TECHNICAL SERIES: OPTICAL PROPERTIES

Material Characteristics

In our previous article, we discussed how an optical material is principally defined by its specific refractive index (n) and dispersive (Vd) properties. Material manufacturers go to great lengths to control these aspects of their products. But while these two fundamental characteristics are generally the first an optical designer considers, they are by no means the only aspects that are important.

Homogeneity

When a glass is manufactured, it's not only the percentage of specific ingredients that are important to its final properties but also how well those ingredients are mixed together. Consider for a moment a polished lens with a diameter of approximately 4". When installed into an optical system, the lens is expected to perform consistently across its entire aperture, that is to say light passing through its center will refract consistently with light passing near the edge. It is the ability to limit localized variations in the refractive index and dispersion that opticians define as a material's homogeneity. A standard material will exhibit no more than 2-4 x 10^(-5) variation in its index values (manufacturer dependent). In circumstances where the performance of an optical system requires more tightly controlled homogeneity, material can be tested and specially selected to meet these requirements. Esco works with all grades of material homogeneity.

When viewed under a polariscope, optics with high stress will exhibit a distinct pattern as the light travels through it.

Stress Birefringence

An important aspect of the glass manufacturing process is the ability to alleviate the internal mechanical stress. As a glass mixture cools from a liquid to a solid, (glass in its "solid" state is technically still a liquid but this is a discussion for another technical article), its atomic structure sets in place and the goal is to achieve a homogenous, well-ordered arrangement of atoms. To this end, glass undergoes an annealing process in three steps. First, the glass is heated to a level above its strain point but below the temperature where the material begins to soften. At this temperature its atoms begin to move within its internal structure. The material is then kept at this temperature for a specific period of time,

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referred to as “soaking”, during which the atoms migrate and find a configuration at which they are most “relaxed”. Finally, the material is slowly cooled resulting in a less stressful state.

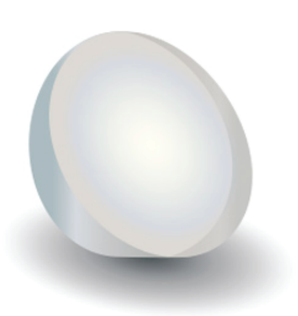
The annealing process helps to control localized variations in the internal stress of a material. If variations are present, light is distorted as it transmits through the optic and this is what opticians define as stress birefringence. A material’s anneal is characterized by the maximum allowable deviation in the optical path, defined in terms of nanometer per centimeter (nm/cm). Glass supplied in a standard fine annealed state will exhibit no more than 10 nm/cm deviation in the light path. More stringent anneal requirements can be certified on request and Esco routinely works with fine and precision annealed material.

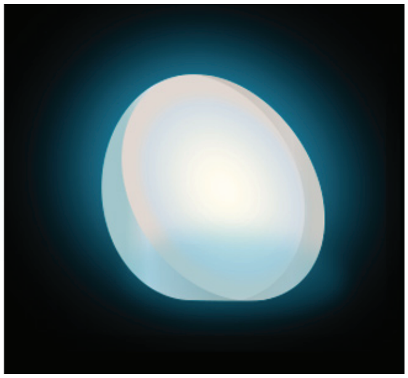
Striae

While rarely an issue with today’s modern glass, striae is defined by localized, visible variations in the index of refraction of a material. Often, these variations appear as distinct lines shaped like thin threads throughout the glass. Most optical materials are considered “A” grade or striae-free, with notable exceptions for some grades of fused quartz and other low-expansion materials.

Fluorescence

When exposed to ultraviolet radiation, some materials exhibit fluorescence which is the absorption and re-emittance of photons. This process literally causes an optical material to glow as it emits the absorbed energy as light. Fluorescence can introduce unwanted noise into an optical system reducing its sensitivity and effectiveness. It is therefore important when choosing a material to consider if fluorescence is possible. An Esco sales engineer can assist in helping you choose the best material for your application.





Some optical materials, when exposed to high energy UV radiation, absorb and re-emit the energy as light.

Coefficient of Thermal Expansion

As the term implies, most optical materials both expand and contract with changes in temperature. This property affects both the manufacturability of an optic, as well as, its ability to retain its final shape once complete. As many optics are polished to a high degree of precision, even small changes in temperature may affect the surface characteristics and therefore its performance in a given system. Optical designers must therefore account for the environment in which an optic is employed and choose materials which best suits the application. Where temperature is a concern, often times low-expansion materials such as fused silica, quartz and Borofloat are the best choice, however, in cases where extreme swings in temperature are present such as outer space, ultra-low expansion materials are available such as Schott Zerodur and Ohara Clearceram-Z.

At Esco Optics, our sales and engineering team routinely collaborate with customers to choose the most cost-effective, best-performing optics for their applications. With hundreds of materials available in today's optical market, you can rely on our fabrication expertise and technical knowledge to answer all of your material questions.

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