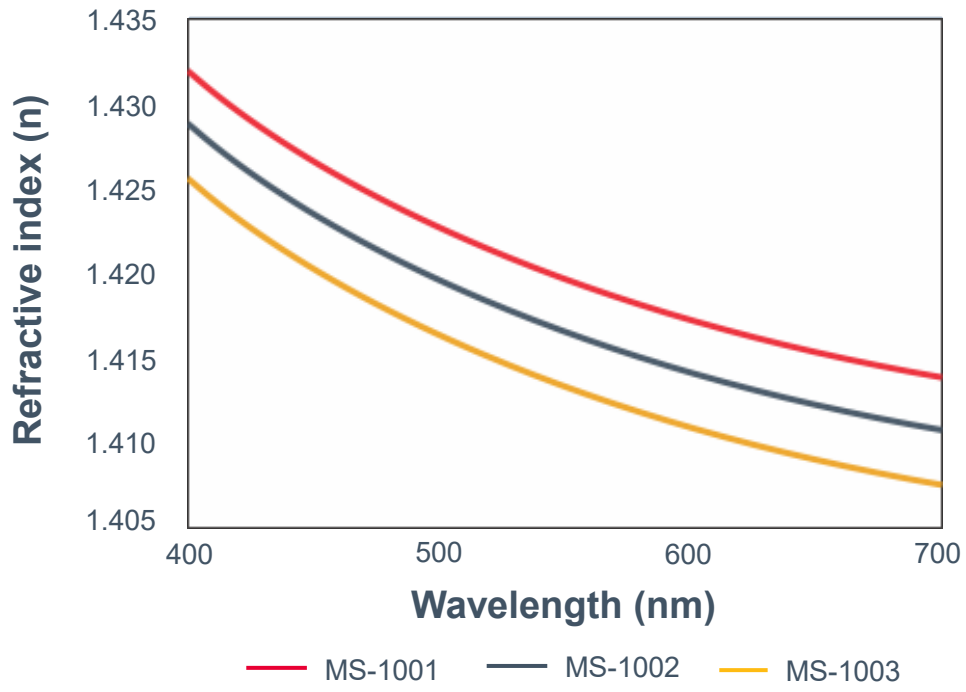
Diverse Properties Enable Unique Designs

Property	SILASTIC™ MS-1003 Silicone	SILASTIC™ MS-1002 Silicone
Viscosity, Part A (Pa-sec)	52	40
Viscosity, Part B (Pa-sec)	37.5	18
Viscosity, Mixed (Pa-sec)	42.3	26.3
Specific Gravity	1.05	1.07
Durometer (Shore A)	51	72
Tensile Strength (MPa)	5.5	11.2
Elongation at Break (%)	325	80
Linear CTE (by TMA) (ppm/˚C)	325	275

