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THE RESEARCH ON THE INFLUENCE OF HEAT TREATMENT ON TRANSMISSION SPECTRA ZnSe THIN FILMS

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The optical transmission spectrums for ZnSe thin films have been obtained in the spectral domain of 330 – 1400 nm. With the growth of the film thickness we observe a growth in the number of interference maxims and minims, and for the thickness of d > 0.77μm, the difference between maximal and minimal transmission decreases.

The presence of interference maxims and minims in transmission spectrums is determined by the multiple reflections from the film surface and represents an index that the samples are uniform and that film surfaces are plane.

For thin layers with thickness d < 0.60 μm heat treatment leads to an increase in maximum and minimum interference, while for phase with the thickness d > 0.60 μm thermal treatment practically does not change the shape of the transmission spectrum.

INTRODUCTION

The study of optical properties of semiconductor thin films, such as transmission spectra, reflection and absorption, refractive index dispersion in certain spectral areas and the influence of heat treatment on them, allows to obtain important information on the energy band structure of semiconductors and the mechanism of interaction of electromagnetic radiation with the thin film. Correlating these results with those obtained in the study of their transport phenomena, one can obtain accurate information of the general characteristics of these films [1-9].

The purpose of this paper is to analyze the evolution of transmission spectra of ZnSe thin films depending on their thickness and heat treatment.

EXPERIMENTAL DETAILS

For the preparation of ZnSe thin films on glass substrates the method of thermal evaporation in a limited volume vacuum was used [10].

The structure of samples was studied by means of X-ray diffraction, scanning electron microscopy and atomic force microscopy. Research has shown that the films are polycrystalline and crystallize in the form of a blend of zinc [11].

Thickness *d*, of thin films ranged between 0.10 μm and 1.30 μm and was measured by an interferential microscope MII-4 (Linnik type) [12].

The deposit rate r_d means the ratio of the total thickness of the deposited film and the deposition time. For thin films prepared by us the deposition rate ranged 1.20 - 1.95 nm/s.

We used the UV-VIS spectrophotometer type Q-II (Carl Zeiss) to obtain the transmission spectra of thin films of ZnSe in spectral range 330 – 1400 nm. Q-II spectrometer contains a light source, which may be a special measuring ultraviolet lamp or an incandescent lamp for measurement in the visible domain and near infrared. Electromagnetic radiation is decomposed by a monochromator that uses a prism as dispersive element. A photomultiplier to ultraviolet range of the spectrum or the visible photocell is used as a radiation detector. Between the slot output of the monochromator and the detector device is fixed the sample that must be studied.

A sample consists of two main components: a glass transparent support and a ZnSe thin film (Fig. 1). In this case, the transmission coefficient of the sample will be

$$\mathrm{T}_{\text{sample}} = \frac{J_{\mathrm{T}_2}}{J_0} = \frac{J_{\mathrm{T}_2}}{J_{\mathrm{T}_1}} \cdot \frac{J_{\mathrm{T}_1}}{J_0} = \mathrm{T}_{\text{sub}} \cdot \mathrm{T}_{\text{film}} . \quad (1)$$

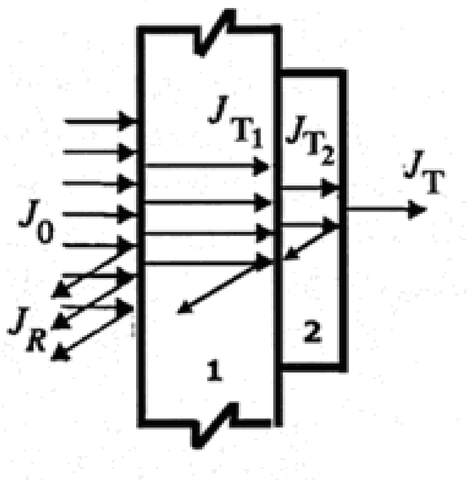

Fig. 1. Optical transmission in a sample.

