

OPTICAL PROPERTIES OF POLYCRYSTALLINE PbSe FILMS IN THE IR RANGE OF THE SPECTRUM

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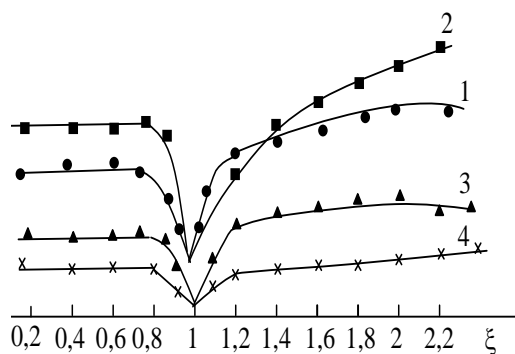
ABSTRACT

Here we consider the optical properties of the PbSe film based on the method. At the same time, special attention was paid to the effect of the annealing time duration on the optical spectra. Naturally, arbitrary changes in the technological parameters of film production lead to changes in its optical characteristics, for example, the shape and position of the absorption band, the dispersion of the refractive index, and the reflection spectrum.

Keywords: annealing time, absorption coefficient, transmittance, refractive index, IR light

Experimental studies show that the transparency coefficient tends to zero, shifting to the long-wavelength region of the spectrum at different annealing times. This leads to an increase in the absorption coefficient of the films. The special character of the absorption spectrum of absorption films monotonically increases in the region $\hbar\omega \geq \kappa T$

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Rice. 1. Dependence of the reflection coefficients of PbSe films on $\xi = \omega / \omega_0$ at different annealing times

In fig. 1 shows the reflection spectra at room temperature, obtained on the basis of measuring the transparency of PbSe film samples. It can be seen from the graphs that there are several bands in the reflection spectra of the films, although they are of a general nature, at the same time they differ in the position of the absorption bands, which experience shifts in the energy scale and some changes in intensity. It was experimentally established [1] that with an increase in the annealing time, the spectral dependence of the absorption coefficient changes in a complex manner.

It has been experimentally proven that for a film thickness of more than 10 μm , the interference pattern does not make a significant contribution to the transmittance. If the absorption in the film ($\kappa^2 \ll n^2$) is small, then the maximum of interference appears under the condition:

$$2nd = m\lambda, \quad (1)$$

where n is the refractive index, d is the film thickness, m is a positive integer characterizing the order of the interference maximum. Formula (1) allows calculating the thickness of polycrystalline films.

The thickness was measured by the weighing method and by the interference method in the MII-4 setup. The results obtained practically coincide. In these samples (17 μm thick), the transmittance tends to zero at a wavelength of 4 μm . IR measurements of the absorption spectrum of films with different concentrations of charge carriers were carried out at room temperature.

The absorption of light by free carriers in polycrystalline films is observed under the condition of low energy of quanta $\hbar\omega < \kappa T$. In this case, a minimum is observed in the IR reflection spectrum. By comparing the theoretical and experimental values of the minimum reflection coefficient, one can determine the electrophysical parameters of inhomogeneous PbSe films. From the experimentally observed curve, the reflectance spectra determine $R_{min}=R \rightarrow 0$ and the wavelength $\lambda_{min}=\lambda_p$, as well as a number of other kinetic parameters of the films.

To determine the optical constants of the film, it is necessary to remove the spectral dependence of the transmittance of the clean substrate and the film-substrate system. In the case of a thin film on a transparent substrate, we used formulas that relate the transmission of the film-substrate system with the film thickness and optical parameters of the film and substrate.

For narrow-band degenerate samples, the spectral curves of optical reflection in the IR region exhibit a minimum due to plasma oscillations of charge carriers. The value of the frequency at the minimum of reflection ω_{min} is related to the plasma frequency ω_p . The value of ω_{min} allows one to determine the effective mass of carriers if their concentration N is known. In addition to the effective mass, measuring the reflection in the plasma resonance region allows one to find the conductivity, carrier mobility, their relaxation time, and other optical characteristics.

In a real crystal, relaxation phenomena must be taken into account. Taking this into account leads to the appearance in the expression for the complex dielectric constant of a term that depends on the relaxation time. In this case, for the real and imaginary parts of the dielectric constant, we will have [2]

$$\text{Re } \varepsilon = \text{Re } \varepsilon_{\infty} - \frac{4\pi e^2 N}{m^*} \left\langle \frac{\tau^2}{1 + \omega^2 \tau^2} \right\rangle, \quad (2)$$

$$\text{Im } \varepsilon = \text{Im } \varepsilon_{\infty} - \frac{4\pi e^2 N}{m^* \omega} \left\langle \frac{\tau}{1 + \omega^2 \tau^2} \right\rangle, \quad (3)$$

where τ is the relaxation time of current carriers; $\text{Re } \varepsilon_{\infty}$ and $\text{Im } \varepsilon_{\infty}$ are the real and imaginary parts of the dielectric constant of the films at $\lambda \rightarrow 0$ ($\omega \rightarrow \infty$).

The main parameters of the PbSe film, depending on the annealing time. Table 1

t_{an}	ε_{∞}	n	d, mkm	K, reg.unit	$\langle \tau \rangle$, $10^{-12}s$	σ_0 , $Om^{-1}sm^{-1}$	μ , sm^2/Vs	$N \cdot 10^{-16}$, sm^{-3}	$\frac{m^*}{m} \cdot 10^2$
Not annealing.	860	7,37	0,14	410	2,27	0,057	5,2	6,85	0,78
30 min	730	12,81	0,13	220	1,22	0,026	2,37	6,86	0,92
80 min	612	11,2	0,116	220	1,22	0,022	1,97	6,97	1,1
120 min	618	7,38	0,09	120	0,66	0,012	1,1	6,86	1,09
180 min	370	9,79	0,02	90	0,5	0,005	0,45	6,87	1,82

CONCLUSION

The results of the calculations are presented in Table 1. It also shows the experimentally determined values of the high-frequency dielectric constant ε_{∞} of the refractive index n, thickness d, coefficient of tensorsensitivity K, specific electrical conductivity σ_0 of films and mobility μ of charge carriers.

The experimental results obtained from optical spectra are in qualitative agreement with the data obtained by other methods, for example, by Hall measurements.

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