# Moldable silicones for secondary optics applications



# Learn more

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S2D 91376/E26584

Form No. 11-3371-01 C

# Advantages of silicone

Consider the advantages of using silicone in lighting applications compared with other optical materials:

- High photo-thermal stability results in very low to no yellowing at operating temperatures and high lumen density.
- UV resistance allows for reliability over time for outdoor applications.
- High transmittance enables low loss optical systems.
- Thermal and moisture resistance enhance reliability and protection of sensitive electronic components.

### Benefits of moldable optical silicones

Count on moldable silicones to enhance your optical applications:

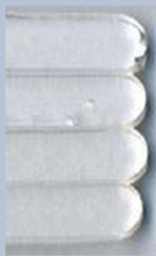
- Lighter than glass.
- Accurate reproducibility of detailed shapes and features, such as optical surfaces, sharp edges and small radii.
- Enables challenging mechanical designs with undercuts and without draft angles, and allows integration of additional functionalities such as gaskets.
- Allows optical designs with large differences in wall thickness.
- Ease of processing enables lower total cost of ownership.
- Process advantages for large optical components, such as lens arrays and thick lenses.
- Better heat resistance than plastic.
- Less yellowing than some plastic.

## Thermal aging test

This test shows a methyl silicone compared to an epoxy at a 4 mm thickness and aged for 200 hours.

Epoxy

Methyl silicone



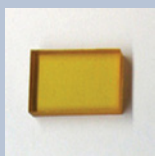
## Materials

These are typical organic materials used for optical systems in lamps, luminaires and silicone resin aged at 200°C for 24 hours.

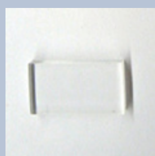
Polycarbonate

Cyclo-olefin Coplymer

Acrylic



Silicone resin



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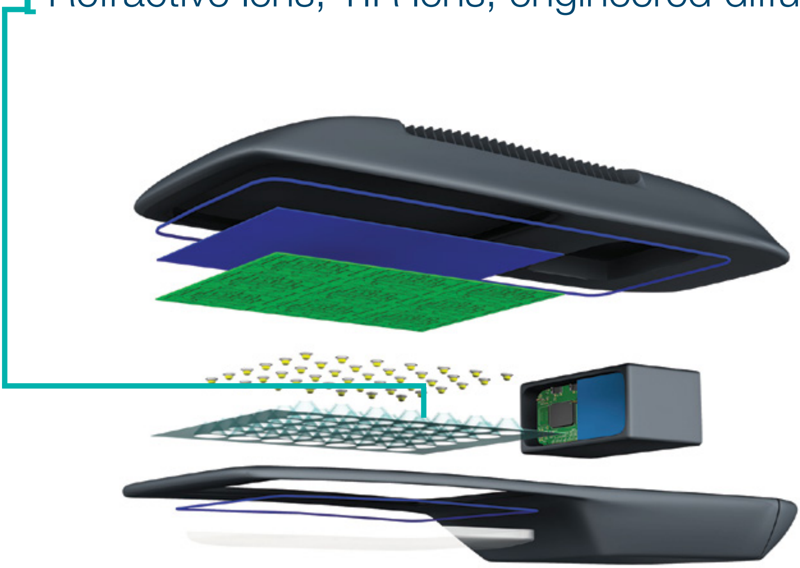
# LED luminaires

## Secondary optics

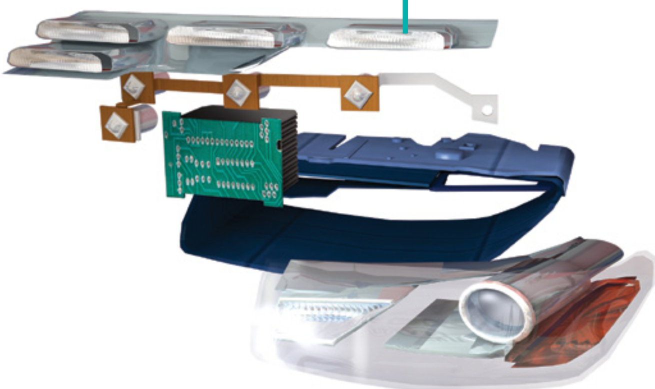
[ Refractive lens, TIR lens, engineered diffusers ]



# LED headlamp assembly

## Secondary optics

[ TIR lens, lilght guides, engineered diffusers ]





# LED Innovation ecosystem for lighting applications

Our LED lamp and luminaire customers gain the support of the Dow Consumer Solutions LED Innovation Ecosystem.

Extending from Europe to Asia to the Americas, this broad and growing global network spans the entire LED value chain. It encompasses dozens of optical and LED component designers and manufacturers, enabling customers to leverage the power of industry-leading silicone technology and navigate their LED lamp and luminaire concept from design, to prototyping to manufacturing – quickly and cost-effectively.