Therefore, the experimental determination of transmission coefficient went through the following steps:

a) measuring the sample transmission coefficient (film + support) (T_{sample});

b) measuring the substrate transmission coefficient (T_{sub});

c) calculating the transmission coefficient of thin films according to the relationship

$$T = T_{film} = \frac{T_{sample}}{T_{sub}} \cdot 100\,\% . \qquad (2)$$

The termal treatment of ZnSe thin films consisted of their slow heating up to 500K, keeping them for 5-10 minutes at maximum temperature and then their slow cooling at room temperature. The transmission spectra were analyzed according to the film thickness and the influence of thermal treatment.

EXPERIMENTAL RESULTS AND DISCUSSIONS

Fig. 2 represents the transmission spectra of nine ZnSe thin films before and after their thermal treatment. Analysis of experimental results show two modes of transmission. For thin layers with a thickness less than 0.60 μm the thermal treatment leads to an increase of the number of maximum and minimum of interference transmission spectrum, and for thin layers with a thicknesses greater than 0.60 μm the thermal treatment practically does not change the shape of spectrum transmission.

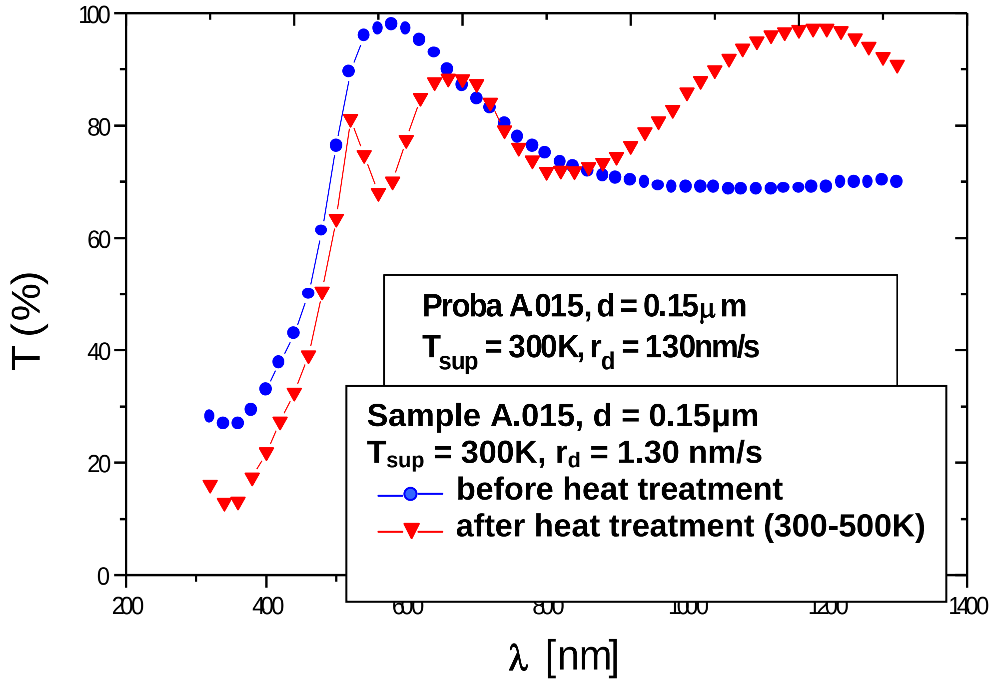

Fig. 2. Influence of thermal treatment on the transmission spectrum of the A.015 sample.

