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Infrared reflection spectra of the films of topological insulator $Pb_{1-x}Sn_xSe$ on the substrates ZnTe/GaAs

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Abstract. Infrared reflectivity spectra of the 700 nm thick topological insulator $Pb_{1-x}Sn_xSe$ films grown by the molecular beam epitaxy technique on ZnTe/GaAs substrates were studied. Using dispersion analysis of reflectivity spectra plasmon and phonon parameters for the samples under study were obtained.

Narrow-gap alloys type IV – VI , such as PbSnSe, PbSnTe has generated great interest from fundamental and applied points of view in the 70s-80s years of the last century. Changing the concentration of Sn and ambient temperature, it is possible to vary the size of the forbidden gap in the L-point of Brillouin zone, reaching a gapless state. The dependence of E_g on the temperature T and the composition (x) is given as:

$$E_g\,(\text{eV}) = 0.13 + 4.5x10^{-4}\,T - 0.89x \quad (1)$$

According to this formula, the values of E_g can be both positive and negative. This means that in the first case, the wave functions describing the conduction band and the valence zone at the L point have the symmetry of L- and L+. In the second case, the inversion zones and their symmetries correspond to L+ (the conduction band) and L- (valence area). Recently [1], in the study of the reflection spectra of ARPES investigation, it was found that the surface of PbSnSe compounds with inverse location areas in the volume has a status Dyakowski range. Such compounds have now been attributed to topological insulators.

We studied the infrared reflection spectra of thin films of different composition of a topological insulator $Pb_{1-x}Sn_xSe$ with a thickness of 700 nm, grown by molecular beam epitaxy on the substrates ZnTe/GaAs. Studies were conducted on four different samples with x = 0.20, 0.22, 0.34 and 0.40. The samples were grown at the Institute of Physics PAN. Spectroscopy reflectance infrared (IR) radiation allows to study the phonon spectra and to obtain optical constants and thicknesses of the films. Reflection spectra obtained with the infrared Fourier transform spectrometer Bruker IFS 66v/s at the angle of incidence close to the normal in the spectral range from 50 to 7500 cm^{-1} and at a spectral resolution of

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4 cm^{-1}. The optical constants of the substrates and the films, their thicknesses and complex permittivities ε were obtained by the dispersion analysis of reflection spectra [2] using the software SCOUT [3] for four films of different composition $Pb_{1-x}Sn_xSe$. The measured IR reflection spectra (Fig. 1) were compared with the spectrum calculated using the model of damped harmonic oscillators for the dielectric functions (2) of films and substrates, taking into account plasmon as well

$$\varepsilon = \varepsilon_\infty + \Sigma f_j^2/(\nu_{TOj}^2 - \nu^2 - i\gamma_j\nu) - f_p^2/(\nu^2 + i\gamma_p\nu) \quad (2)$$

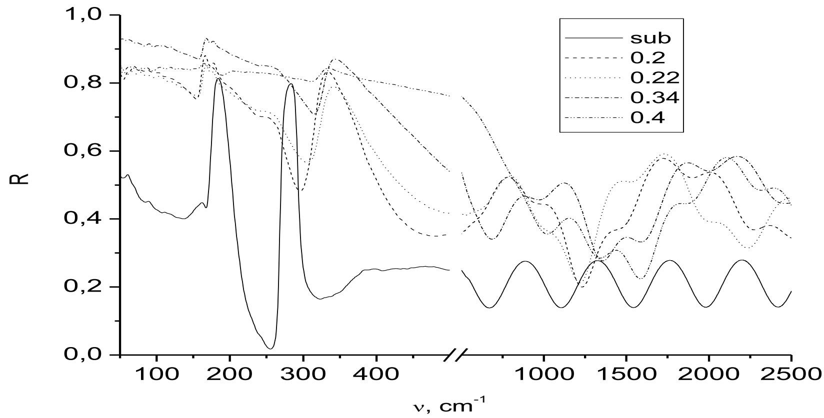

Fig. 1. Spectra of the substrate and of four $Pb_{1-x}Sn_xSe$ films.

The film thicknesses and the parameters of the oscillators (the transverse phonon frequency - ν_{TOj}, the oscillator strength f_j and the damping γ_j) and plasmons (f_p and attenuation γ_p) were varied to minimize the differences of the spectra. At first this procedure was applied to the spectrum of the clean substrate (ZnTe film on GaAs plate). The parameters of the two materials and the thickness of the ZnTe film were obtained. Then the spectra of the films were fitted taking into account the reflection from all the interfaces. The film dielectric functons are shown at Figs. 2 (Re ε), 3 (Im ε) and 4 (Im ε^{-1}).

