5 Optical Properties of Solid Polymers

5.1 Light Transmission

The intensity of light incident on the surface of a plastic is reduced as the light enters the plastic because some light is always reflected away from the surface. The intensity of light entering the plastic is further reduced as the light passes through the plastic since some light is absorbed, or scattered, by the plastic. The luminous transmittance is defined as the percentage of incident light which is transmitted through the plastic. For comparison purposes the exact test parameters are documented in ASTM D 1003. Some typical light transmission values are presented in Table 5.1 for most common optical plastics. Light transmission is a measurement of the transparency of a plastic.

5.2 Haze

Haze is defined as the percentage of transmitted light which deviates from the incident light beam by more than 2.5 degrees. Its measurement is also defined by ASTM D 1003. Some typical haze values are presented in Table 5.2 for most common optical plastics. Haze is a measure of the clarity of a plastic.

5.3 Refractive Index

The refractive index n of an isotropic material is defined as the ratio of the speed of light in the material v to the speed of light in a vacuum c, that is,

$$n = v/c$$

The speed of light in vacuum is 300 Mm/s. The refractive index decreases as the wavelength of the light increases. Therefore the refractive index is measured and reported at a number of standard wavelengths, or atomic emission spectra (AES) lines, as indicated in Table 5.3.

Table 5.1: Light Transmission, or Luminous Transmittance of Some Common Optical Plastics

Material	Luminous Transmittance D 1003
ABS	85
PC	89
PMMA	92
PMMA/PS	90
PS	88
SAN	88

Table 5.2: Haze of Some Common Optical Plastics

Material	Haze
ABS	10
PC	1–3
PMMA	1–8
PMMA/PS	2
PS	3
SAN	3

Table 5.3: Refractive Indices as Functions of Wavelength

AES line	Wavelength	PMMA	PS	PC
F	486 nm	1.497	1.607	1.593
D	589 nm	1.491	1.590	1.586
C	651 nm	1.489	1.584	1.576

The refractive index is usually measured using an Abbe refractometer according to ASTM D542. The Abbe refractometer also measures the dispersions, which is required for lens design. An extensive list of refractive indices is provided in Table 5.4. Since speed of light in the polymer v is a function of the density, polymers which exhibit a range of densities also exhibit a range of refractive indices. Since density is a function of crystallinity, the refractive index is dependent on whether the polymer is amorphous or crystalline, and on its degree of crystallinity. Since density is also a function of temperature, decreasing as temperature increases, the refractive index also decreases with increasing temperature.

Table 5.4: Refractive Indices of Some Plastics as Functions of Density [1]

Polymer	Refractive index n_D^{20}	Density kg/m³	Transparency
PE-LD	1.51	914/928	transparent
PE-HD	1.53	940/960	opaque
PP	1.50/1.51	890/910	transparent/opaque
PVC	1.52/1.55	1380/1550	transparent/opaque
PS	1.59	1050	transparent
PC	1.58	1200	transparent
POM	1.48	1410/1420	opaque
PA 6	1.52	1130	transparent/opaque
PA 66	1.53	1140	transparent/opaque
PMMA	1.49	1170/1200	transparent
PET	1.64	1380	transparent/opaque

5.4 Gloss

Surface gloss is the percentage of light intensity reflected relative to that reflected by an ideal surface. Also called specular reflectance or specular gloss, the gloss is measured within a specific angular range of the ideal reflected angle. It is then compared to a standard, polished black glass with a refractive index of 1.567, which possesses a specular gloss of 100%. The gloss reduces rapidly as the surface roughness increases. The specular gloss is measured according to ASTM D 523-80.

5.5 Color

Color may be measured using tristimulus colorimeters (a.k.a. colorimeters), or spectrophotometers (a.k.a. spectrocolorimeters). These instruments measure color by illuminating a sample and collecting the reflected light. Colorimeters use filters to simulate the color response of the eye. They are used for quick and simple measurements of color differences. Spectrocolorimeters measure color as a certain wavelength of light. The color is reported as three numbers. The L-value measures the grayness, with pure white scoring 100 and pure black scoring 0. The a-value measures the redness when positive and the greenness when negative. The b-value measures the yellowness when positive and the blueness when negative. So from the L, a, and b values a color can be defined.

Literature

1. *Domininghaus, H.:* Plastics for Engineers, Hanser, Munich 1993