# XLVI-th IEEE-SPIE Joint Symposium Wilga 2020

# OPTICAL ABSORPTION STUDIES OF $(Ga_{0.1}In_{0.9})_2Se_3$ THIN FILM


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## ABSTRACT

Thermal evaporation technique was used to deposit$(Ga_{0.1}In_{0.9})_2Se_3$ thin films. The optical transmission spectra of $(Ga_{0.1}In_{0.9})_2Se_3$ thin film were studied in the temperature range 77-300 K. Temperature behaviour of the Urbach absorption edge as well as the temperature dependencies of the energy pseudogap and Urbach energy were investigated. The influence of different types of disordering on the optical properties of $(Ga_{0.1}In_{0.9})_2Se_3$ thin film was discussed. Optical parameters of $(Ga_{0.1}In_{0.9})_2Se_3$ thin film and single crystalwere compared.


## EXPERIMENTAL RESULTS AND DISCUSSION

Interferential transmission spectra of (Ga0.1In0.9)2Se3 film at various temperatures within the range of 77–300 K are shown in Fig.1. With temperature increase, a red shift of the transmission spectra and decrease of transmission in the interferential maxima are observed. Optical absorption edge spectra in the range of their exponential behaviour in (Ga0.1In0.9)2Se3 thin film are presented in Fig.2. It should be noted that similarly to the (Ga0.1In0.9)2Se3single crystal they are described by the Urbach rule

$$\alpha(h\nu,T)=\alpha_o\cdot\exp\left[\frac{\sigma(h\nu-E_0)}{kT}\right]=\alpha_o\cdot\exp\left[\frac{h\nu-E_0}{E_U(T)}\right]$$

where $E_U$ is the Urbach energy (a reciprocal of the absorption edge slope $E_U^{-1}$=(ln $\alpha$)/D($h\nu$)), $s$ is the absorption edge steepness parameter, $\alpha_0$ and $E_U$ are the convergence point coordinates of the Urbach bundle, $h\nu$ is photon energy. The coordinates of the Urbach bundle convergence point $\alpha_0$ and $E_0$ for $(Ga_{0.1}In_{0.9})_2Se_3$ thin film as well as for $(Ga_{0.1}In_{0.9})_2Se_3$ single crystalare given in Table 1.

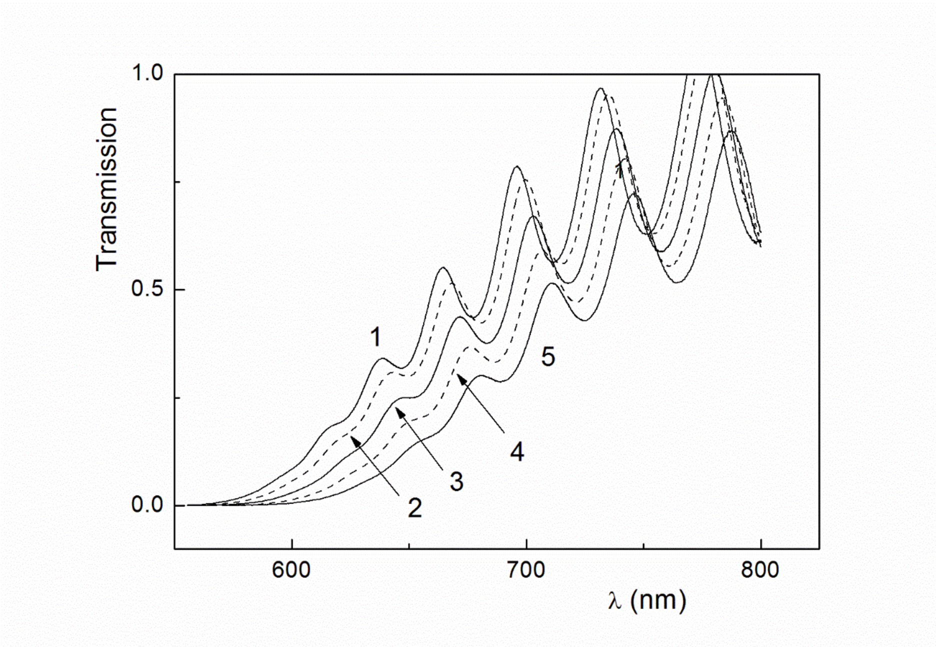


Fig. 1. Optical transmission spectra of (Ga0.1In0.9)2Se3 thin film at various temperatures: (1) 77, (2) 150, (3) 200, (4) 250 and (5) 300 K.