For complete data sheet, visit dow.com

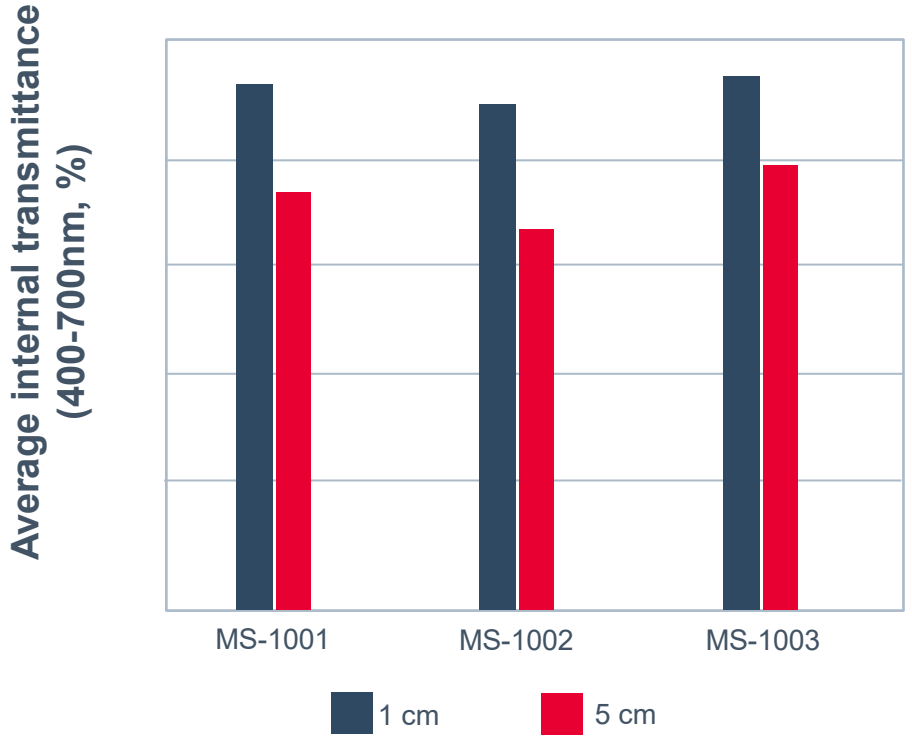
Optical Properties

Refractive Index VS. Wavelength



Internal Transmittance

(Average 400-700 nm)



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

Full optical data sets available upon request for simulation

HELLA KGAA Hueck and Co.

Adaptive Headlamps

High Complexity Headlamp Module

- Silicone light guides
- Acrylic lens'

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.

Image courtesy of HELLA

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.

Image courtesy of Daimler AG

Circuit board with 84 LED chips (mounted individually) integrated in control unit with heat sink

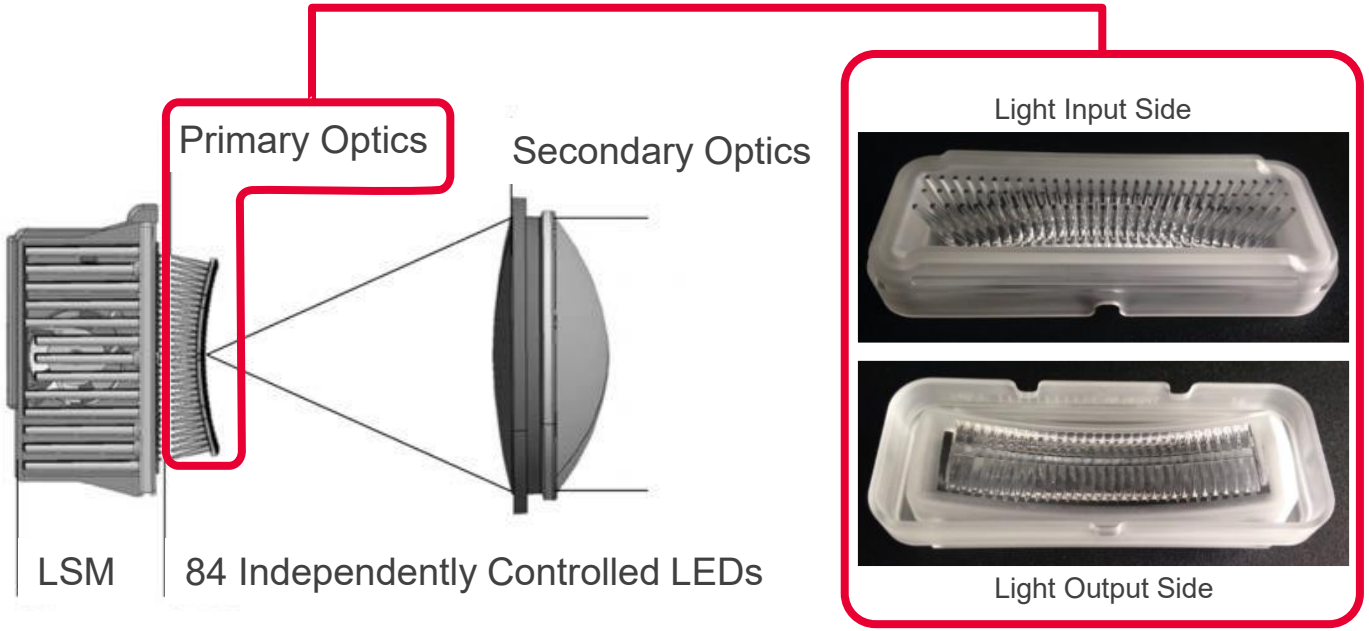
Primary optics (silicone)

Secondary optics (PMMA lens)

Design implementation of the precision LED grid module – all components have clear interfaces defined with very small tolerances.