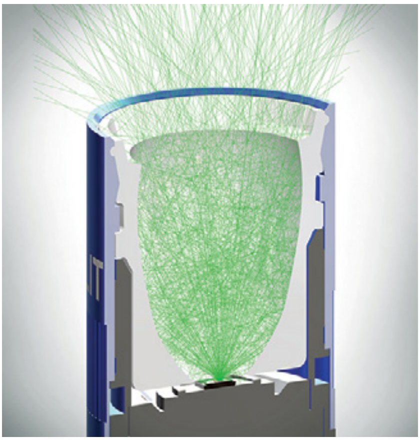
Dow Consumer Solutions’ advanced materials technology and expertise combined with our LED Innovation Ecosystem offer you a true total solutions package to advance and enhance your applications with services, such as:

- Material development
- Analytical testing
- Optical design
- Application development
- Prototyping
- In-house molding expertise and equipment

In addition to all this, Dow Consumer Solutions customers also gain the support of our extensive global network of equipment manufacturers, distributors and specialty re-packagers. Together, this broad array of internal resources and external relationships offers the LED industry one of the most comprehensive sources for advanced materials solutions.

Find out how Dow Consumer Solutions can help you break through design and manufacturing barriers to become more competitive, innovative and successful in your target markets. It is as easy as contacting your Dow representative.

# 10° TIR lens



Reflection is that portion of light that bounces back from the surface of a medium. This lens makes use of Total Internal Reflection (TIR), a phenomenon which eliminates light loss during reflection. This phenomenon allows for the formation of narrow beam angles, such as 10°, when using appropriately designed lenses, as shown in the ray trace diagram below.

TIR can be illustrated by using a laser to shine through the lens. As the laser is pointed down the lens, you can see it 'bounce' from the wall of the lens toward the exit face.

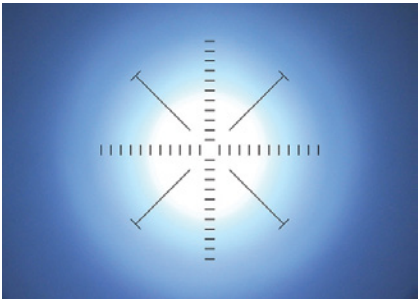
One practical use of this is demonstrated using the 10° TIR lens. Since no light escapes from the sides of the lens, there is no loss of light; such a lens can be more effective than a traditional reflector. Also, the beam can be more accurately controlled to evenly deliver the necessary level of illumination to a specified target area.

## Points to note:

The highly polished exterior surfaces, coupled with the lens shape, produce a TIR optic.

This optic ‘snaps’ into the flashlight cap and replaces a metalized reflector, an end cover, and two O-rings. It is a single part – compared to four parts for a traditional reflector assembly.

Notice the very tight beam and uniform light distribution with neither a halo effect nor striations.



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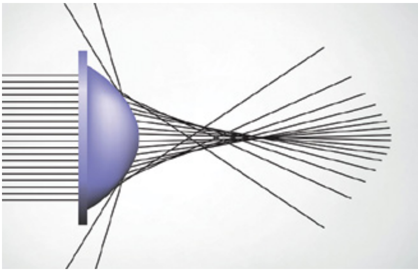
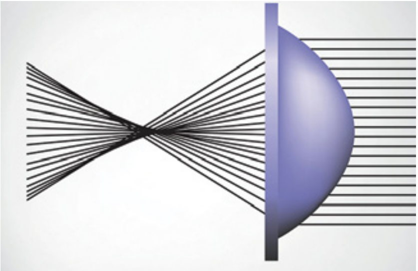
# Aspheric lenses

Aspheric, or non-spherical lenses, are commonly used in imaging optics. Unlike Total Internal Reflection style lenses, this Aspheric optic is designed so the incident light strikes the surfaces at an angle that is less than the critical angle; light will pass from the lens into the air but is bent at the interfaces. By accurately shaping the curve on one side and maintaining a flat surface on the other, this lens will focus incoming light, similar to a magnifying glass.





## Points to note:

- The flat back (no sink) is hard to achieve in plastic. Unlike plastics, it is easy to mold variable (thick and thin) cross-sectional regions with silicone.
- Tight tolerance control, and the high polish give sharp focus.
- Lens focuses light ray into a point, and can be used to start a fire as a magnifying glass does.
- Moldable optical silicones enable fine detail in the writing on the rim.

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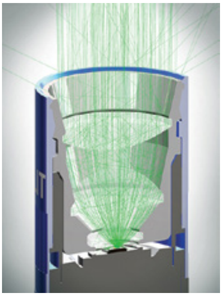
# Long throw collimator

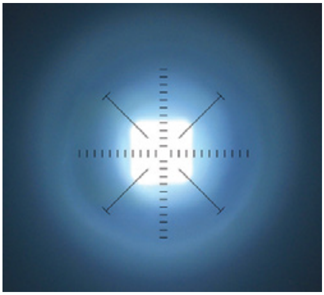
For some applications, it is desirable to project light in a narrow beam or column. This can be accomplished by a variety of devices, such as projecting light through a series of long narrow slits. The problem then is that much of the light is lost due to reflection off the face of the slits, as seen in the diagram below.