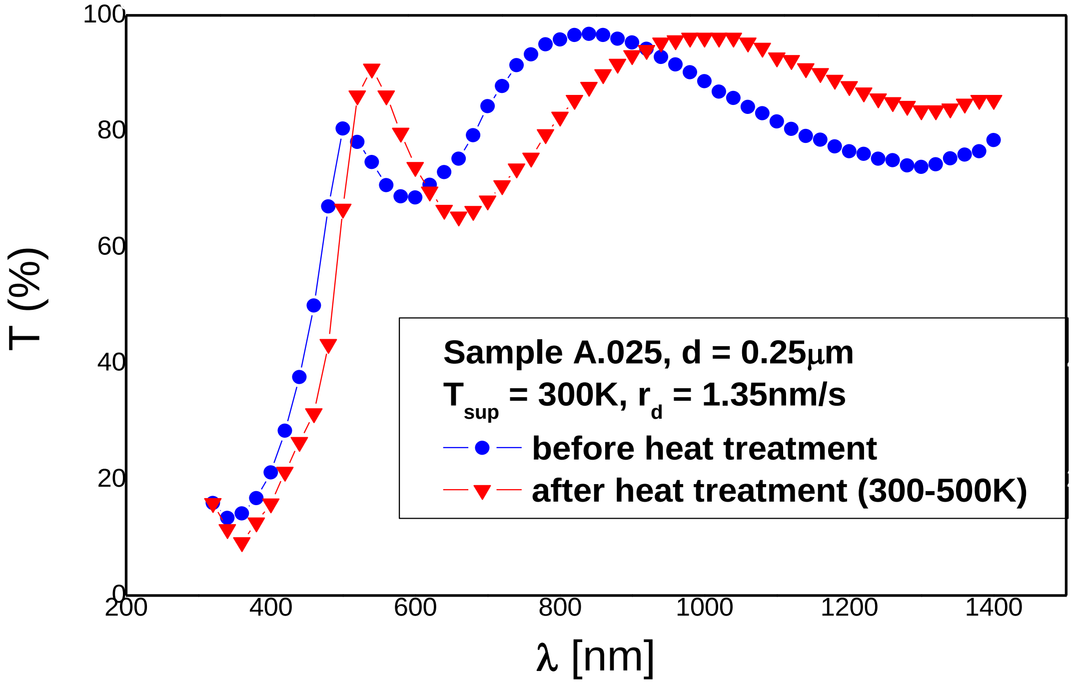

Fig. 3. Influence of thermal treatment on the transmission spectrum of the A.025 sample.

