Injection molded silicone resins are being commercialized for optical parts in a variety of applications. These silicones are well suited to precision molding applications, as micrometer-sized features can be replicated on the lens surface for benefits in directing light output. Silicones have been fabricated using a variety of techniques, including injection molding, casting/cavity molding and others. However, the optimal molding equipment and process conditions are very different from traditional thermoplastics or LSRs. In order to assist customers in evaluating these materials without the high cost of capital expenditures, Dow Corning has installed equipment to prototype and help optimize the molding processes for manufacturing of silicone lenses or optical parts. In running this equipment, we have found that assumptions made based on experience with plastic or LSR molding do not necessarily apply to silicone resins. In order to help people understand why, we have prepared this comparison.

**Injection Process**

Looking first at how the material is handled in the feed system and in preparation for reaching the actual mold, a brief overview of each process follows.

**Plastic Injection Molding**

- The resin or raw material for injection molding is usually in pellet or granule form.
- Material is fed from a hopper above the screw and barrel.
- The screw is rotated and feeds the pellets up the flights of the screw which also helps improve material uniformity.
- The material is melted by shearing and heat in the barrel, primarily from the high pressure and friction generated by the screw.
- The depth of the screw flights decreases toward the end of the screw nearest the mold, compressing the heated plastic.
- Injection is accomplished by using a check valve at the end of the screw and moving the screw forward, effectively using the screw as a plunger.
- Injection pressures are typically very high.
- At the end of the injection cycle, material pressure is typically held for some time to “pack” the material in the mold.
**LSR Injection Molding**

- The material is in the form of a high viscosity, heavily filled liquid.
- The material is fed to a static mixer and then into the hopper port on the barrel at medium pressure.
- The screw is rotated and the barrel cooled to prevent the friction and pressure from curing the material.
- The screw does provide some extra mixing, but this is generally not required.
- The depth of the screw flights decreases toward the end of the screw nearest the mold, compressing the LSR.
- Injection is accomplished by using a check valve at the end of the screw and moving the screw forward, effectively using the screw as a plunger.
- The check valve and screw are often modified to accommodate the thixotropic abrasive nature of the LSR.
- Injection pressures are typically high.

**Optical Resin Molding – Ideal Equipment (Plunger Style Injection Unit)**

- The material is in the form of a medium viscosity, unfilled resin mixed at a 1:1 ratio.
- The resin is fed through a static mixer and then into the hopper port of the barrel at low pressure.
- The feed screw transfers material into the plunger chamber.
- The screw feeds the material to the front end of the plunger, forcing it backward in its stroke path.
- Friction in the screw warms the material slightly and lowers the viscosity somewhat.
- When the plunger is filled, the motor drives the plunger forward, injecting the material into the mold.
- Injection speeds are typically slow as compared to LSR and thermoplastic.
- Injection pressures are typically very low as compared to LSR and thermoplastic.
- The barrels can be cooled, but this is not mandatory under normal operating conditions.
- For shutdowns, the material can be kept uncured in a 5°C barrel for at least a couple days.
- Packing is not required; occasionally, specific designs will require the pressure to be held until the material can begin to set.

**Optical Resin Molding – in LSR Equipment**

We are often asked if injection molding equipment designed for LSRs can be used. At first glance, the equipment seems the same; but in fact the differences are significant. While good results can be obtained, the problems outlined below will need to be addressed to get satisfactory results.

- The material is fed to a static mixer and then into the hopper port on the barrel at medium pressure.
- The screw rotation and pressure warms the material and drops the viscosity significantly.
- Injection is accomplished by using a check valve at the end of the screw and moving the screw forward, effectively using the screw as a plunger. This check valve requires back pressure from the material to seat it. The lower viscosity, unfilled resin may not provide sufficient back pressure to fully seat some styles of check valves.
- The check valve also requires the injection speed to be fairly high to ensure that the valve doesn’t “float” in the material and cause loss of control over the shot size, which can cause turbulence and bubbles in the mold.
- Injection pressures are typically high. This can cause significant flashing of the heat-thinned material if the mold is not designed for it.