Unlike the slit method, the long throw collimator assembly works by using a series of Aspheric lenses to focus the light into the desired path. Individually, the lenses in this design focus the incoming light and, by combining the three lenses, the light rays are merged into roughly parallel beams or columns.

The three lenses are mounted in a reflective housing that further increases the efficiency of the assembly. As a result, the light is projected in a very narrow beam with little stray light escaping the front of the assembly.

## Points to note:





- There are three unique optical lenses utilized.
- Moldable optical silicones enabled complex, yet flexible shapes with undercuts and trapped rings inside the part.
- The complex shape of the reflector results in the mandrel being trapped in material during molding. The material flexibility allows it to be removed from the mold as one part, unlike incumbent materials which may need to be welded together.
- This example combines two materials; the SILASTIC™ MS-1002 Moldable Optical Silicone lenses 'snap' into a SILASTIC™ MS-2002 Moldable Reflective Silicone holder, which snaps into the retaining cap of the flashlight.
- The extremely tight beam projects the image of the LED die.

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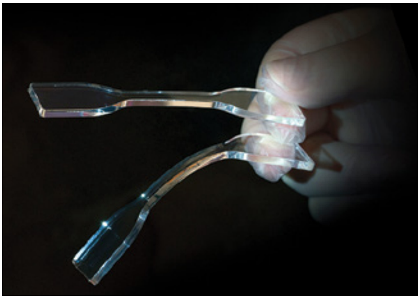
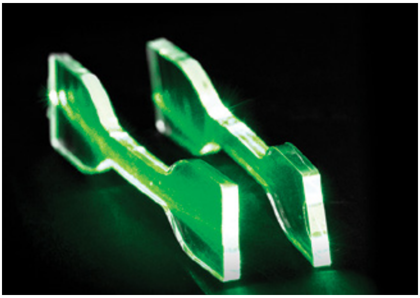
Form No. 11-3371-01 B Insert D

# Tensile bar

This is the traditional shape for ASTM D-412 tensile and elongation testing. In addition, this particular mold is highly polished so it has a good optical surface. Our aging tests are run using this bar for both physical and some optical testing. If held by one end, with the wider surface horizontal, you can readily observe the difference in hardness between the materials. The part made of SILASTIC™ MS-1002 Moldable Silicone will remain nearly horizontal, while the softer SILASTIC™ MS-1003 Moldable Silicone part will droop down. If either bar is rotated with the wider surface to vertical, there will be much less sag observed, even with the narrow neck. This is similar to using thicker ridges in a part to provide stiffening for some designs.





## Points to note:

- Holdpartsbytheendsandnotice the flexibility and rigidity difference in the materials.
- Pullthepartsforstrengthandnotice the difference in elongation (tensile break strength).
- A laser pointer beam can be transmitted through the part.

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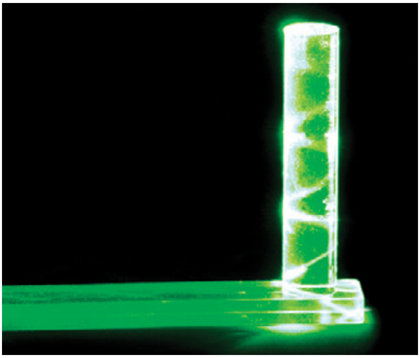
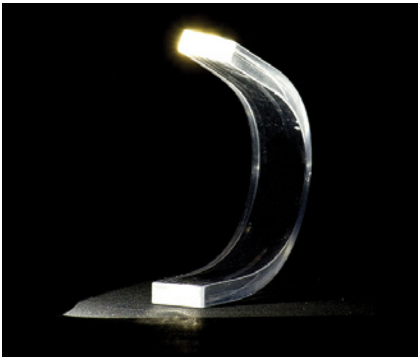
# UL 94 Flame bar





This shape is required for UL 94 flame classification testing. In addition, this particular mold is highly polished so it has a good optical surface. The polished surface and long uniform length of this bar also make it suitable for demonstrating Total Internal Reflection. You can see the light internally reflected in low ambient light by shining a laser pointer in the polished end and varying the angle.