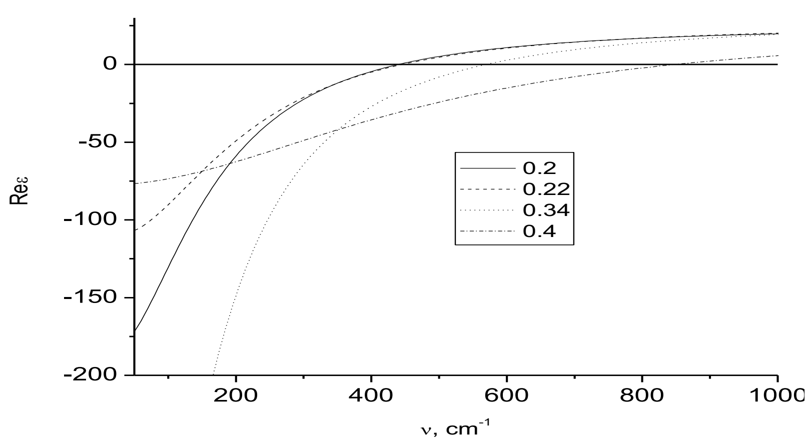

Fig. 2. Re ε of four $Pb_{1-x}Sn_xSe$ films.

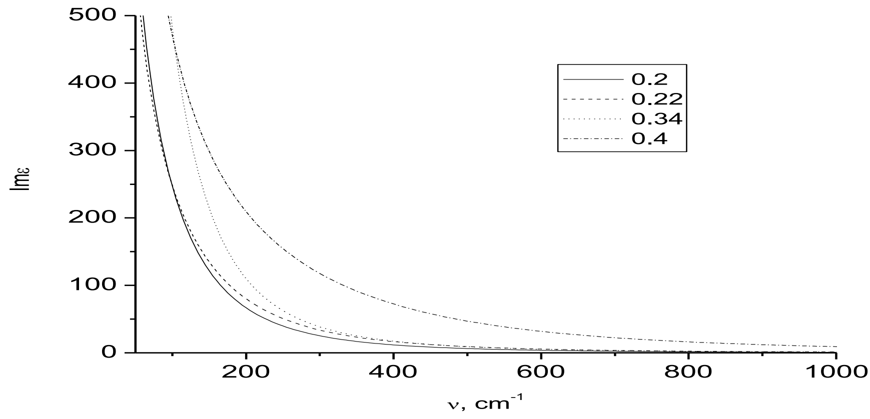

Fig. 3. Im ε of four $Pb_{1-x}Sn_xSe$ films.

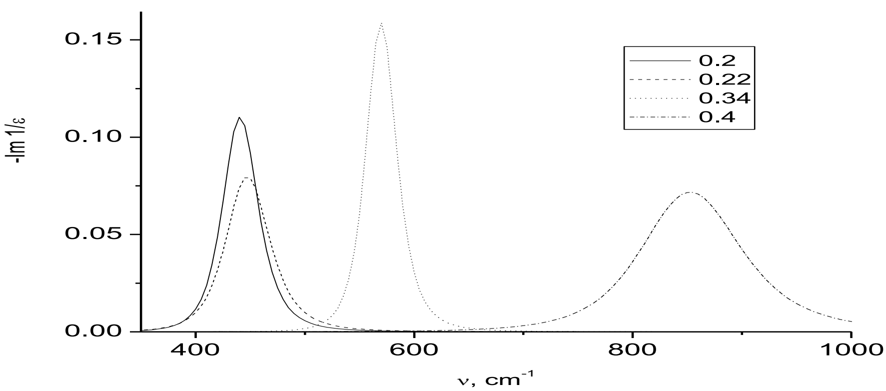

Fig. 4. Loss functions of four $Pb_{1-x}Sn_xSe$ films.

Negative values of Re ε (Fig. 2) and high Im ε (Fig. 3) show that the main contribution into the film dielectric functons is due to the film plasmon (formula 2). The maxima at the loss functions (Fig. 4) spectra show the film plasmon frequencies. $Pb_{1-x}Sn_xSe$ phonons are lower (around 40 cm^{-1}).

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