Benefits of SILASTIC™ MS-1002 Moldable Optical Silicone

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



SoundOff Signal

Emergency Vehicle Light

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

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.

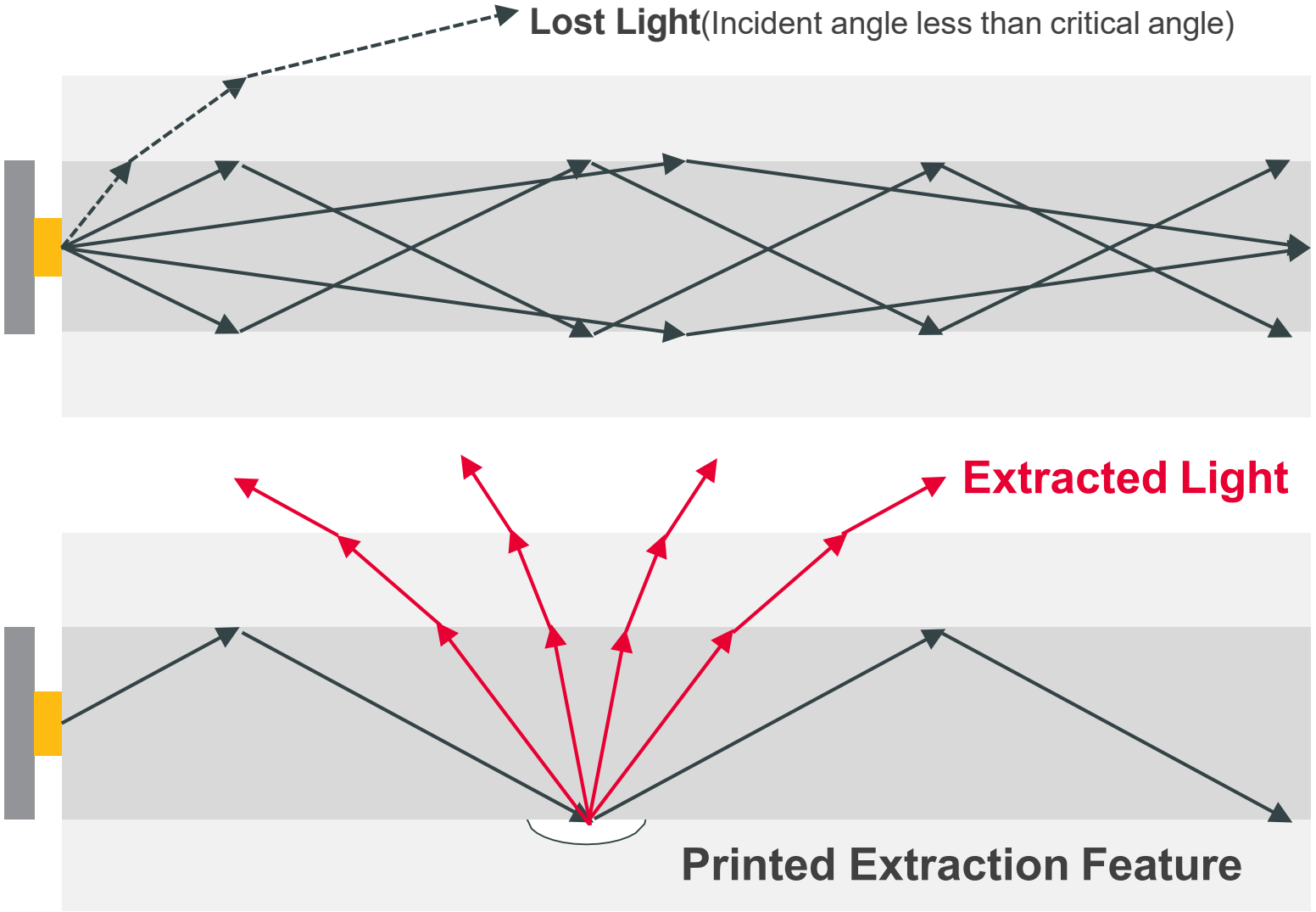
Flexible Light Guide Films

New Illumination Concepts

Flexible Silicone Light Guide Concept

How thin?
How flexible?
How clear?
How useful?

Flexible Silicone Light Guide Concept



Propagating Light
(Total Internal Reflection)

