THE ADVANTAGES OF PLASTIC OPTICAL COMPONENTS

WHEN COMPARED TO GLASS, PLASTIC OPTICAL COMPONENTS OFFER NUMEROUS ADVANTAGES TO MANUFACTURERS, INCLUDING REDUCTIONS IN COST AND WEIGHT, AND GREATER FLEXIBILITY IN COMPONENT DESIGN. PLASTIC OPTICAL COMPONENTS ARE INCREASINGLY BEING USED IN AUTOMOTIVE AND OTHER CONSUMER TECHNOLOGIES.

BY J.P. MENENDEZ, F. ERISMANN, AND M.A. GAUVIN

Plastic optical components provide manufacturers with many significant advantages over glass. Although tooling and mold manufacture with plastic is costly, once this portion of the manufacturing process is accomplished, plastic parts cost just pennies to manufacture in mass quantity. Plastic optics are lighter, shatterproof, implement mounting and alignment features, and allow the creation of micron size features that are almost impossible with glass. Several plastic parts can be molded at once, reducing manufacturing time and costs by using multiple cavity tools. Multiple lenses can be tooled into one part to form lenslets. Finally, plastic can be coated and molded with a variety of options, including colors and coatings. These advantages make plastic optics the logical choice for the electronic consumer industry.

Typical applications for plastic optics include

- imaging lenses that replace optical components in conventional optical systems such as projector systems, camera lenses, night vision systems, and heads up displays—several optical components of this type are shown in Figure 1.
- lightpipes that are used to sidelight and backlight information displays such as LCD computer displays, instrument panels in cars, and hand-held telephones—sample lightpipes of this type are shown in Figure 2.
- medical optics such as lab on a chip micro-electronic mechanical systems (MEMS), and medical disposable instruments—sample optics with very small feature size are shown in Figure 3 (page 30).
- automotive lenses, headlamps, tail lamps, stop lamps, reading lamps, and instrument back lighting using lightpipes—plastic pieces coated with chrome to create reflectors are shown in Figure 4 (page 30).
- collimators for laser diode and LEDs to provide different viewing angles
- security systems lenses, which are multiple zone fresnels to detect IR signature of oncoming heat radiating bodies
- consumer products from childrens' toys with optical sensors such as Furbys™ to printers, scanners, copiers, disk drives, and DVDs, which use small optics to either activate, display information, or scan information in optical format.

Injection and compression molding are used to manufacture plastic optics. These injection molding machines melt the raw plastic material at high temperatures and then flow the heated plastic into a previously diamond turned or computer numerically controlled machine (CNC) tooled mold. For optical applications, molding processes can be quite complex. To accurately reproduce optical features in plastics, the molder must maintain strict control of the molding parameters, materials, and temperatures. Knowing the correct material, temperature and time to allow the part to be plastic injected molded is a black art that even skilled manufacturers may take several iterations to perfect.

The molds are usually made out of nickel or steel, depending on the number of parts made per mold and tolerancing requirements. To create the part, melted plastic flows through special channels tooled into the mold to create an even flow to every portion of the mold. These channels are called gates and runners, and are tooled into the mold to accomplish even plastic flow.

Injection molds also include vents to assist in the removal of trapped air from mold cavities. These gates, vents, and runners are crucial steps in creating quality high precision optical parts. The molds also include ejector pins and draft angle features, which are used to extricate the part after it cools. If the mold is not designed correctly, it may be impossible for the plastic component to be released from the mold. These features are even more critical in an optical component where a small defect such as a streak or bubble can be acceptable in a household item or toy, it might have disastrous consequences in an optical component. Poor mold flow can mean the difference between a perfectly functioning optical part and a part that degrades the entire optical system.

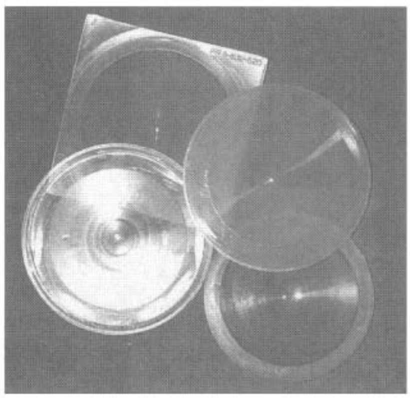

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Figure 1. Fresnel lenses are used when there is a limited amount of space and power is required of the optical component to either magnify or collimate light to an illumination screen or security detection system. These types of Fresnels are commonly seen in overhead projectors.