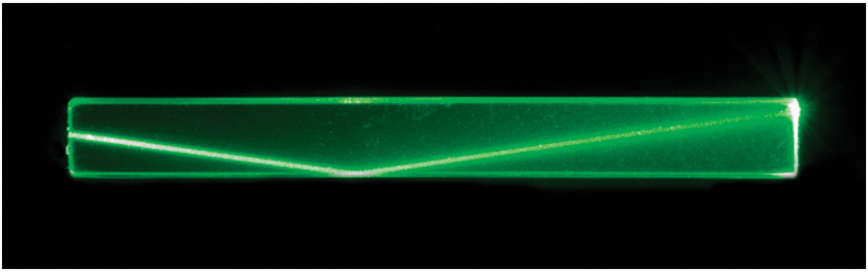
Another interesting demonstration is to hold a light or laser pointer against the end while bending the bar; this forms a basic light guide to change the direction of the light. Light will follow the bar until it is bent sharply enough that the critical angle is reached, at which point light will escape the bend.

Finally, if a laser is placed at the end of the bar, and a light pipe cylinder is stood upright and pressed against it, light can be extracted along the cylinder. This light extraction is useful in some designs and can also be accomplished by roughening the portion of the mold where the light extraction is desired.

## Points to note:

- SILASTIC™ MS-1002 Moldable Silicone has a UL 94 HB at 1 mm and V-1 at 8 mm rating.
- Hold part by one end and note the rigidity along the thickness.
- This part can be used to demonstrate long, flexible light guides (125 mm).
- Light can be bent and directed using a laser on one end.

Learn more



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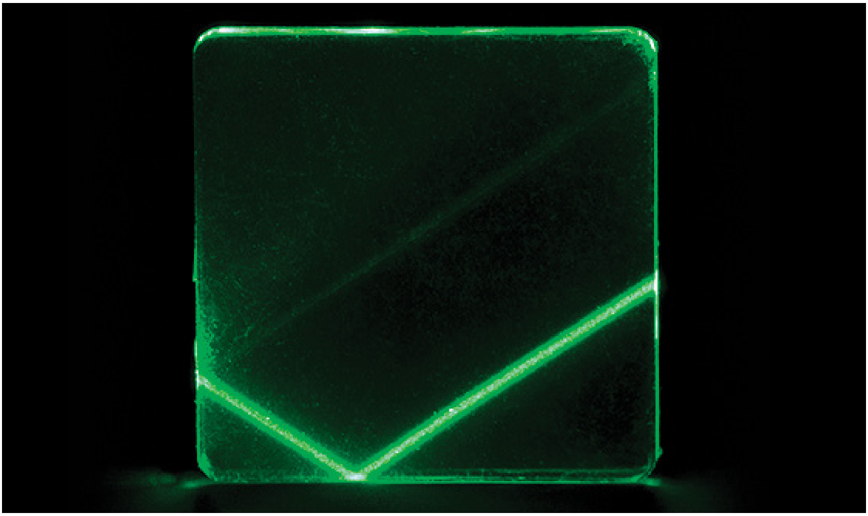
# Optical plaque



This shape was molded in response to requests for a larger and thicker plaque for optical testing. This mold is highly polished so it has a good optical surface; overall dimensions are approximately 50 mm x 50 mm x 4 mm (2 inches x 2 inches x 5/32 inches). The polished surfaces again work well to show internal reflection and can be used to show light extraction.

## Points to note:

- Theopticalgrade,high-polishfinish (SPI A-1) on all surfaces.
- This part will bounce light from nearly every surface as in the image above.

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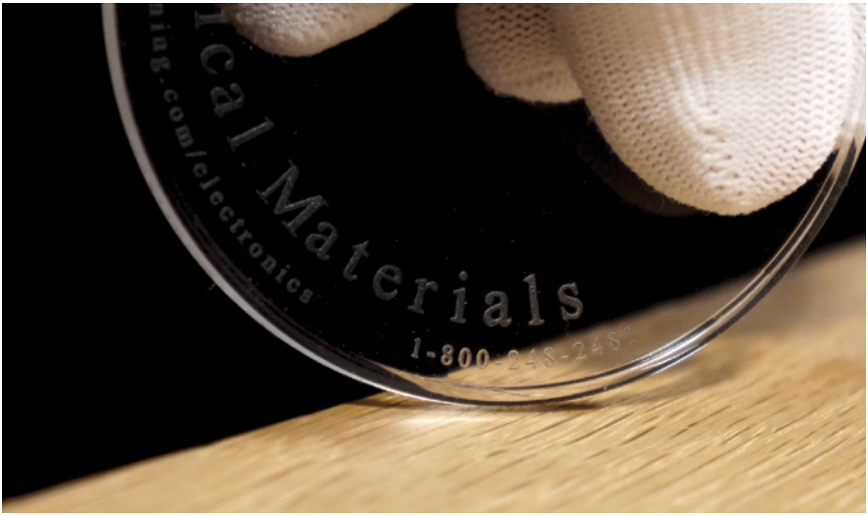
# Coaster




This shape was molded as a promotional item for customer visits. The disc is 68 mm (2.67 inches) in diameter and 3 mm (0.12 inches) thick in the center area. This mold is highly polished so it has a good optical surface and can be used for optical testing. The writing around the perimeter was etched in approximately 0.002” deep and shows how well surface finishes can be reproduced.

