coatings

Editorial

Special Issue: Optical Properties of Crystals and Thin Films

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Crystalline materials and coatings can be found almost everywhere in the modern world. Crystals are used, for instance, in acoustooptical devices [1], Pockels' cells [2], Q-switches [3], optical parametric oscillators [4], optical switches for gigahertz frequencies [5], optical spatial low-pass filters [6], tunable filters [7], as a material for holographic information recording [8], laser matrixes [9], optical waveguides [10], and as photorefractive and photoconductive material [11]. Crystalline materials displaying a number of properties are used in two-wave and four-wave mixing [12], optical phase conjugation [13], phase and frequency shifters [14], real-time holography [15], optical data storage [16], electro-optical modulation [17], X-ray information and dosimetry [18], active material of electromagnetic calorimeters [19], deflectors [20], scanners [21], and valuable active centers of Raman lasers [22].

Thin coatings are used in many technological areas such as decorative coatings, tribological coatings, biomedical coatings, self-cleaning coatings, etc. The use of thin-layer coatings has expanded to many other applications in the optical industry, such as antireflective coatings [23], scratch-resistants [24], reflecting UV and IR rays [25].

Antireflective coatings are an example of optical coatings that reduce the reflection of optical surfaces, i.e., in photo lenses. Importantly, these changes can be achieved without significantly increasing the cost of the element (the base material and manufacturing technologies remain the same, and the cost of the coating itself is low). Optical coatings deposited in the form of layers of metallic or ceramic material on an optical material (i.e., a lens made of glass or plastic) serve to change its transmission and reflection. Thin layers are also used, among others in photovoltaic elements, as an optically active layer [26]. Another application of thin films as optical coatings are thin-film polarizers, or optical polarizers, which rely on the interference effect of a thin dielectric layer. Optical polarizers are used, for example, as a basic element of LCD displays to reduce glare in optical systems. Optical interference coatings have been applied for a broad variety of uses as high reflection mirrors [27], such as low reflection optics [28], telecommunications [29], solar energy management [30], infrared sensors [31], and others.

Therefore, for crystals and thin films for optical applications, the parameters characterizing their optical properties such as transmission, reflection, absorption, refractive index, optical band gap width, optical oscillator strength, cross-section of the laser transition, Urbach energy, and many others are very important. Investigations into the optical properties of thin films and crystals include very well-developed methods like reflectivity and transmission/absorption measurement. These measurements are performed using spectrometers that, regardless of their configuration, have a light source; a monochromator, i.e., a device capable of selecting wavelength components; and a light detector. The different wavelengths of the spectrum can be broken down into the frequency spectrum with diffraction grating systems or prisms. Fabry-Perot spectrometers belong to the class of narrowband spectrometers with optical filters. An alternative analysis uses the Fourier transform of the signal to obtain a time-dependent signal (Fourier transform spectrometers). The basic parameter that characterizes the optical material is its absorption. For example, in photovoltaic structures, the absorption of the active layer should be very high (on the order of 10^5 cm^{-1} and higher), while for solid-state laser matrix, minimum material absorption values in the transparency area are required, without the presence of color centers absorption bands (unless they are intended as sensibilizator or active centers of lasers), the presence of which worsens the characteristics of the solid-state laser. Thin layers for optical applications should be characterized, inter alia, by high homogeneity. This homogeneity can be confirmed by optical tests, including optical spectroscopy. For thicker homogeneous films, the optical reflectance and transmittance spectra show several interference patterns, which can be used to obtain the optical constant using Swanepoel and other related methods. Therefore, the Swanepoel method allows us to determine the dispersion of the refractive index of the layer and its thickness based on the layer transmission measurements [32]. In the absence of interference, it is possible to determine the refractive index of the layer as a function of the wavelength from transmission and reflection measurements, according to the theory of Leupacher and Penzkofer [33].

Knowledge of the absorption of the material allows for the determination of the extinction coefficient, which determines its optical quality. With the knowledge of the extinction coefficient and refractive index, it is possible to determine the real and imaginary components of the dielectric constant from optical measurements.

Ellipsometry is another optical technique, after optical spectroscopy, commonly used to characterize thin films using the properties of polarized light. The change in polarization is measured after the light is reflected from the surface of the thin film. These changes depend on the thickness, refractive index, and absorption coefficient of the thin film and the substrate. This method allows, among others, to determine the refractive index of thin layers [34].

Based on the absorption spectrum by the Tauc method [35], the optical band gap width can be determined. It is an important parameter characterizing optical materials-the optical band gap is the threshold for photons to be absorbed. For example, it plays an important role in photovoltaic systems based on thin films. The optical band gap determines what portion of the solar spectrum a photovoltaic cell absorbs because material will not absorb photons of energy less than the band gap, and the energy of the electron-hole pair produced by a photon is equal to the band gap energy. For materials with high absorption, reflection spectra can be used instead of measuring the absorption spectra to determine the optical band gap. According to the theory of P. Kubelka and F. Munk [36], measured reflectance spectra can be transformed to the corresponding absorption spectra by applying the Kubelka–Munk function, which enables the correct determination of the optical band gap based on the reflection spectrum [37].

When there are structural defects in materials, their presence is often manifested by a distortion of the basal absorption edge, which leads to the formation of the Urbach tail. From optical measurements, it is possible to determine the Urbach energy characterizing the width of the tails of the bands. Urbach energy has been shown to increase with dangling bond density in hydrogenated amorphous silicon [38] and has been shown to be strongly correlated with the slope of evaluated band tails [39].

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