Thin Benefit

- Smaller extraction features
- Reduced design profile

Thin Challenges

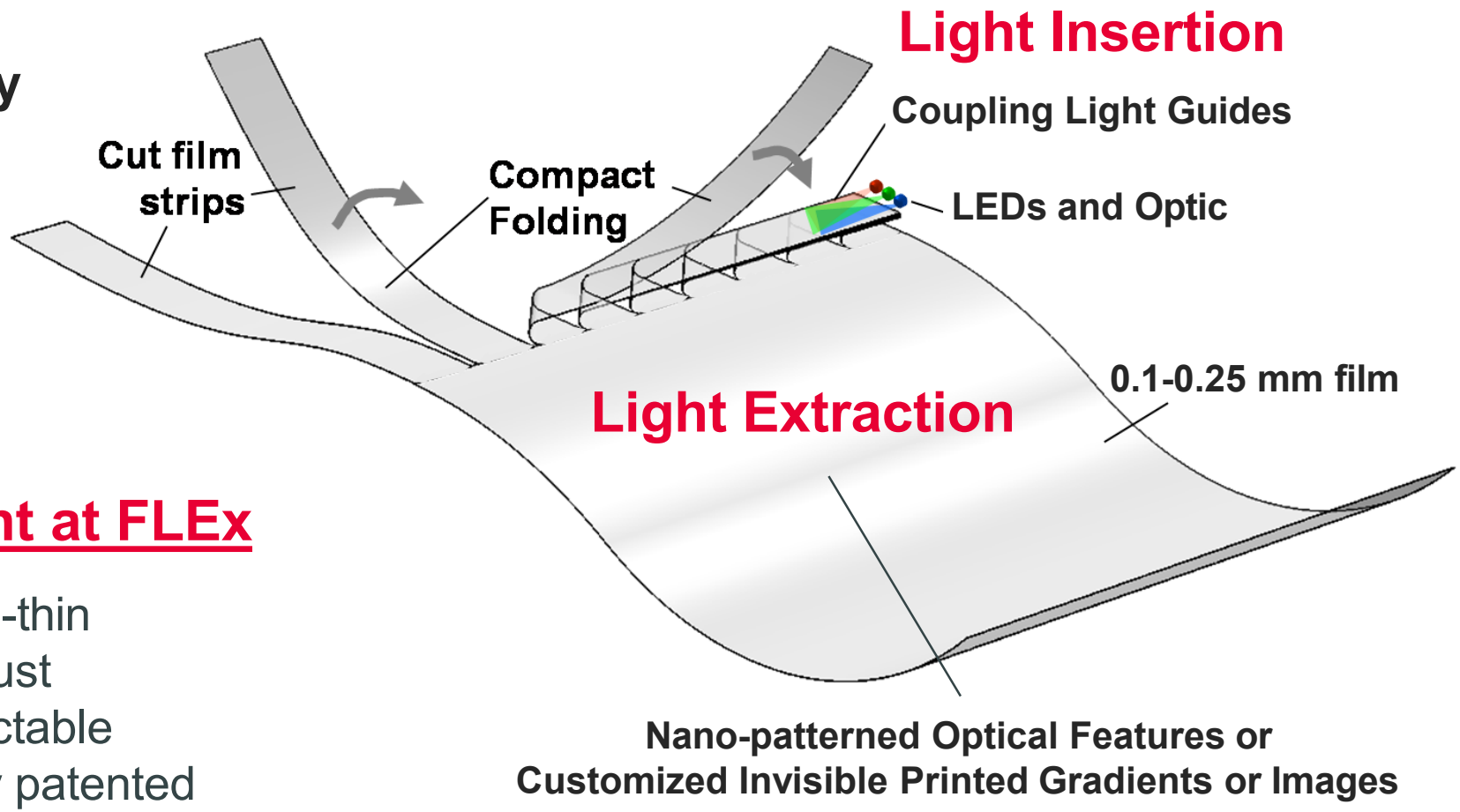
- Light coupling from LED

FLEx Lighting Control of Light in Thin Films

In collaboration with:
FLEx Lighting II, LLC.

FLEx Lighting Technology

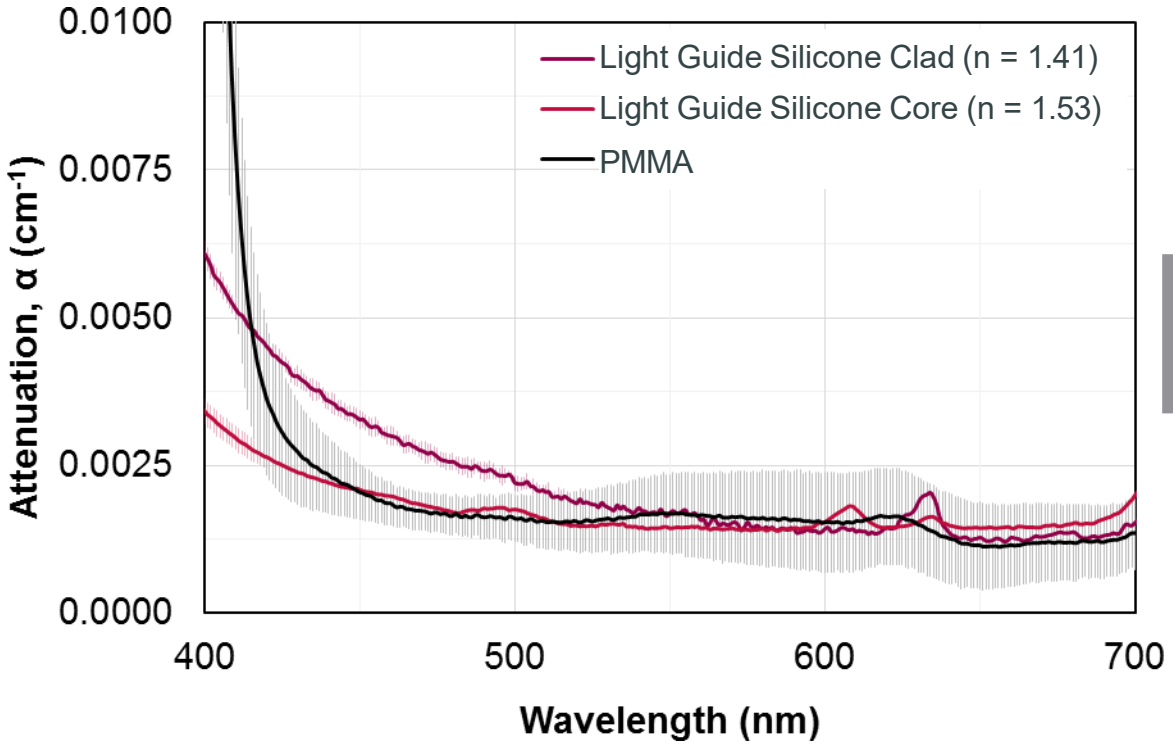
Drive LED light into thin films and then **selectively direct it as a lighting source** with great efficiency and control.