## Points to note:

- The optical grade, high-polish finish (SPI A-1) at center of part.
- There is fine detail in writing on the edge.

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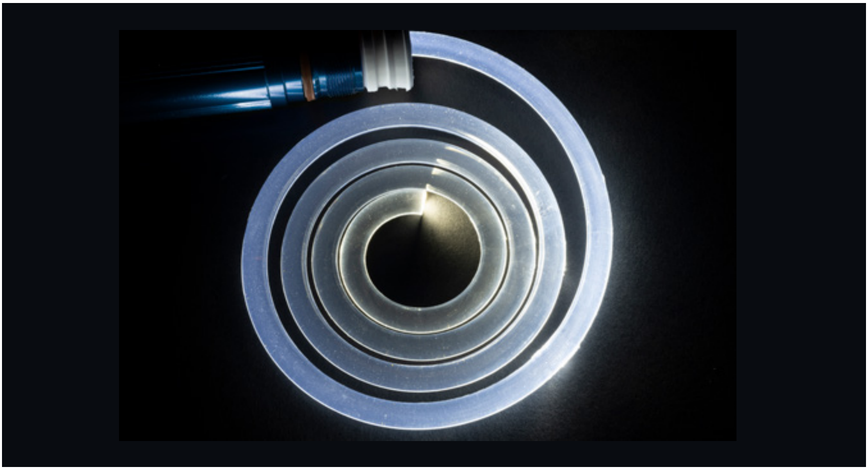
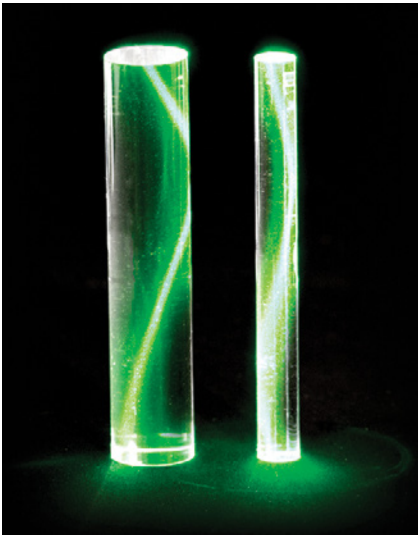
# Light pipes



The light pipes are best used for a simple light guide. They are Ø 5 mm x 50 mm and Ø 10 mm x 50 mm (Ø 0.2 inches x 2 inches and Ø 0.4 inches x 2 inches) with highly polished sides and ends. They are molded at same time in the same mold with equally sized runners and gates. There is no need to balance mold flow here.



## Points to note:

- The light pipes can bend light.
- Demonstrate with a laser or flashlight without cap.
- When two parts are pressed together, the surfaces will provide some optical coupling.

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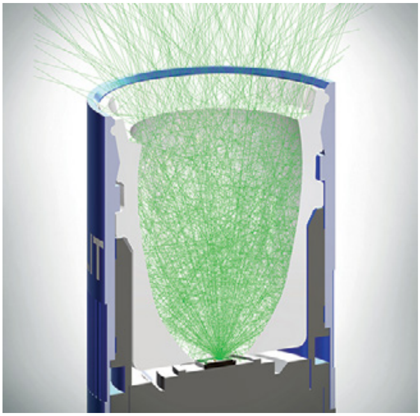
# 40° White reflector

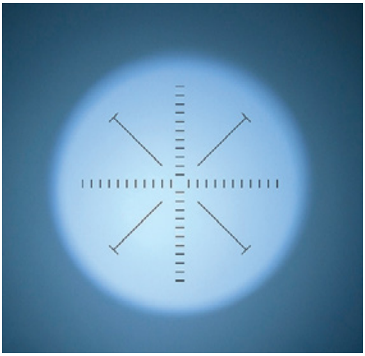
When discussing reflectors, it is common to think of mirrors or polished metal surfaces. These devices, which allow one to see a reflected image, are called specular reflectors. However, when the objective is not to image, but rather to just reflect light, a higher amount of light can actually be reflected from a white surface, which is a diffuse reflector. Diffuse reflection can happen in the volume of the reflector as well as at the surface.



A practical use of this reflective material is shown with the 40° white reflector part. The effect is similar to a Total Internal Reflection lens, but it does not rely entirely on surface reflection to guide the light. The curved shape and lip at the end help reduce stray light outside the desired pattern. This shape, with a negative draft angle, helps achieve a wider beam angle than conventional designs with specular reflectors. Surface patterning is easily accomplished in the mold and can be used to produce more diffuse reflectance.

## Points to note:

- There is even light distribution with no hot spots or halo effect. It's much easier to read text under this light than with the traditional hot center aluminum reflector.
- This part enables higher system efficiency due to higher material reflectivity.
- Silicones enable molding in complex, yet flexible shapes.
- The complex shape of the reflector results in the mandrel being trapped in material during molding. The material flexibility allows it to be removed from the mold as one part, unlike incumbent materials, which may need to be welded together.