Today's plastics have overcome many of the problems that plagued optical components in the past. Yesterday's plastics could not tolerate UV light or transmit light in the IR region. Newer raw material mixing technologies create vibrant colors, thinner injection material for tighter tolerances, and thinner and more transmissive parts. Today's plastics can withstand years of UV incident light in hostile environments. These newer plastics allow for higher transmittance over a range of wavelengths from the UV into the IR. High temperatures were a problem in the past but several new plastics like TPX and Ultem can handle temperatures of almost 100°C without physical or optical degradation. New techniques involving hot oil and forced hot air solve the problem of melting these higher temperature plastics for injection molding.

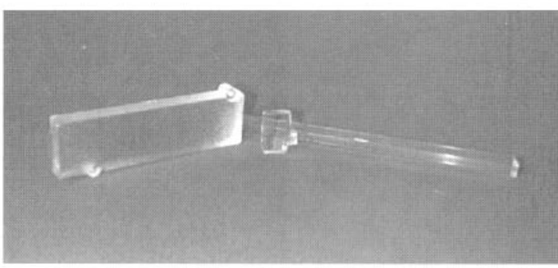

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Figure 2. Lightpipes are especially suited for plastic injection molding. These pieces are created to move light around mechanical features. Lightpipes like these are used for back lighting and sidelighting LCD displays, LED turn on and off displays, and on/off switches. The part can be molded with diffuse features to create a bold or softly diffused display depending on the application.

One of the final steps in manufacturing is the grinding/polishing process. The plastic process holds mechanical tolerances 50% better than the glass process. Plastic optics can reduce costs significantly over glass in this respect. In a glass component, each surface must be ground and polished. In a molded plastic optical component, only the mold is polished to a very high quality finish. Other factors contributing to the cost advantage of plastic are its high impact resistance, lighter weight, and greater configuration alternatives.

The weight of glass is typically two to five times greater

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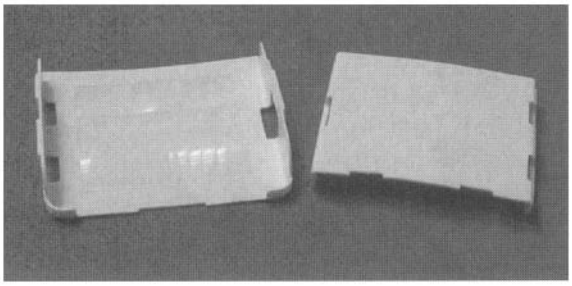

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Figure 3. Alignment and mounting features can be molded directly into the part. Small features on the scale of a few microns can be tooled into the mold. These fresnel lenses have many zones with part features on the order of less than 25 μm. It has been possible to make medical inspection slides with features on the order of 5 μm.

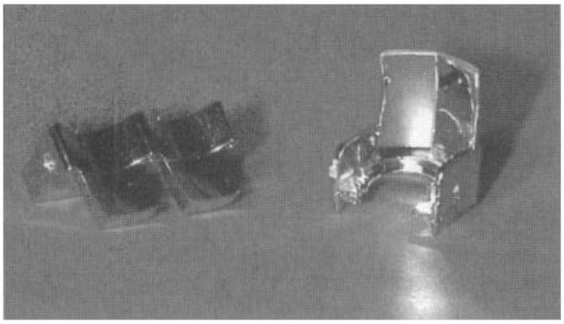

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Figure 4. Coatings can be applied directly to the plastic part. Sputtered aluminum can be applied to create high quality, highly reflective parts. Parts can be coated with gold, aluminum or chrome. Other coatings include antireflection, UV and IR band-pass filters, and polarizing media.

than the weight of plastic. This is a significant factor in material selection depending on system requirements. A lower weight allows for a more simple mounting mechanism to be designed and allows for the weight reduction of the entire product. To further reduce the weight and simplicity of the product, the mounting features and alignment keys can be designed and molded directly into the part. Weight is always an impact on cost when shipping. When considering large volumes or a large number of parts, shipping costs can be exorbitant for glass optics, especially when mounting hardware is also shipped with the optic.