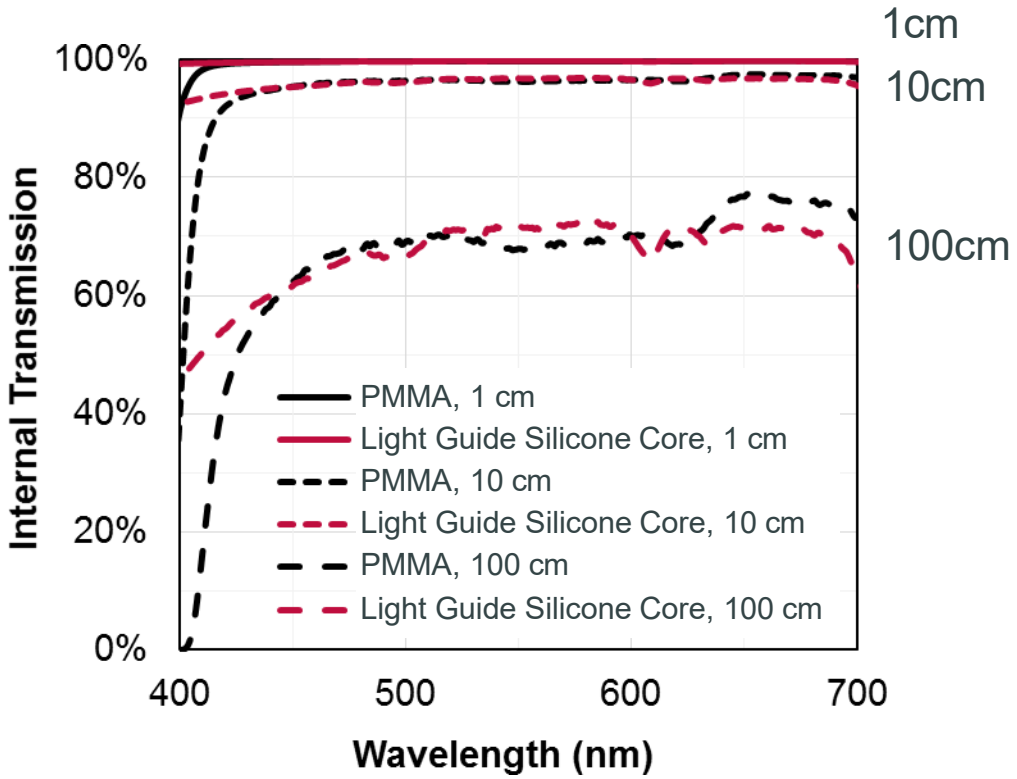


10 Years of Development at FLEx

- Power efficient
- Cost reduced
- Flexible
- Uniform
- Ultra-thin
- Robust
- Directable
- Fully patented

Optical Properties





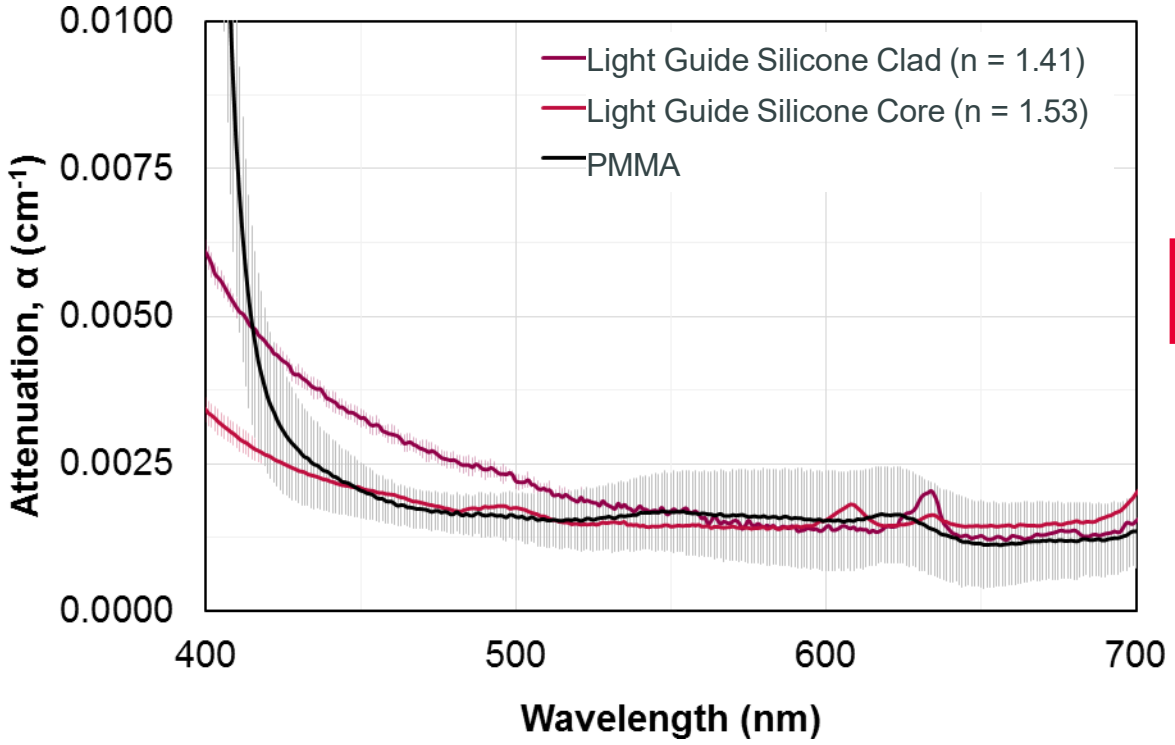
Internal Transmission = $10^{-\alpha z}$