In the mold itself, there can be significant process differences.
**Mold Design**

**Plastic Injection Molding**
- The mold is cooled and the melted material sets in the mold.
- The material is high viscosity going into the mold and large gates with impingement surfaces are common.
- Injection is at high pressure, but high material viscosity helps to prevent flash or leakage.
- The material must be cooled enough to prevent distortion or warping after removal.
- The material will continue to shrink as it cools, making large parts or flat surfaces difficult to reproduce.
- Venting can often be accomplished around the part, as the thick material forces air out in all directions.
- Injection can be done anywhere on the part.

**LSR Injection Molding**
- The mold is heated to cure the material as it sits in the mold.
- The material is highly filled and when the shear is removed the thixotropic nature helps reduce flashing.
- The material is cured coming out of the mold. Distortion is not usually an issue.
- The flexible, elastomeric nature of the cured material facilitates mold removal. Surfaces can be left rough to aid in release.
- Venting can usually be accomplished via the parting line or with vents located around the cavity.
- Injection can be done anywhere on the part.

**Optical Resin Molding – Ideal Equipment**
- The mold is heated to cure the material as it sits in the mold.
- Upon heating in the mold, the viscosity of the resin drops significantly prior to cure.
- A low injection pressure helps prevent flash or leakage around pins.
- A low viscosity allows excellent reproduction of surfaces.
- The material is cured coming out of the mold. While some shrinkage will occur due to coefficient of thermal expansion (CTE), the shrinkage is uniform and the final part is usually not distorted.
- Slow feed rates into the mold help prevent turbulence and bubble formation.
- Venting is most easily done at the top of the cavity; the low viscosity material tends to fill the cavity from the bottom up regardless of the injection point.
- Fill is usually best accomplished from the bottom, forcing air out the vents at the top.

While there are significant differences in the processes overall, the molding of silicone resin-based materials does not present greater difficulty than traditional materials. The challenges are different, but in many cases, there are actually fewer obstacles with silicone materials.

**Some Considerations in Mold Design for Optical Resin Molding**

In designing a mold for prototyping or production using silicone resin-based materials, there are some generic points to keep in mind:
- Surfaces should be polished since any imperfection will be reproduced.
- Mold releases, lubricants, etc. can cause cloudiness in the resin if they migrate to the mold cavity.
- Pins, ejectors and other components should be specially constructed and designed to prevent resin leakage.
- Gates and runners do not need to be large and impingement surfaces are not required.
- Turbulence should be avoided and venting should be provided to allow air flow out of the mold.
- The sprue should be kept as short as possible to minimize waste and to allow for sprue pulling. The sprue should be polished.
- Runners should be polished to allow for good mold release.

In order to assist customers in evaluation of these materials without the high cost of capital expenditures, Dow Corning has installed equipment to prototype and assist in optimizing molding processes for manufacturing of silicone lenses or optical parts.

**Sodick Plunger Style Injection Molding Machine**
- Precise shot control for small- to medium-sized parts
- Programmable speed and pressure controls, multistep variable
- Integrated mold heating controls
- Feed screw speed and pressure control
- Cooled barrels for shut-down periods without requiring cleaning

In addition to the injection unit itself, a standard U-frame mold is available and allows inserts to be made for testing and trials. There are also a few standard inserts for mold construction and processing trials, demonstrations and sample parts. In addition to our standard application and testing equipment, optical and environmental aging and testing equipment is now available.
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Your Global Connection
AMERICAS:
Dow Corning Corporation
Corporate Center
PO Box 994
Midland, MI 48686-0994
United States
Tel: +1 989 496 4400
Fax: +1 989 496 6731

EUROPE:
Dow Corning Europe SA
Parc Industriel – Zone C
Rue Jules Bordet
7180 Seneffe
Belgium
Tel: +32 64 888 000
Fax: +32 64 888 401

ASIA:
Dow Corning Toray Co., Ltd.
Otemachi First Square Building
East Tower 23F,
5-1, Otemachi 1-chome,
Chiyoda-ku, Tokyo
Japan 100-004
Tel: +81 3 3287 1011
Fax: +81 3 3287 1201

Dow Corning Taiwan, Inc.
10F, No. 246, Sec. 1, Nei Hu Road
TAIPEI-NEI HU 11493
TAIWAN
Tel: +886 21 3899 5500
Fax: +886 21 5079 6567

Dow Corning (China) Holding Co., Ltd.
1077 Zhangheng Road
Zhangjiang Hi-Tech Park,
Shanghai
P.R.C.
201203
Tel: +86 21 3899 5500
Fax: +86 21 5079 6567

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