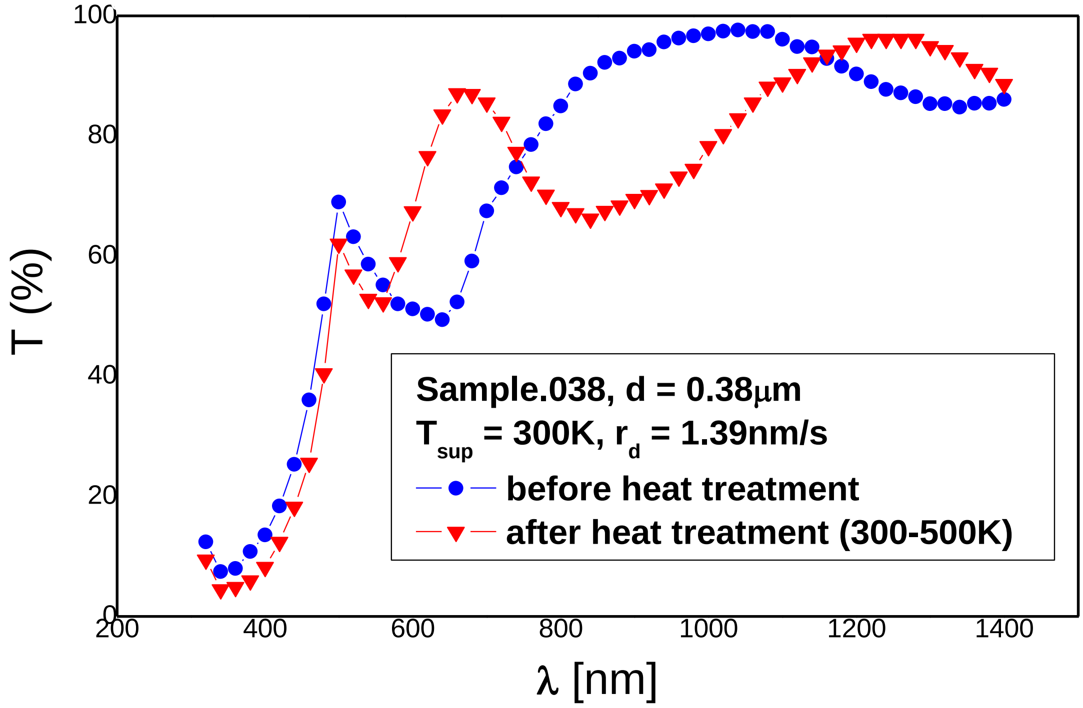

Fig. 4. Influence of thermal treatment on the transmission spectrum of the A.038 sample.

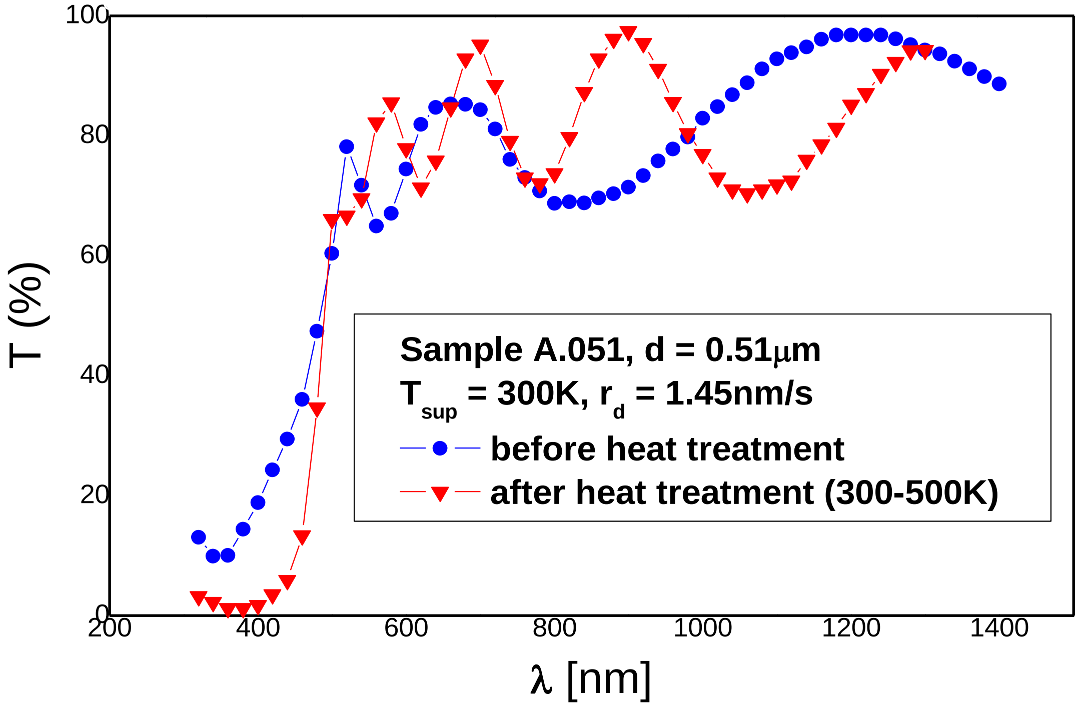

Fig. 5. Influence of thermal treatment on the transmission spectrum of the A.051 sample.