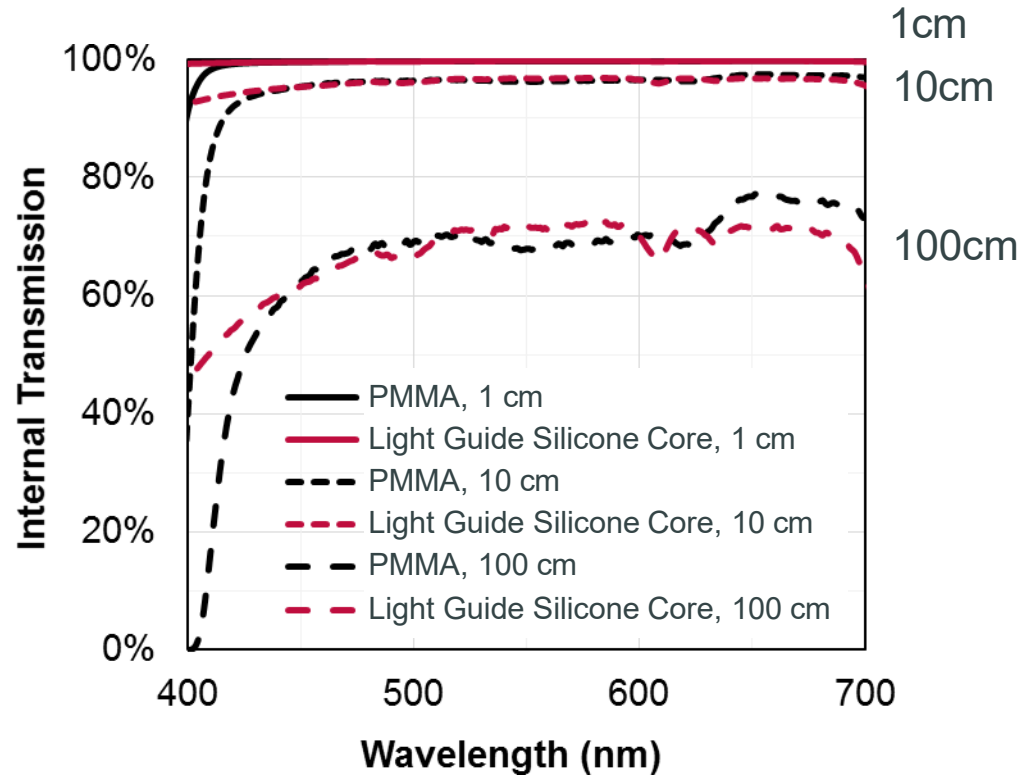
α = attenuation coefficient

z = propagation length

Balanced Transmission between 400-700nm

Optical Properties





Internal Transmission = $10^{-\alpha z}$

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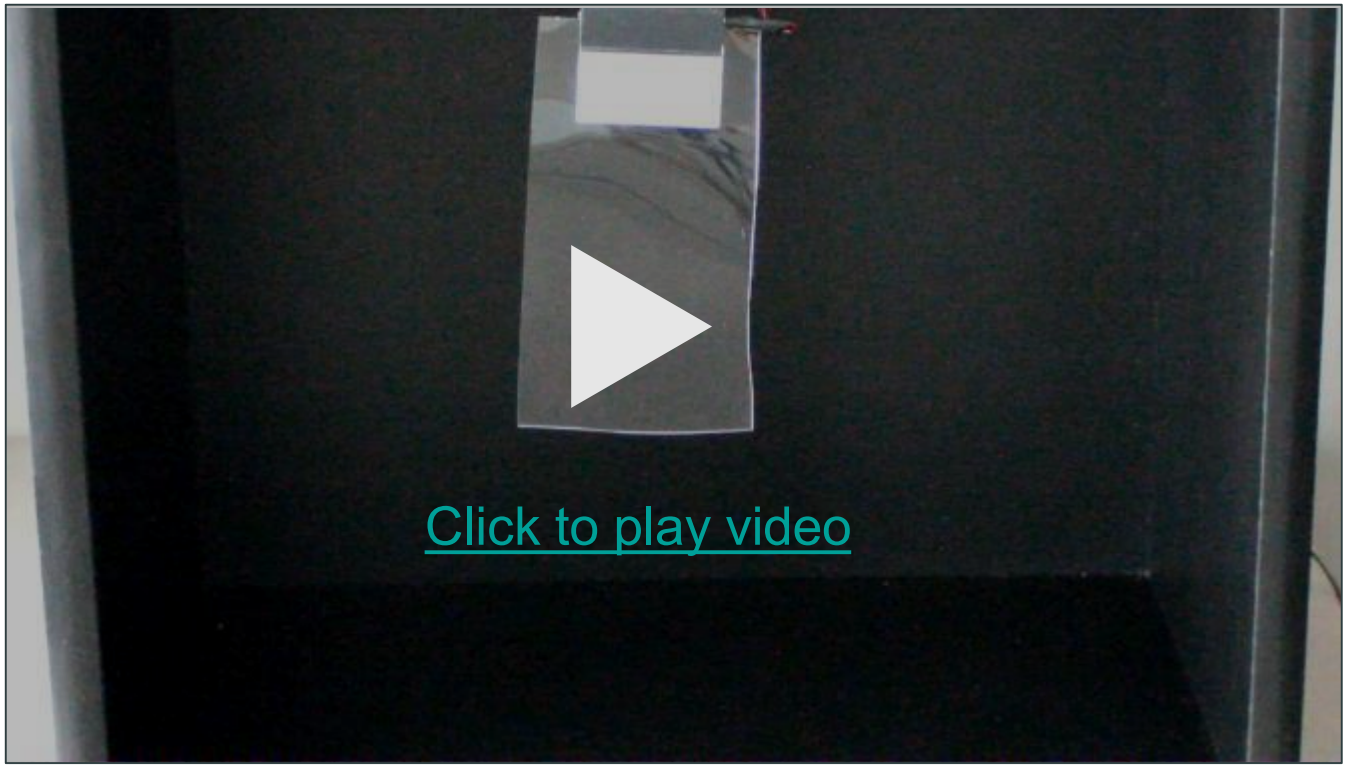
Balanced Transmission between 400-700nm

Flexible Silicone Light Guide Demo Video

Flexible. Thin. Brilliant.

- Optical Performance Achieved
- Optical Coupling Demonstrated
- Large Scale Film Production
- Prototyping Options Available



Summary

- **Creative transportation lighting concepts require new optical materials & products**
- **New optical silicones from Dow enable performance and design freedom**

We look forward to innovating with you!

For more information, go to **dow.com/lighting**

Thank You

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Together™