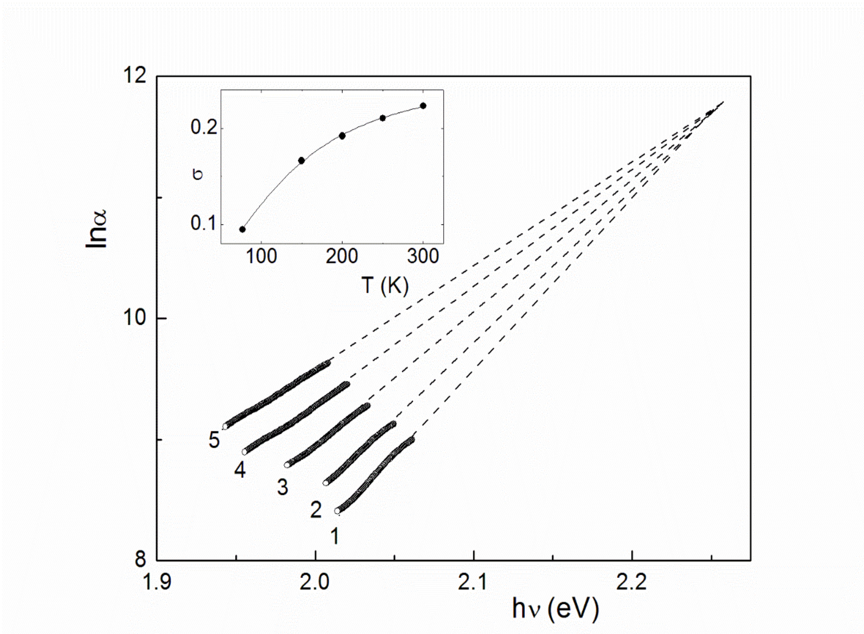


Fig. 2. Spectral dependences of the absorption coefficient for $(Ga_{0.1}In_{0.9})_2Se_3$ thin film at various temperatures: (1) 77, (2) 150, (3) 200, (4) 250 and (5) 300 K. The insert shows the temperature dependence of the steepness parameter $\sigma$.

The temperature variation of the Urbach absorption edge in the thin film similarly to single crystal is explained by electron-phonon interaction (EPI).The insert to Fig.2 shows the temperature dependence of absorption edge steepness parameter σ. From the dependence of σ(T) the EPI parameters are calculated using the Mahr formula

$$\sigma(T)=\sigma_0\cdot\left(\frac{2kT}{\hbar\omega_p}\right)\cdot\tanh\left(\frac{\hbar\omega_p}{2kT}\right)$$

where $\hbar w_p$ is the effective phonon energy in a single-oscillator model, describing the electron-phonon interaction (EPI), and $s_0$ is a parameter related to the EPI constant $g$ as $s_0 = (2/3)g^{-1}$ (parameters $\hbar w_p$ and $\sigma_0$ are given in Table 1). For$(Ga_{0.1}In_{0.9})_2Se_3$thin film $\sigma_0$< 1 that is the evidence for the strong EPI. It should be noted that in the thin film, compared to the single crystal, the EPI is enhanced (this corresponds to a decrease of the $\sigma_0$ parameter) and the energy $\hbar w_p$ of the effective phonon, taking part in absorption edge formation, increases (Table 1).

Among the numerous theoretical treatments of the Urbach rule the most often cited are (i) Sumi and Toyozava model of self-trapped exciton and (ii) Dow-Redfield (DR) microelectric-field theory (internal Franz-Keldysh effect). According to this theory, the broadening of the excitonic maxima with temperature and the resulting exponential absorption edge is related to the interaction of exciton with microelectric fields generated by LO phonons in ionic crystals. To check whether the DR theory could describe the EPI in $(Ga_{0.1}In_{0.9})_2Se_3$ thin film as well,we have applied the procedure suggested in Ref., where the influence of external electric field $F_e$, causing the internal Franz-Keldysh effect, is replaced by the root-mean square value of the phonon-induced internal electric field $F_p$, leading to the expression

$$E_g^{\alpha}(T)\cdot\tanh\left(\frac{\hbar\omega_p}{2kT}\right)=E_g^{\alpha}(0)-E_0\cdot\left[1-\tanh\left(\frac{\hbar\omega_p}{2kT}\right)\right]$$

