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OPTI 521

Technical Review Paper

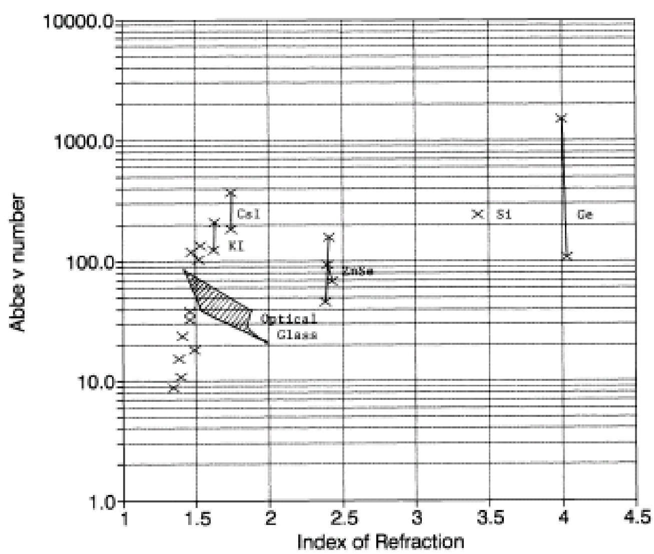
Parks, Robert E. Fabrication of Infrared Optics. *Optical Engineering*, 33(3): 685-691, 1994.

Overview

In this paper, Robert Parks discusses methods of grinding and polishing IR transmitting materials, proposes a novel postpolishing process for materials which single point diamond turning does not produce adequate surface finish and provides a general review of good diamond turning techniques. The common need for aspheric surfaces in infrared systems makes consideration of the effects of fabrication an important aspect of system design in this wavelength region.

Comparison of Visible and IR Optics

A typical glass map in the infrared will look tremendously different than a familiar visible glass map. It is not an unreasonable assumption that materials with such different optical properties will also



Infrared Glass Map

have vastly different mechanical properties. For example, many common infrared materials have very high coefficients of thermal expansion and low thermal conductivities which give rise to thermal gradients within the material. From a manufacturing standpoint this is an issue of concern as mechanical flaws introduced from surface shaping procedures can be sources of thermally induced stresses and break the optic. Additionally, the alkali halide materials can be roughly shaped using water aided processes such as a wet felt lap due to their water solubility. Despite some of these unique materials the general rule, at least in the initial stages of manufacturing, is that infrared materials can be treated in a similar fashion and with similar tooling to traditional visible optical materials.

Selection and Testing of IR Materials Before Polishing

Unlike materials used in the visible band, suppliers of infrared optics do not have the same standard of quality. There are two primary reasons for this problem, 1) it is hard to test infrared optics since most materials do not transmit in the visible, and 2) most infrared optical materials manufacturers sell their product for primary uses other than optics. Designers should make certain to check the material quality before any processing occurs when homogeneity is a potential concern.

Fabrication of Spheres and Flats

Differences between polishing materials in the IR and the visible are strictly issues of chemistry and care. Exactly the same criteria for technique and hardware selection are used. For visible materials the polishing compound is generally high in cerium oxide, which is thought to dissolve and re-coat the optic with a thin film of silica after the lap has passed over the surface with the effect of filling in any surface damage from the polishing process. For IR materials the polishing compound will use various sizes of Linde (C - 3um, A - 1um or B - 0.3um) depending on the stage of the surface polishing. Generally, Linde C will be used first until the grinding marks have been removed and then Linde A will be used to finish. Here, the optician may find that he or she needs to brush the lap with wax in order to ensure that the Linde sticks to the lap and cuts the glass rather than simply rolling around on the surface.

For the water soluble crystals mentioned previously, using a pitch with water and alumina such as Linde will not be sufficient. Instead, the crystals are initially shaped by rubbing the material over a wet felt surface and then polished using a pitch lap coated in beeswax and a compound of Linde A in ethylene glycol. During this process the humidity should be strictly controlled, gloves worn at all times and any unused polishing components stored in desiccators. Polishing of such materials is extremely fast and almost always performed by hand.

Fabrication of Aspheres

Infrared systems commonly use aspheric surfaces in their design since there is a limited catalog of materials available, they tend to be expensive and detectors are usually less efficient. In the case of aspheric surfaces whose surface profiles do not significantly deviate from a sphere, the traditional methods of manufacture will be adequate. However, for fast aspherics the optician will need to resort to single point diamond turning by which a numerically controlled lathe moves over the surface to cut the desired shape. In doing so, the tool feed marks will leave grooves in the surface that may need to be removed through postpolishing. Most common IR materials are candidates for quality diamond turning, including germanium, zinc selenide, zinc sulfide, magnesium fluoride and calcium fluoride.

The tool markings left on the surface will generally have a groove spacing of 10 to 20 microns and a height of 0.1 microns. Since the scattering efficiency is proportional to the square of the rms roughness, postpolishing of the surface to remove the tooling marks should be considered.

In the case of shaping mirrored surfaces, an economical method of diamond turning has been proposed. Traditionally, an aluminum substrate is rough cut with a diamond tool, e-plated with nickel and then re-cut to precision. Two disadvantages arise in this process. First, there are two sets of diamond turning involved adding both time and cost. Second, the part must be precision aligned after plating of the nickel before the final SPDT which adds additional time and room for error. If it is instead assumed that the surface will need to be postpolished, the aluminum substrate can be cut to figure with a diamond tool at a fast feed rate, plated with e-nickel and then polished to figure. The surface roughness achieved by the second method is comparable to the first but with one less cutting requirement and less stringent alignment.

Comments on Diamond Turning

Although current diamond turning lathes are very precise a common error can occur in operation when the diamond turning point is at the center of the optic rather than on the axis of symmetry. The resulting surface error cannot be corrected by realignment of the optic. The optician should test the optic during cutting and make adjustments as necessary. In the case of aspheric optics, a reference surface should be turned at the same time as the aspheric surface to ensure that the optic is properly set during testing.

Conclusion

There are several unique considerations to be made in the fabrication of IR optics with respect to visible optics. Although the tools and techniques used are similar the chemistry of the materials is quite different. Polishing compounds using alumina oxide or Linde in ethelyne glycol should be used for common surface types while SPDT provides an efficient means of fabricating aspheric surfaces when the tooling is properly set. A method of fabricating aspheric mirrors by SPDT with postpolishing was proposed in an effort to reduce costs and increase efficiency. Perhaps most importantly, the author stresses that although SPDT is a valuable and accurate technique it is no substitution for sound kinematic mechanical design principles.