Plastic is the preferred material when high impact resistance is required. The military has replaced many glass applications with plastic due to the lack of impact resistance in glass. There are plastic engineered parts that will withstand the impact of a projectile from a firearm. This not only provides a still functioning binocular or scope, although with an embedded bullet, but a living breathing soldier as well.

In the past, glass triplet lens designs were used to provide diffraction limited focusing camera lenses. The triplet design is excellent in compensating for all major geometric aberrations like spherical, coma, reducing color aberration, and providing low f-numbers. To the delight of low-cost camera makers, plastic lenses have been designed to replace these heavier, costlier lenses. Figure 5 is a computer-aided drafting (CAD) plot of a triplet design created totally in acrylic. The plastic parts not only include the lens but its mounting hardware as well. The mounts are tooled into the plastic parts and snapped together for quick, inexpensive assembly. This creates a non-moving, toleranced design that is inexpensive and effective for throw away cameras, complementary metal oxide semiconductor (CMOS) array surveillance systems, or video conferencing cameras. The included snap and hook in-line mounts and alignment keys guarantee that the lenses will not shift over time and create focusing or misalignment of the individual lenses. Usually, a glass triplet design would need three glass lenses with at least two different materials.

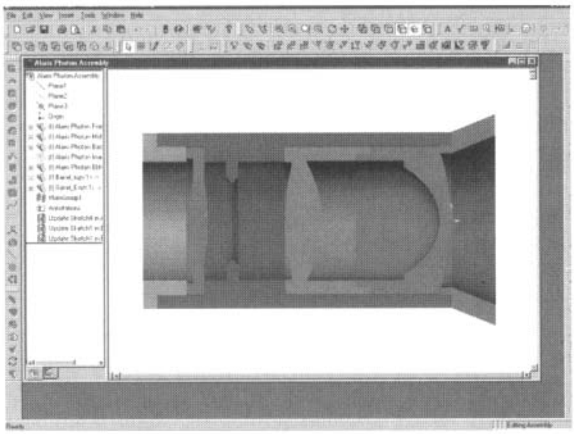

Figure 5. Cutaway view of an acrylic triplet design with integrated mounting features.

Mounting hardware would also be needed to assemble the unit. However, molding diffractive optical elements (DOEs) and aspheric surfaces into the plastic lenses reduces the need for multiple materials. This allows the plastic molder to use one type of plastic material for the entire assembly. The DOEs reduce color aberration and the different widths, curvatures, and aspheric surfaces of the plastic lenses compensate for the geometric aberrations. This particular triplet is diffraction limited with an excellent modulation transfer function (MTF) both on and off-axis. This plastic triplet with barrel is less than $2 per unit in quantities of 10,000. Similar glass triplets range anywhere from $5 to $50 per unit.

Although plastic offers significant advantages over glass, there are some limitations. Plastic optics do not perform well in environments where large temperature fluctuations exist. However, most optical systems do not operate in conditions that exceed the thermal limits of plastic. Thus, optical systems made of glass will not withstand much more abuse than its plastic counterpart. The variety of materials for glass optics exceeds those that are currently available for plastic optics. In lay terms, this means that there are greater design freedoms in glass. However, a designer can compensate for this by using aspherics, binaries, and diffractives. These surfaces are very cost effective to produce in plastic, so a good designer can overcome the narrower selection of materials by a judicious use of aspherics, binaries, and diffractives.

Overall, plastic is an excellent alternative to glass when mass quantities or feature abundant parts are needed. Plastic optics excel in applications where multiple feature, lightweight, mounted optics are needed for consumer oriented products. In the future, the need for new plastic optical components will explode into the market place.

P. Menendez is applications engineer, F. Erismann is chief executive officer, and M.A. Gauvin is vice president of sales for Wavelength Optics in Sacramento, CA.