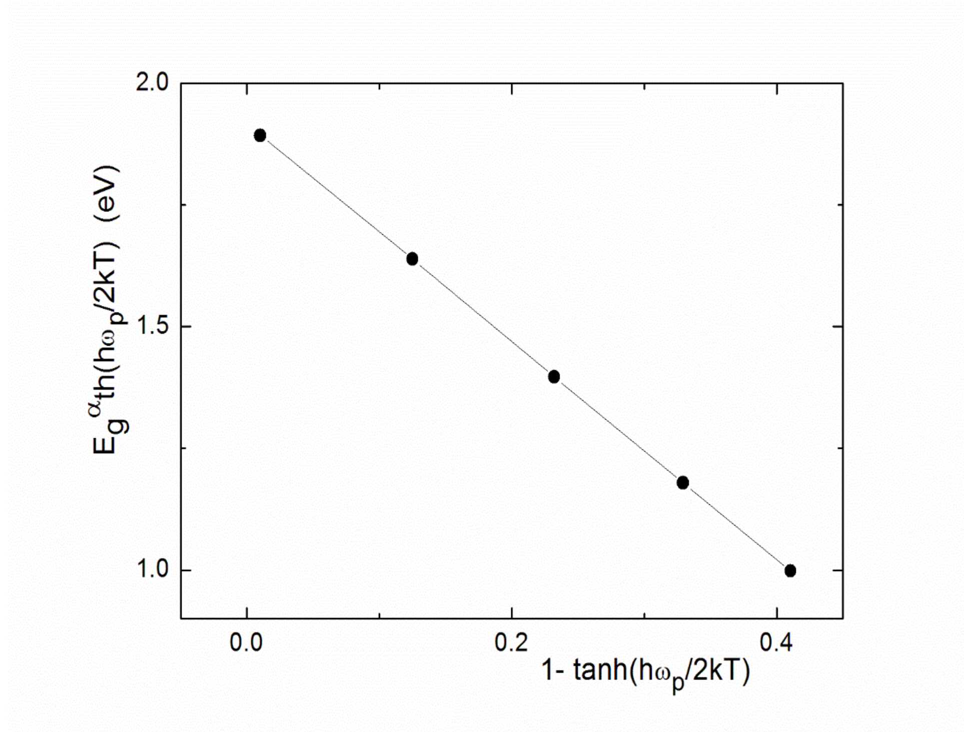


Fig. 3. Linearity between $E_g^{\alpha}(T)\cdot\tanh\left(\frac{\hbar\omega_p}{2kT}\right)$ and $1-\tanh\left(\frac{\hbar\omega_p}{2kT}\right)$ for $(Ga_{0.1}In_{0.9})_2Se_3$ thin film.

Table 1. Parameters of Urbach absorption edge and EPI for $(Ga_{0.1}In_{0.9})_2Se_3$ single crystal (for $E||c$ polarization) and $(Ga_{0.1}In_{0.9})_2Se_3$thin film

| Material | single crystal | thin film |
|---|---|---|
| $\alpha_0$ (cm$^{-1}$) | $1.8\times10^9$ | $1.3\times10^5$ |
| $E_0$ (eV) | 2.395 | 2.256 |
| $E_g^{\alpha}$ (eV) | 1.940 | 1.693 |
| $E_U$ (meV) | 31 | 116 |
| $\sigma_0$ | 0.922 | 0.256 |
| $\hbar\omega_p$ (meV) | 29 | 35 |
| $\theta_E$ (K) | 337 | 408 |
| $(E_U)_0$ (meV) | 16 | 69 |
| $(E_U)_1$ (meV) | 32 | 137 |
| $E_g^{\alpha}(0)$ (eV) | 2.160 | 1.916 |
| $S_g^{\alpha}$ | 15.3 | 18.5 |

