Improving Cost & Performance with Plastic Optics

EMPIRE PRECISION
WHERE YOUR IDEAS TAKE SHAPE

Cost & Weight Savings of Polymer Optics

For many technologies, polymer optics offer significant advantages, including:

- A polymer optic is approximately 2 to 5 times **lighter in weight** than a comparable glass lens.
- The impact resistance of most plastics surpasses that of glass, **enhancing safety** within an optical system.
- Injection molded optics offer a more cost-effective ramp to **full-volume production** than is possible with glass.

Complex Shapes, Higher Performance

The significant cost reduction that is attainable through the use of polymer optics is often overlooked. A key advantage to injection molding, the typical process used for fabricating polymer optics, is the ability to replicate complex shapes in a cost-effective manner.

The most lucrative reductions result from combing optical and mechanical features into one platform; eliminating or minimizing optical mounts, hardware, optical alignment and assembly. Maximizing mechanical features within the polymer optical design substantially reduces the cost of the overall system. If done correctly, this design approach should enable a smaller system configuration and eliminate a majority of the optical alignment costs. Plastic should be the material of choice in optical systems with a high number of components and a combination of optical and mechanical requirements.

For example, this injection molding advantage works well for LED lighting applications because of its ability to integrate optical elements (lenses, light pipes, mirrors) and mechanical features (snaps, apertures, holes, barrels) into a single part.

Common Misconceptions

Misconceptions about polymer optics can rob designers of significant cost and performance improvement opportunities. For instance, it's *not true* that polymer optics is only for:

1. **Low-quality optic applications:**
   Some believe that polymer optics is not applicable to precise applications, which is not the case.

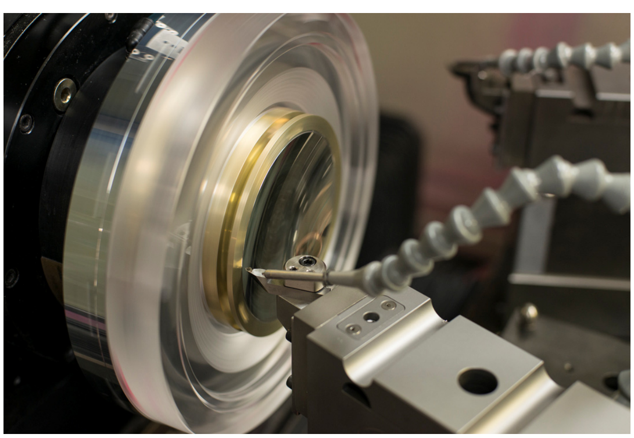
2. **High volume production:**
   High volume is not required to justify the capital tool investment; many customers experience attractive cost reductions at significantly lower production levels than are typically realized in traditional injection molding applications.

3. **Simple configurations**:
   In fact, the opposite is true. One of the most significant values of polymer optics is that it offers design freedoms that are simply not attainable or cost-effective in glass; configurations such as aspheres, lens arrays, freeforms, Fresnel and diffractive surfaces. Plastic is easily the material of choice for complex surface optics.

*Empire was able to achieve a dramatic cost reduction for a customer's optical assembly by converting their seven aspheric lenses from glass to plastic. By adding assembly features and maximizing the benefit of a plastic design, Empire **reduced the part count from 50 to 6** and eliminated most of the assembly cost.*

This multi-feature design approach often creates complex geometric shapes which make many injection molders uncomfortable because of their significant variation in thickness. However, there are a handful of optic molders whose niche is molding these complex configurations while maintaining accurate optical surfaces, and it is definitely worth the time and investment to locate them. Some best fits for glass-to-plastic conversions include:

- **Aspheric lenses** – Aspheric configurations are readily reproducible and affordable via injection molding. In some applications, a single aspheric lens may be able to eliminate a more complex, multi-element design. Aspheric surfaces also offer improved image quality due to their unique configuration that often reduces or eliminates spherical aberrations.
- **Lighter weight applications such as aerospace, night vision lenses, guidance systems** – Polymer optics may be a better alternative when design restrictions such as limited space or lighter weight are required.
- **Disposable applications such as clinical diagnostics** – Medical devices are a great fit for lower cost polymer optics, as disposable optical systems may be a lower cost alternative to sterilization expenditures. Surgical applications should also be considered.
- **Point-of-sale or bar code reader systems** – Multi-faceted surface applications such as these are also a good fit for low-cost plastic optics.



Single point diamond turning (SPDT) reduces the cost of prototype plastic optics, allowing for small-volume runs before moving into full-scale production.

Overcoming Design Limitations

Certain design limitations exist that prevent plastic from being an absolute substitute for glass; however, by working strategically with your supplier, most of these limitations can be overcome.

