General Characteristics Of The Materials

Crystalline materials are often used in optics applications because of their unique optical and physical properties. Their high translucence in the UV and IR spectral regions, wide variety of dispersion properties, etc., permit a considerably wider choice of applications as compared with optical glasses.

CRYSTALLOGRAPHIC

Monocrystalline materials possess an ordered three-dimensional periodic spatial atomic structure. Four useful crystallographic parameters are the syngony, the symmetry class, the lattice constants, and the cleavability. ***Syngony***, ***symmetry class***, and ***lattice constants*** refer to the type of crystal structure and determine the nature of the basic physical properties. The ***cleavability*** is the property of the crystal (of forming) cleavage cracks parallel to definite crystallographic faces. For denoting cleavability we indicate the crystallographic symbol of the system of easy cleavage of faces (e.g. 111 or 100). Qualitatively, the cleavability is characterized as "highly perfect", "perfect" or "imperfect". The crystallographic characteristics of polycrystalline materials are given in the same form as those given for monocrystalline, but are applicable to each separate crystal.

OPTICAL

The ***refractive index***, n, denotes the ratio between the velocity of electromagnetic radiation in a vacuum and the phase velocity of radiation in a given material. For the optically uniaxial Magnesium Fluoride and Sapphire crystals the refractive index is presented both for the ordinary rays, n_o, as well as for the extraordinary rays, n_e.

The refractive index of an optical material depends on its temperature. The values of the ***thermal coefficient of the refractive index*** $\beta\ (t,\lambda) = dn(\lambda)/dt$, deg C^{-1} are presented for the indicated wavelengths within the temperature range from minus 60°C to plus 60°C. For Magnesium Fluoride and Sapphire the relative temperature coefficients of the refractive indices are given for both the ordinary n_o, as well as for the extraordinary n_e rays.

The reflection (Fresnel) loss from one surface may be calculated by the formula:

$$\text{REFLECTION LOSS} = \frac{(n-1)^2}{(n+1)^2}$$

The transmittance of crystalline optical materials is characterized by the spectral transmittance $\tau\ (\lambda)$, spectral internal transmittance $\tau_i\ (\lambda)$, absorbance coefficient $\mu\ (\lambda)$ and transmission range. The ***spectral transmittance*** $\tau\ (\lambda)$ is the ratio between the flux of monochromatic radiation that has passed through the sample of the material and the incident flux of radiation. The ***spectral internal transmittance*** coefficient $\tau_i\ (\lambda)$ is the ratio between the flux of monochromatic radiation that has reached the exit surface of the sample and the flux of radiation that has passed its entry surface. The ***absorbance coefficient***, $\mu\ (\lambda)$, is a magnitude which is inverse to the distance at which the flux of radiation forming a parallel beam is decreased in intensity by a factor of ten. The absorbance coefficient is due to the combined action of absorption and scattering in the material.

The ***absorbance coefficient*** may be calculated by means of the formula:

$$\mu\ (\lambda) = \frac{-\log_{10} \tau_i\ (\lambda)}{\text{Thickness}}$$

where $\tau_i\ (\lambda)$ is the internal transmittance, and Thickness is the thickness of the sample in cm.

The ***transmission range*** of the material shows the wavelengths of light that can pass through the material. Typical transmittance curves $\tau\ (\lambda)$ are given for a sample of 10 mm thickness.

THERMAL

Values are given for the thermal linear expansion, thermal conductivity, specific thermal capacity, thermal stability and fusion temperature of melting points.

Thermal linear expansion α_t, deg C^{-1} characterizes the relative change in length of the sample at a change in temperature of one deg C. It is determined by the formula

$$\alpha_t = \frac{1}{L} \times \frac{dl}{dt}$$

where L is the length of the sample and t is the temperature.

Average values of the thermal linear expansion coefficient are presented within the given temperature ranges. For optically uniaxial Magnesium Fluoride and Sapphire crystals, thermal linear expansion coefficients are given for directions parallel to and at right angles to the optical axis.

Thermal conductivity, $W/(m \cdot \text{deg } C)$, characterizes the capacity of the material to transmit heat and is determined by the amount of thermal energy that has gone through a unit area in a unit time at a unit temperature gradient. For Magnesium Fluoride and Sapphire crystals, thermal conductivity values are given in directions parallel to and at right angles to the optical axis.

Specific heat capacity, **J/(kg·deg C)**, characterizes the energy necessary for heating the material and is determined by the amount of heat needed for warming the material by one degree. Data are presented for specific heat capacity at constant pressure.

Thermal stability, deg C, characterizes the capacity of the material to resist sharp temperature changes without destruction. The measure of thermal stability is the maximum difference in temperature in an abrupt change of the latter, which the sample can withstand without destruction.

Melting points are given in deg C.

MECHANICAL

Density, **g/cm^3** is determined by the ratio between the mass of the sample and its volume. Reference data are presented for densities at room temperature and at normal pressure.

Moh hardness is a relative scale showing the capacity of a material to resist being scratched by another material. Reference values are presented for hardness according to the conditional Moh scale, in which 10 standard minerals are arranged in the order of increasing hardness (Talc, Moh=1 to Diamond, Moh=10).

Vickers microhardness, **Pa**, is characterized by the resistance of the surface of the material to impression by the indentor in the form of a four-faced diamond pyramid at indentor load of 1 Newton. Reference microhardness values are presented for optical uniaxial crystals of Magnesium Fluoride and Sapphire in directions parallel to and perpendicular to the optical axis.

Elastic properties are characterized by the ***constants of elastic compliance*** and by the technical elasticity characteristics: the ***Young modulus***, **Pa**, the ***shear modulus***, **Pa**, and the ***Poisson ratio*** (coefficient of transversal deformation). The constants of elastic compliance are the proportionality coefficients between the stress and deformation components. The elastic properties depend on the crystallographic directions in which the stress and deformation are applied.

For cubic crystals, constants of elastic compliance S11, S12, S44 are given. This makes it possible to carry out transformation of Young's modulus and of the shear modulus in any arbitrary system of coordinates. It is also possible to obtain maximum and minimum values of the Young modulus and the shear modulus corresponding to the crystallographic directions <100> and <111>, as well as the Poisson Ratio.

For optically uniaxial Magnesium Fluoride and Sapphire crystals, six constants of elastic compliance are given, as well as values of the Young modulus and of the shear modulus for directions and faces parallel to and at right angles to the optical axis. Values of the Poisson Ratio are given for two possible positions. The first is used if the stress is directed parallel to the optical axis, and the deformation of the material under effect of this stress is considered in the direction of the plane perpendicular to the optical axis. The second is used if the stress is directed at right angles to the optical axis (in the case of a magnesium fluoride crystal in the direction at right angles to the face <100>). The deformation of the material under action of this stress, being different, is considered in two planes, positioned parallel and at right angles to the optical axis of the crystal. For polycrystalline materials isotropic Young modulus, shear modulus and Poisson ratio are given without regard to the possible effect of texture formation of the material.

CHEMICAL

The chemical properties of the crystalline materials are characterized by ***molecular weight*** and ***solubility***. The ***solubility*** of the material is inversly related to its resistivity against the action of aggressive media: water, acids and organic compounds.