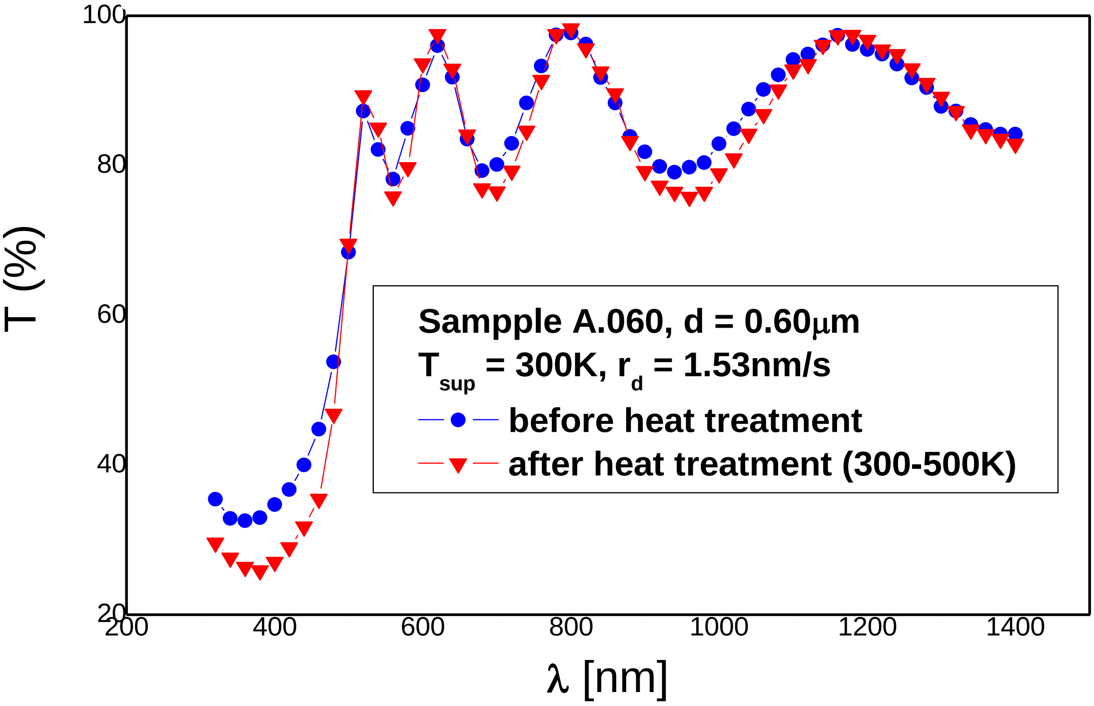

Fig. 6. Influence of thermal treatment on the transmission spectrum of the A.060 sample.