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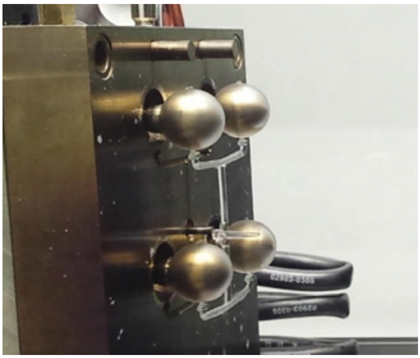
# Small globes

Globes of various sizes and shapes are a common element in lighting designs. Traditionally, these globes were either blow-molded in glass, or could be molded in two halves and glued or welded together out of plastic. With the introduction of moldable silicone optical materials, these types of devices can now be injection-molded in one piece. Additionally, the combination of the injection molding process and the material's ability to reproduce fine features allows for the incorporation of surface patterning or other options. This material gives lighting designers much greater flexibility than traditional methods allow.

These globes take advantage of the elasticity and toughness of moldable silicones. They are molded in one piece over a mandrel, in a closed injection mold. After curing, the mold is opened and the globes are removed from the mandrel, by stretching with air pressure to 'pop' off. In fact, some are stretched more than the elongation value shown on the product data sheet, but return to the cured shape after de-molding. This is possible since the parts have not yet been post-cured to their ultimate hardness.



There are several different mandrels used for the interior of these globes; wall thickness varies from the neck to the tip. Much like metals can be made in wide flats for springs, or shaped as an I-beam for structural support, the variable cross section dramatically alters the feel of these globes.

## Points to note:

- Globes are molded in one piece, whereas plastic would be made in two pieces and glued or welded together.
- Stiffness variation exists between parts; squeeze the bulbs and note the stiffness variation with thickness.
- Globes have a polished interior with a diffuse or matte finish (bead blast) exterior.
- Other features or structures could easily be reproduced in the part.

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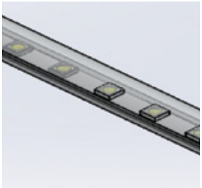
Images: adobe_2708674, dow_40491414957, dow_40491414442

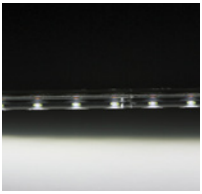


S2D 91376/E26584

Form No. 11-3371-01 B Insert L

# Modular optics





For some applications, very long, thin optics are desired. In plastics, these can sometimes be created through extrusion processing. Current moldable silicones, however, are not suitable for running in this traditional extrusion process. Additionally, the extrusion process limits designers to 2D shapes only. Highly polished surfaces, features, corners, ends or other stops, 3D lenses, etc. are not possible without additional processes.

Modular optics were designed to present a possible solution for applications which need long optical parts. There are two sets of parts included to show this concept, one with rounded end couplers and the other with dove tails. These parts take advantage of several properties of moldable silicones. Firstly, since the material is flexible, parts are made to snap together at the ends. Additionally, in the rounded coupler design, a pair of slots also allows them to be snapped over an LED strip without additional mounting features. Secondly, moldable silicones have the ability to wet to each other, conforming together to eliminate air gaps.

This wetting reduces reflection losses at the interface, so optical output does not have shadows or bright spots. The rounded coupler sample is linear to fit on an LED strip. The dove tail coupler could also be designed and molded with angles, crosses and splits, and the part could be end-lit and include extraction features at various points as desired. Optionally, a drop of curable material can also be put in the joint to prevent disassembly and make an even more robust joint.

## Points to note:

- Parts slip together and snap onto LED strips; no additional mounting is needed.
- Complex cross sections can be very accurately produced.
- Features for light extraction, diffusion, etc. can be molded where needed; they don't need to be continuous as they would with an extrusion.
- Overmolding or co-molding with white reflective material is possible to increase design flexibility and reduce processing costs.

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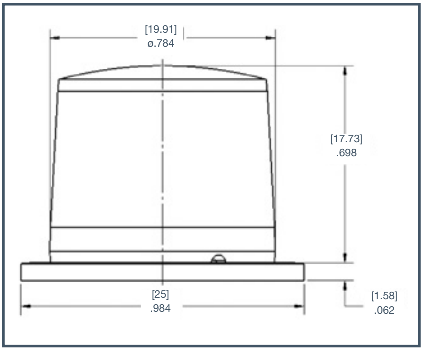
S2D 91376/E26584 Form No. 11-3371-01 C Insert M

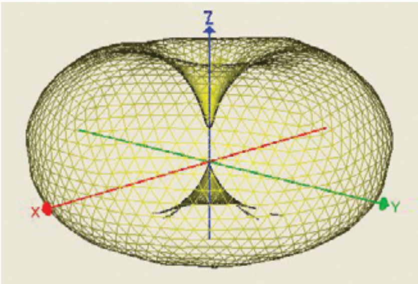
# Mini HEOC

The High Efficiency Optical Coupler (HEOC) is a patented design created to convert an LED point source to a distributed source, similar to an incandescent bulb.

