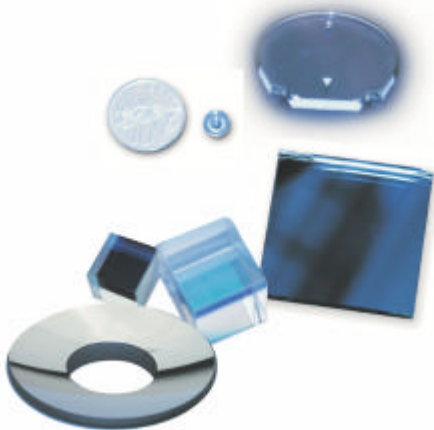




Optical Thin Film Coating On Plastic Components

Why Plastic?

Glass has long been the substrate of choice in the optical component industry and will remain so for many years to come. The reason is that glass has very good optical properties, high thermal stability, can be easily shaped and polished. It is for this reason that high-end, high quality optical instruments are still made of glass. Plastic (polymer) optical components, in the past, had been mainly found in industrial applications such as optical sensors, barcode readers and ophthalmic. However, in recent years plastic optical components had gained popularity in the consumer electronics industry, as newer and more cost-effective plastic injection molding processes are being introduced into the market. Plastic optical components are widely found in consumer products such as optical mice, digital cameras and optical storage devices such as CD-ROM and DVD players.



There are various advantages in using plastic optical components. Some of them are as follows:

- (a) the components can be molded to the final form factor without any secondary processing such as grinding or polishing as in glass optics
- (b) manufacturing process is fast and determined only by the injection molding machine cycle-time and the number of cavities in the mold
- (c) complex lens surface, such as aspherical or Fresnel surfaces (diffractive optics) can be molded and these lenses can make optical systems more compact
- (d) the mechanical fixtures, which holds the lens, can be molded together with the lens, and sometimes multiple lens on one fixture can be molded together

- (e) plastic components are light weight and these is advantageous for portable optical devices or optical storage devices, where the lower weight of the plastic parts reduces the seek time
- (f) plastic parts has high impact strength
- (g) plastic materials are low cost.

Types Of Plastic Optics

Plastic optical components are either reflective or transmissive. Reflective parts are, for example mirrors, found in barcode readers or scanners. Transmissive parts can be generalized into three categories. They are:

- (a) optical windows
- (b) focusing lens
- (c) imaging lens

Optical windows are transparent parts, which usually forms part of the enclosure; allowing light in and out of the enclosure with little loss and at the same time protecting the internal parts of the equipment from the environment. Focusing lenses, or sometimes called focal length lenses, are used to focus light to a point. Some of these lenses are used in optical sensors. Imaging lens, as its name implies, is used in imaging systems such as cameras.



The common materials used in making plastic optics are:

- (a) Acrylic (PMMA)
- (b) Polycarbonate (PC)
- (c) Polystyrene (PS)
- (d) Cyclic Olefin Copolymer (COC)
- (e) Cyclic Olefin Polymer (COP)

Earlier optical components were made using the first three types of material but the latter materials are becoming more popular because of the higher continuous operating temperature, better thermal stability, lower water absorption



and good coating adhesion (Table 1). Not all plastic optics requires thin film coating. It depends on the optical design.

Optical Thin Film Coating

Putting functional optical thin film on plastic poses some challenges. First of all, plastics are organic material and the optical thin films are typically made of inorganic oxide materials. Getting a good bonding between the oxide thin film and the plastic substrate is a challenge. This is made worse by the tendency of plastic to absorb moisture, which does not help in getting good adhesion between the plastic substrate and the thin film. Some plastic materials demonstrate better adhesion properties than others, e.g. PC, COC and COP.

The surface finish of the plastic part has to be very smooth to give good light transmission. Surface imperfections do not show up very well before coating due to light reflection from the surface of the part but will be very obvious once an anti-reflective coating is deposited onto it. There must not be any stress concentration generated within the part during the injection molding process or the coatings are likely to crack at these high stress areas. The stress also causes birefringence, a variation of the refractive index in the material.

Optical coatings on plastics are commonly deposited using evaporative or sputtering process [1]. The process starts at a low temperature and the temperature within the coating chamber can rise as more layers of coatings are added. Plastic parts have low melting temperature and the coating temperature cannot be too high. Moreover, thermal stress can also be created due to the different coefficient of thermal expansion between the coated materials and the plastic substrate. As a result, not too many layers of coatings can be deposited onto plastic substrates. We cannot have coatings that perform demanding optical functions such as narrow-band filtering.

Despite all the difficulties mentioned, with better injection molding process (e.g. injection compression molding), and coating technologies (e.g. ion-assisted evaporative vacuum deposition [1]), various optically coated plastic optical components have been successfully mass produced.

The common coatings found on plastics are metallic reflective coatings and anti-reflective (AR) coatings [2,3]. Reflective coatings are found in the plastic mirrors of barcode scanners. They are also found in the reflectors of car headlamps. The reflective surface of CD is also vacuum deposited.

AR coated plastic components are found in many low power laser applications such as laser sensors and optical storage systems. They are also used widely in eye-glasses.

Plastic parts are soft and scratches easily. Some optical parts have a layer of transparent hard coat on them. Common ways of depositing hard (organic) coat on plastic are by using wet process such as dipping or spin-coating. Hard coat can also be deposited using vacuum deposition and this has better control over the uniformity of the coating.

In conclusion, there is much attractiveness to using plastic optics in products and due to pressures to reduce manufacturing cost; the trend of plastic optics replacing glass optics is likely to increase over the years.

Table 1: Properties of Optical Plastics

	PMMA	PS	PC	COC
Light Transmittance (% , 3mm, visible spectrum)	92	87-90	85-91	92
Abbe Value	57.2	30.8	34.0	58.0
Refractive Index	1.491	1.589	1.586	1.533
Haze (%)	1-2	2-3	1-2	1-2
Water Absorption (% , 24h)	0.3	0.2	0.15	<0.01
Specific Gravity	1.19	1.06	1.20	1.03
Hardness	M97	M90	M70	M89
Impact Strength (ft-lb/in)	0.3-0.5	0.35	12-17	0.5
Coeff of Linear Thermal Exp ($10^{-5}/^{\circ}\text{C}$)	6.74	6.0-8.0	6.6-7.0	6.0-7.0

References:

- [1] "Ion-assisted deposition", *Opto-Precision Application Note A002*
- [2] "Optical thin film coatings", *Opto-Precision Application Note A001*.
- [3] "Optical thin film applications", *Opto-Precision Application Note A003*.

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