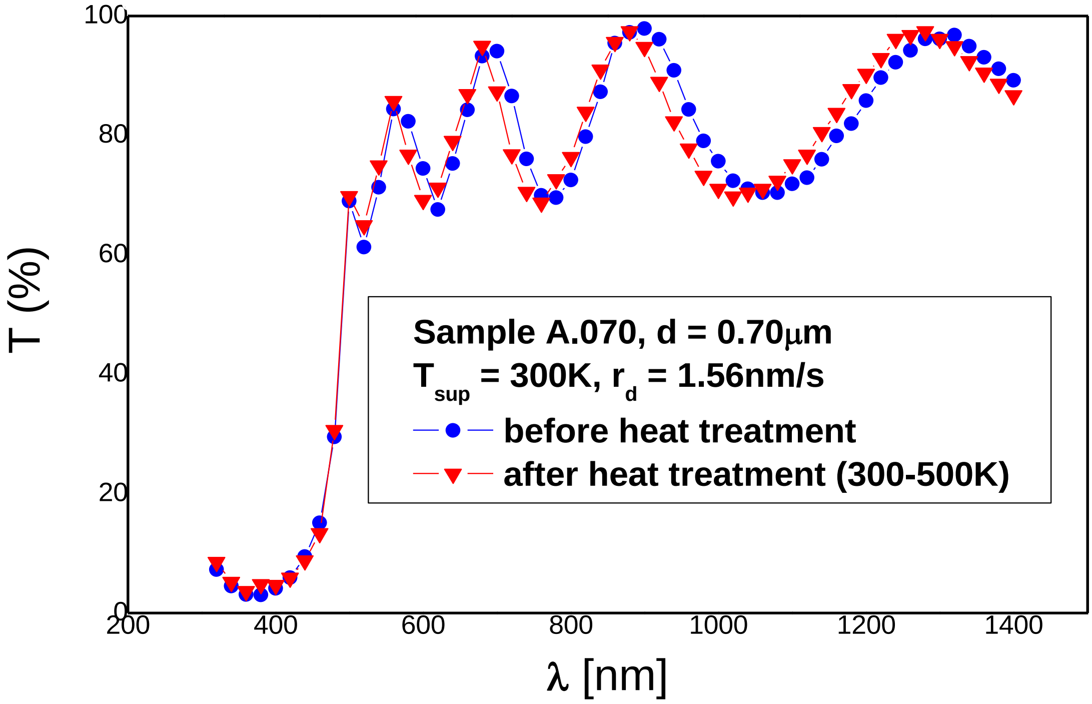

Fig. 7. Influence of thermal treatment on the transmission spectrum of the A.070 sample.

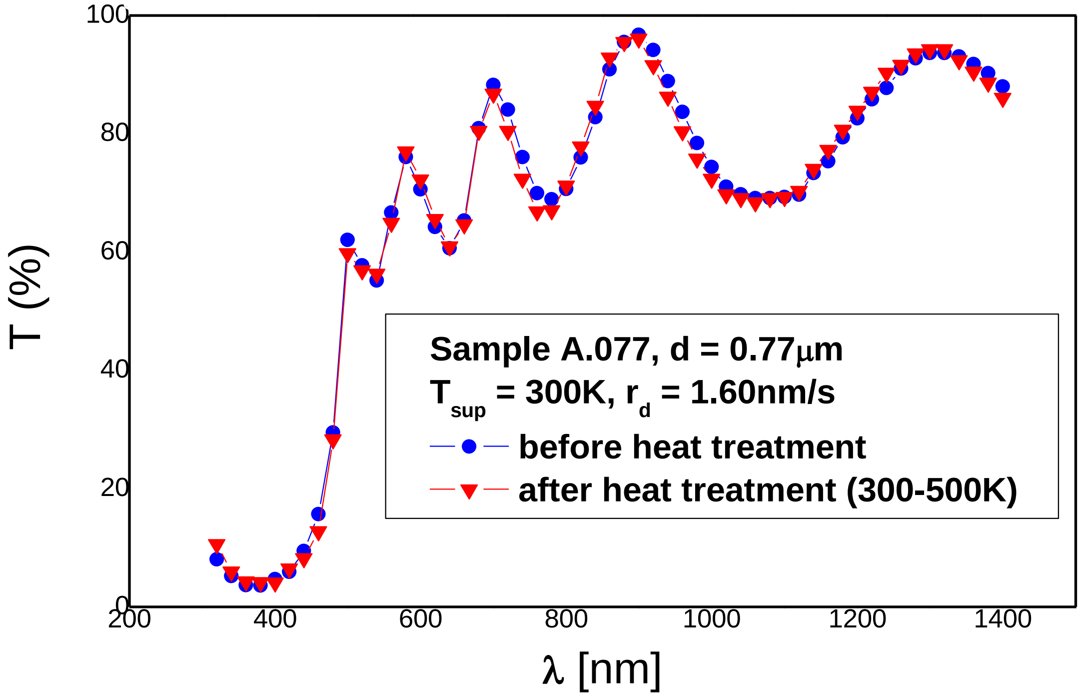

Fig. 8. Influence of thermal treatment on the transmission spectrum of the A.077 sample.