The design of the HEOC utilizes two moldable optical materials that are overmolded to produce the single part.



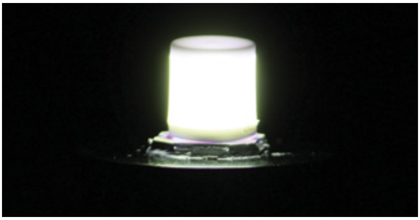

HEOC

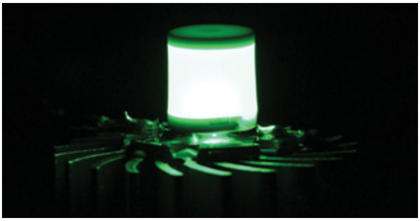



HEOC pattern

The top and bottom white reflective parts are molded first. These parts are then set into a second mold and the center clear section is injected between them and cured. The complete part is then post-cured and the resulting assembly has a robust interface without a need for additional adhesive.

In high volume production, a rotating mold and second injection unit could be added to the press to allow co-molding of the part. This process would eliminate the handling of the top and bottom reflector needed in the overmolding process used to create these sample parts.





The sample HEOC is created with a clear center portion. In its production form, the center section could include phosphor and utilize a blue LED to produce a variety of emission outputs. This alternative allows the single design to produce warm white light, cool white light, daylight, or a specialized grow or biologic spectra from the same LED electronics, or molds by varying the phosphor used.

## Points to note:

- This is an overmolded part—no adhesive is used for assembly.
- Productionpartscouldincludedifferentphosphorstoproducevaryingspectrafrom a standard platform.
- Light output is omni-directional.
- The bottom reflector has a small groove in its base for adhesive attachment to the board.

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S2D 91376/E26584

Form No. 11-3371-01 B Insert N



# Flashlight end caps

One of the benefits of using SILASTIC™ Moldable Optical Silicones is the ability to reproduce fine detail from the molds. There are many optical reasons for adding texture to a component, and there are a wide variety of surface finishes or textures that are available from different companies that can be incorporated in a part. Texture is often used simply to improve the tactile feel of a part, or to increase moldability, by having the part remain selectively on one side of the mold. For our discussion, we are more concerned with the way surface finish can affect light transmission through the piece.

Patterns provided by LumenFlow Corp. and Holo-Source.

The first end cap above (Figure 1) is highly polished. Light transmission losses through this cover cap are mainly due to surface reflection effects on each side of the part.

Figure 1

Figure 2

Figure 3

Figure 4

The next cap (Figure 2) has been surface blasted with 3 mil glass beads. This process produces a matte surface that provides diffusion of the light with only a small amount of transmission loss.

The third end cap (Figure 3) reproduces chemically etched square grid diffusion type structures. This process and corresponding surface produces a similar diffusion of light as compared to the bead-blasted surface. The structures are about 75 microns (0.003”) deep.

The fourth end cap (Figure 4) is a somewhat more complicated surface. The pattern placed in the mold is a set of flakes or chips which have grooves across each of them.

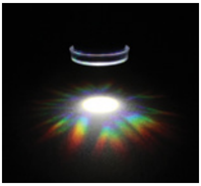

Figure 5

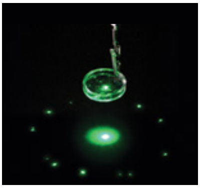

Figure 6

These grooves are 0.5-0.8 microns deep and 2-4 microns apart. (At 2 micron spacing this provides 12,700 grooves/inch or 500 grooves/mm.) This fine pattern acts as a diffraction grating. It splits (diffracts) the light into a series of rainbow spikes around the center beam when placed over the collimator lenses on the flashlight (Figure 5). The splitting effect can also be seen by shining a laser pointer through the cap. A circle of smaller dots will appear around the center main beam (Figure 6).

Care should be taken to keep the inside patterned surface of this cover clean. Oil from fingerprints can fill the fine grooves, negating the diffraction effect. Should this occur, the part can be easily cleaned with soap and water or eyeglass cleaner, etc. Upon drying, the diffraction effect will return.

## Points to note:

- These end caps snap over the end of the flashlight hoods using a bead on the inside for tension.
- Place the end caps over the end of the flashlight and observe the change in output on a surface using the various end caps.
- Use the diffraction grating over the collimator to produce the rainbow spikes effect.
- All end caps can be cleaned if they become fouled from repeated handling.