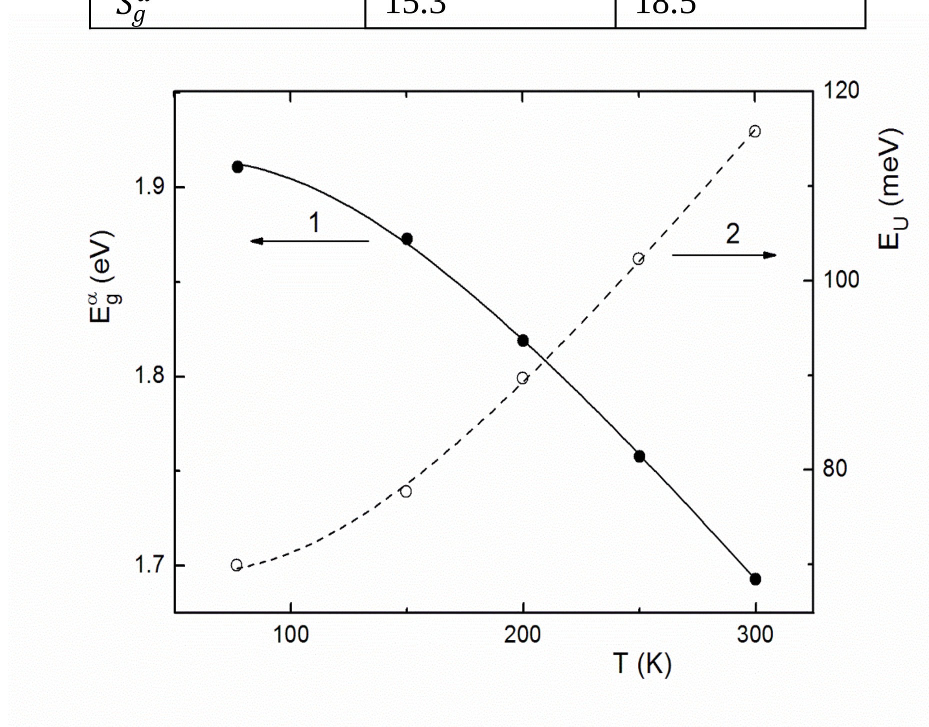


Fig. 4. Temperature dependences of the energy pseudogap $E_g^{\alpha}$ and Urbach energy $E_U$ for $(Ga_{0.1}In_{0.9})_2Se_3$ thin film.

It is well-known that the Urbach energy $E_U$ is known to characterize the degree of the edge smearing due to disordering induced by several internal and external factors.For the thin film the lengthy Urbach tails which result in the high value of the Urbach energy $E_U$ are observed. The influence of temperature and structural disordering on the shape of Urbach absorption edge is studied. Thus, according to the references the Urbach energy $E_U$ is described by the equation

$$E_U=(E_U)_T+(E_U)_X+(E_U)_C=(E_U)_T+(E_U)_{X+C}$$

where $(E_U)_T$, $(E_U)_X$ and $(E_U)_C$ are the contributions of temperature, structural and compositional disordering to $E_U$, respectively. Note that in the thin films under investigation the temperature disordering arises due to the thermal vibrations of atoms, structural disordering results from the presence of defects, pores, topological disorder in the location of atoms etc, and compositional disordering is determined by substitution of atoms of different chemical elements. In thin film we have observed: (1) the red shift of the optical absorption edge of thin film compared to the single crystal; (2) thin film is more disordered than single crystal, since the Urbach energy increases from 31 meV to 116 meV; (3) EPI enhances and phonon energy increases; (4) the absolute value of the sum of structural and compositional disordering contribution in to the Urbach energy increases from 16 meV to 69 meV and the relative contribution increases from 52% to 60%.

## CONCLUSIONS

$(Ga_{0.1}In_{0.9})_2Se_3$ thin film was deposited onto a quartz substrate by thermal evaporation technique.The spectral dependences of the absorption coefficient were derived from the spectrometric studies of interference transmission spectra. Temperature variation of the transmission spectra as well as the temperature behaviour of the absorption edge spectra in the range of its exponential behaviour were studied. A typical Urbach bundle was observed, temperature dependences of the energy pseudogap and the Urbach energy were analysed. The influence of different type of disordering on the Urbach tail was studied andthe comparation of the Urbach absorption edge parameters for $(Ga_{0.1}In_{0.9})_2Se_3$ thin film and single crystal was performed. It is shown thatDow-Redfield microelectric-fieldwell explained the electron-phonon interaction in $(Ga_{0.1}In_{0.9})_2Se_3$ thin film.