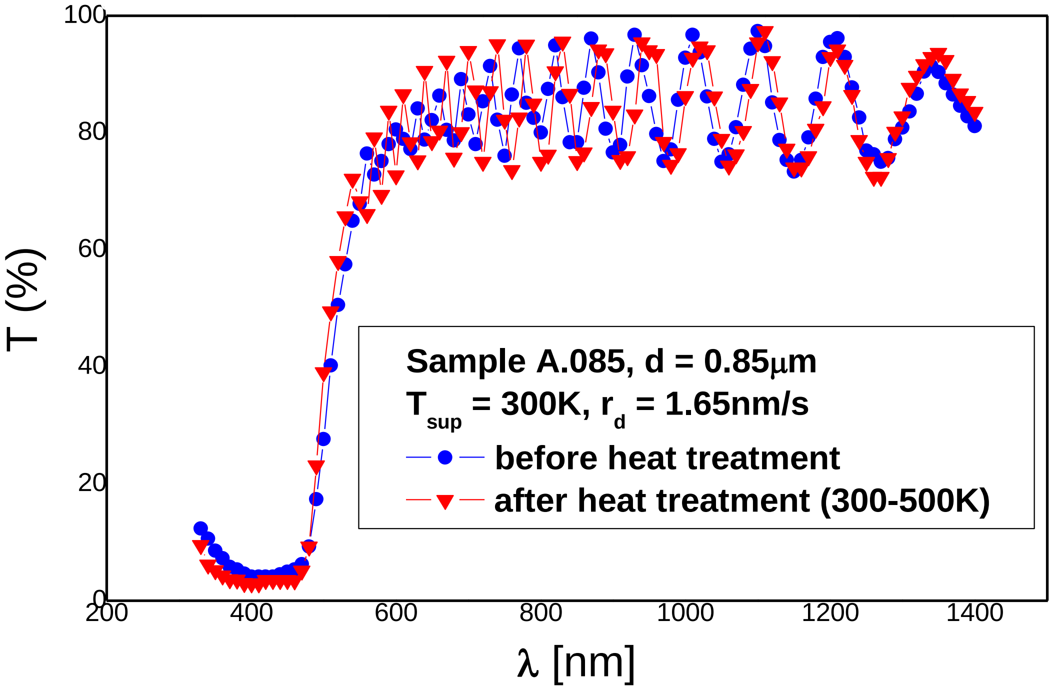

Fig. 9. Influence of thermal treatment on the transmission spectrum of the A.085 sample.

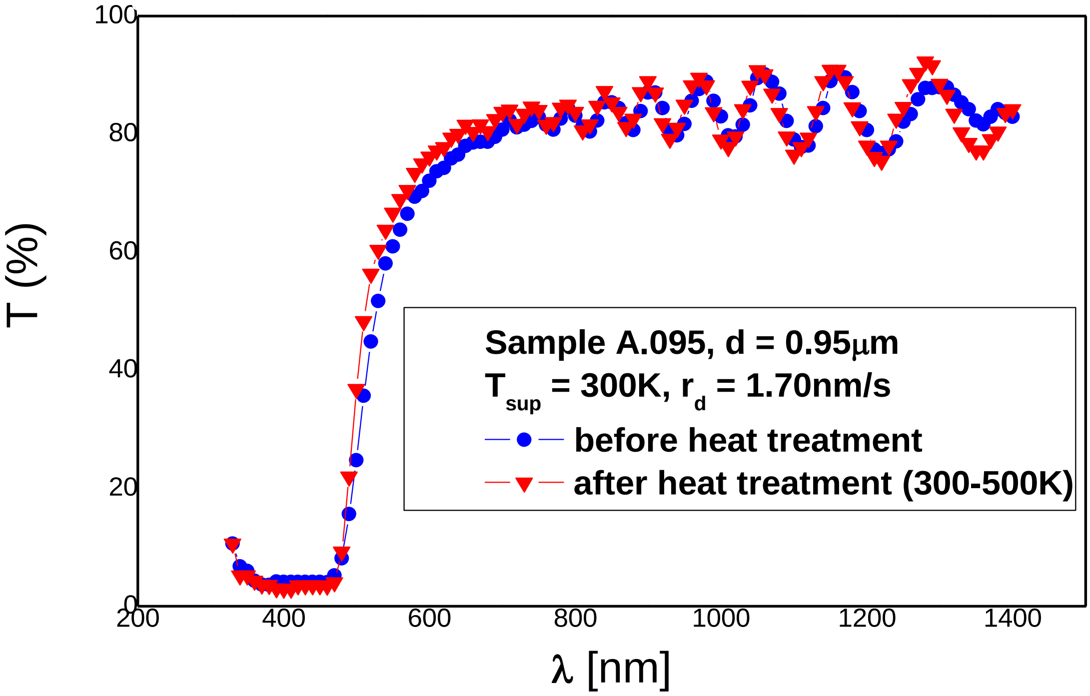

Fig. 10. Influence of thermal treatment on the transmission spectrum of the A.095 sample.