Optical Polymer Limitations (compared to glass)	Impact	Strategic Solution
Optical plastics have a lower refractive indices than glasses	Generally 1.49 to 1.59 (plastic) compared to 1.45 to 2.05 (glass)	A hybrid design or fully utilizing the design freedoms available with plastic
Considerably narrower operational temperature	60 °C to 250 °C (plastic) compared to 400 °C to 700 °C (glass)	Durable, protective coatings and/or protective enclosures
Higher thermal expansion		
Susceptible to radiation that could cause chain cross-linking	Results in discoloration and non-uniform energy absorption	Inhibitors added to the polymer to deter cross-linking
A typical plastic optical surface may absorb from 0.003% to about 2% water by weight	Dimensional changes and minor alterations in spectral transmission	Coating surfaces with less hygroscopic materials to reduce water absorption
Effective electrical insulators; subject to a buildup of electrical charge on surfaces	Subsequent attraction of oppositely charged contaminants	Using room temperature/humidity control and air ionizers immediately after molding
Relatively soft	Susceptibility to surface damage (scratches, digs, etc.)	Harder surface coatings or locating plastic elements internally to protect against abrasion

The limitations of polymer optics should not deter their consideration for optical design. An excellent way to address these limitations is to incorporate the strengths of glass and polymer optics into a single hybrid system. This approach enables an ideal balance between cost and performance that is not attainable in all-glass or all-polymer systems.

Advancing Technology, Expanding Applications

Polymer optic technology has been advancing for several decades. Cutting-edge injection molding, ultra-precise diamond turning, and sophisticated optical metrology has enabled the transition from toys and low cost film camera applications to a common, enabling technology in high-end products utilized in applications such as medical, defense, homeland security, fiber optics, and biometric scanning devices.

Initial technical advances were primarily driven by high-quality, consumer photographic applications. Optical leaders in this field such as Eastman Kodak, Polaroid, Philips and Fujinon paved the way for a wide range of other high tech uses.

Injection Molding of Complex Configurations

The value of polymer optics is more than simply replacing glass lenses with plastic. The number of applications is growing rapidly; plastic optics are fabricated from an ultra-precise insert, which means that any complex configuration that can be machined into the insert can ultimately be injection-molded cost-effectively into a precision polymer optic. This enables optic designers to utilize complex optics for use in imaging, scanning, detection, or illumination systems. These types of optics include:

- asphere or paraboloidal surfaces
- free-form optics
- micro-lens arrays
- Fresnel lenses
- refractive-diffractive optics
- toroids or focusing surfaces

Common Applications of Plastic Optics

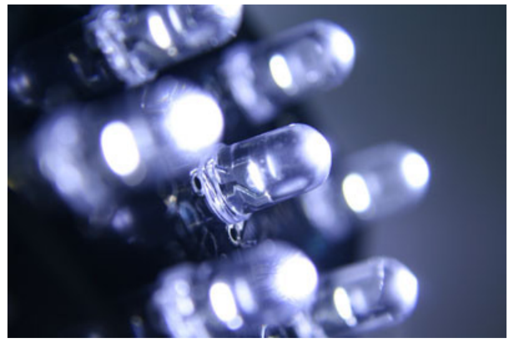
Biomedicine: Lower part cost of polymer optics makes it practical to replace medical applications that require extensive sterilization with single-use systems. This includes clinical diagnostic applications and certain surgical and treatment devices such as laparoscopes and arthroscopes.

Biometrics: Design versatility, precision and cost-effectiveness make polymer optics a great fit for biometric applications such as retinal scanners, 3-D facial imaging, and palm/fingerprint readers.

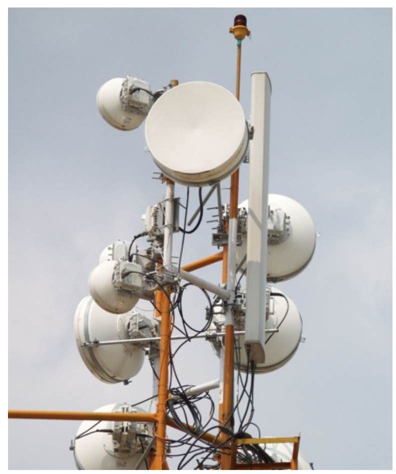
Consumer products: Cell phone cameras and displays, bar code readers, automated flush valve systems, digital cameras, viewfinders, rangefinders, smoke detector optics, automotive heads-up displays, videoconferencing cameras, personal computer optic accessories, automatic door sensors, optical scanners, handheld portable optic systems and considerably more!

Defense / Security: Includes guided weapons, head-up displays, sighting systems, tracking devices, and night-vision lenses.

Illumination systems: Lighting applications, such as LED systems, are a rapidly expanding market for polymer optics because of polymer optics' versatility, low cost, precision, and repeatability. Design freedoms enable solutions that are precisely configured to the specific angular distribution of a given LED array to the desired area of illumination via a proper light mix while avoiding color-banding. In addition, polymer optics provide lighter weight components and high transmission in the visible to near-IR wavelength.



Telecom / Datacom: The ability to precisely manufacture micro-structures such as refractive or diffractive surfaces, gratings, Fresnel surfaces, and micro-lens arrays has made polymer optics attractive for applications in the telecom and datacom markets.



The rewards attainable through the use of polymer optics far outweigh the costs, and optimal solutions can be found when supply partners are fully knowledgeable of the possibilities. The Empire Precision team has a strong base of expertise in the injection molding of plastic optics and years of experience helping customers realize cost and quality improvements for their programs.

To learn how you can achieve better cost and performance for your optics program, contact Empire**.**

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