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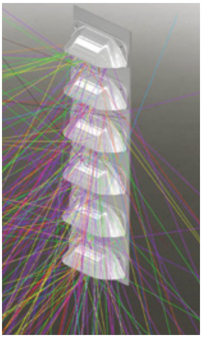
S2D 91376/E26584 Form No. 11-3371-01 C Insert O



# Reflective hood

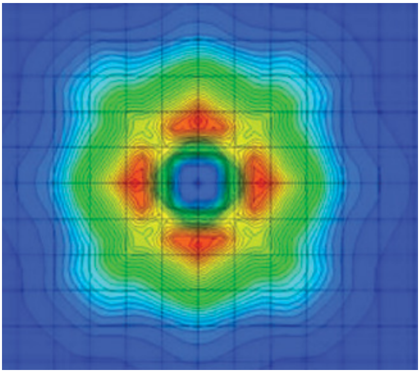


There are many different ways to shape and direct light where it is needed. Often lenses can be used, but with LED lighting, the glare can be magnified. This glare in applications such as streetlights can be at best annoying, at worst a safety hazard. To reduce the effects of glare, a reflective hood can be used; this reflective hood is designed for an 'acorn-shaped' streetlight.

This reflective hood design provides lower glare than a typical lens design, especially since the LEDs are partially concealed by the reflector. The underside of the reflector is used to direct light downward, especially light above the LED's viewing axis, to help meet International Dark-Sky Association (IDA) recommendations.

It also provides improved downward-directed light near the pole since it projects a smaller shadowed area around the base. The top side of the reflector is used to redirect low angle light outward from the LEDs above it to improve total output and uniformity, whereas low angle light is typically lost within a refractive optic or the lamp housing.

One example of the use of the



reflective hood design is shown above. Note that it creates a uniform output pattern, even without a Fresnel Globe for 360 degrees around the streetlight as shown in the simulation.

## Points to note:

- Parts can be attached using the glue groove or screw attachment.
- Both top and bottom surfaces participate in directing the light.
- Othersurfacefinishescouldbeused; the bead blast here provides a very diffuse reflection.
- SILASTIC™ MS-2002 Moldable Silicone is highly reflective and UL listed.
- Partscanbemoldedinasheet,but are done as individual parts here; this allows for flexibility in the number of LEDs on a fixture.

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S2D 91376/E26584

Form No. 11-3371-01 B Insert P



# One-piece compound lens

LED output power has increased to the point where a single LED can be used to produce enough light to meet the needs of many applications. This gives designers the ability to miniaturize the light source package, provided the light can be appropriately shaped. At the same time, they don't want to have to customize the board or package for each pattern variation.

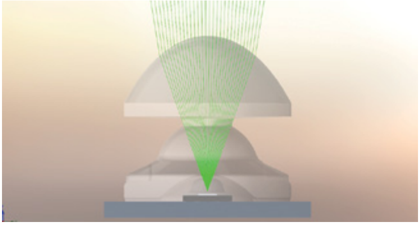
This small compound lens was designed as one way to produce a variety of output patterns from a given source. The part consists of two lenses joined along the center by a light pipe. Narrow angle output from the source along the center of the optic is effectively shaped by a single lens (two surfaces), wide angle output is shaped by two lenses (four surfaces).

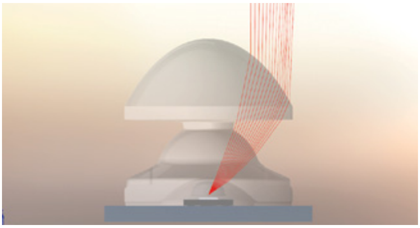
While these multiple surfaces are each distinct lenses, they were injection molded in a single shot and are one piece – making the otherwise very small lenses much easier to handle. Unlike other multiple lens systems, they require no additional lens mount, alignment, or holding fixture to assemble them. This eliminates significant assembly costs.

By varying the curve of the lens surfaces and the finish in the mold, different output angles and patterns can be achieved. A series of lenses can be designed to fit a given package with identical mounting features and varying output patterns.

Two examples of these one-piece compound lens parts are shown here. While these have grooves on the mounting rim for spring clip attachment to the LED board, alternatively they could be adhesively mounted or held in place with a mounting ring. These are designed to fit onto the same light engine, but produce very different outputs. The taller example part with the clear output surface provides a 10 degree output that projects the image of the LED die similar to the three-lens long throw collimator assembly. The shorter example shown here has a fine talc finish on the output surface and projects a 25 degree round spot of very even intensity across the pattern.

Lens design provided by LumenFlow Corp.





## Points to note:

- This is a complex, compound lens, molded as a single piece.
- There is good replication of the fine talc finish on the shorter part.
- Moving a laser pointer beam at varying angles to the input surface, you can see the beam at the edge being directed back into the pattern.
- These are designed for clip mounting, but could be mounted using a retaining ring or adhesive.
- No individual lens holders or alignment fixtures are required for use.

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Form No. 11-3371-01-0121 Insert Q S2D