We will initially analyze the transmission spectra for samples that were not treated thermally. Transmission of sample A.015 (Fig. 2) increases abruptly up to a maximum and then decreases slowly in the interval between 600 and 900nm, after which it depends little on the wavelength. In sample A.025 (Fig. 3) two maximum transmissions appear, in sample A.051 (Fig. 5) – three, in sample A.060 (Fig. 6) - four, and in sample A.077 (Fig. 8) - five. The transmission spectra for samples with a thickness higher than 0.80μm include of a set of maximum and minimum, and the difference between maximum and minimum transmission decreases when the thickness of ZnSe thin films increases.

The first maximum from all transmission spectra corresponds to the wavelength of about 460nm. The energy of this maximum is about 2.7 eV and coincides with the ZnSe band gap width. Thus, we assign this energy to the transition valence band - conduction band at the Brillouin zone center.

The presence of other maximums in the transmission spectra is probably determined by deep energy levels, located within the band gap. In ZnSe crystals, the native defects are interstitial zinc atoms (Zn_i) and selenium vacancy (V_{SE}). Zn_i donor levels are located lower than the conduction band minimum (ΔE_d = 0.90 eV) and the acceptor levels V_{SE}, are located above the top of the valence band (ΔE_a = 0.01 eV) [13]. Thus, we believe that the other maximums in the transmission spectra can be associated with the transitions acceptor level - donor level, donor level - conduction band, valence band - acceptor level.

In films with a thicknesses higher than 0.80 μm the decrease of transmission can be explained by the increase of absorption coefficient in these films [12].

The presence in the spectra of transmission of maximum and minimum due to the interference of beams resulting through in multiple reflections on the surface film is an indication that the samples are uniform in terms of thickness and surface films are flat. In fact, this was revealed through atomic force microscopic studies [12], indicating that the free film surface roughness is small. A high rough or uneven thickness would have led to the disappearance of interference, i.e. the disappearance of minimums and maximums of the interference transmission spectra [14, 15].

If a untreated thermally - sample spectrum A.015 (Fig. 2) consists of a single maximum, after the treatment, three maximum of interference occurs. The increase from two to three of the number of maximums for sample A.038 (Fig. 4), from three to five – for sample A.051 (Fig. 5) shows that the thermal treatment of these films leads to improving the crystallization level of the layers.

An analogous behavior was also observed for other semiconductor thin films [7].

CONCLUSIONS

The obtained transmission spectra can be used to determine the absorption coefficient, of the refractive index and other characteristic sizes of thin films. They can obtain important information on the basis of which one can manufacture various optical and optoelectronic devices.

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CERCETAREA INFLUENŢEI TRATAMENTULUI TERMIC ASUPRA SPECTRELOR DE TRANSMISIE ALE STRATURILOR SUBŢIRI DE ZnSe

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Spectrele de transmisie optică pentru straturile subţiri de ZnSe au fost obţinute în domeniul spectral 330-1400nm. Odată cu creşterea grosimii straturilor, creşte şi numărul maximelor şi minimelor de interferenţă, iar pentru grosimi $d > 0.77\mu m$ diferenţa dintre transmisia maximă şi minimă se micşorează.

Prezenţa maximelor şi minimelor de interferenţă în spectrele de transmisie sunt datorate reflexiilor multiple de pe suprafaţa stratului şi reprezintă un indiciu că probele sunt uniforme şi că suprafeţele straturilor sunt plane.

Pentru straturile subţiri cu grosimi $d < 0.60\mu m$ tratamentul termic conduce la creşterea numărului de maxime şi minime de interferenţă, iar pentru cele cu grosimi $d > 0.60\mu m$ tratamentul termic, practic, nu modifică forma spectrului de transmisie.

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