Photoacoustic Study of $Zn_{1-x}Be_xTe$ Mixed Crystals

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Introduction

Beryllium is applied as a component of II-VI heterostructures for blue-light-emitting diodes, lasers and photodetectors. A partial substitution of a cation (Zn or Cd) by Be improves the device properties because of highly covalent bonding and high cohesive energy in beryllium chalcogenides. Therefore, it allows for extension of the domain of structural and band-gap engineering of II-VI semiconductors towards lower lattice parameters and higher energy gaps.

There is a number of papers on the properties of bulk and layered ZnBeSe but a relatively little information on tellurium based II-VI compounds with partial cationic substitution by Be atoms. Theoretical studies [1], [2] have shown that BeTe could be an attractive substitute to ZnTe.

Recent result shows that $Zn_{1-x}Be_xTe$ is a promising material for p-type cladding layer of ZnCdSe/MgZnCdSe lasers on InP [3] and in fabricating short wavelength lasers based on II-VI compounds. ZnBeSeTe has been successfully applied in design of quantum wells [4]. ZnBeTe ternary alloy has been applied as p-contact layer in II-VI lasers [5].

High hole concentration ($4.8*10^{18}$ cm^{-1}) has been achieved in $Zn_{0.6}Be_{0.4}Te$ layer (on InP substrate) exhibiting the band-gap energy 2.97 eV [3]. Preliminary investigation of luminescence and photoacoustic spectra of bulk $Zn_{1-x}Be_xTe$ has been performed in [6] and [7], respectively. In this work, basic optical and thermal properties of bulk $Zn_{1-x}Be_xTe$ crystals grown by high pressure Bridgman method are reported.

Experimental

Photoacoustic (PA) measurements were carried out using an open cell with continuos wave excitation. The 300 W Cermax Xenon short arc lamp (in the range from λ=400 nm to λ=650 nm) as radiation source and SPM-2 monochromator were applied for spectroscopic measurements. He-Cd laser (λ=325 nm) was used as excitation source for thermal diffusivity estimations. PZT transducer detected the photoacoustic signal with lock-in amplifier (Stanford SR-510) using sine wave conversion method. All photoacoustic spectra were corrected for the spectra response of the optical system by normalising the output signal to that of photodetector.

Results and discussion

Typical photoacoustic amplitude spectra, at room temperature, for as-grown and annealed zinc vapour $Zn_{0.93}Be_{0.07}Te$ are shown if Fig 1. The observed PA curves for as-grown samples exhibit well-expressed change of the slope at points which the energy gaps were determined from. It was found that band gap increases with increasing of Be content. Quite different PA spectra are observed for annealed samples. In this case three maxima are observed in the sub-band-gap region which positions and intensities depend on modulation frequency. This behaviour is characteristic for non stechiometry in composition or impurities concentration of semiconductors. The annealing in zinc vapour can lead in p-type crystals to create defects which causes decreasing of conductivity and increasing of radiationless recombination.

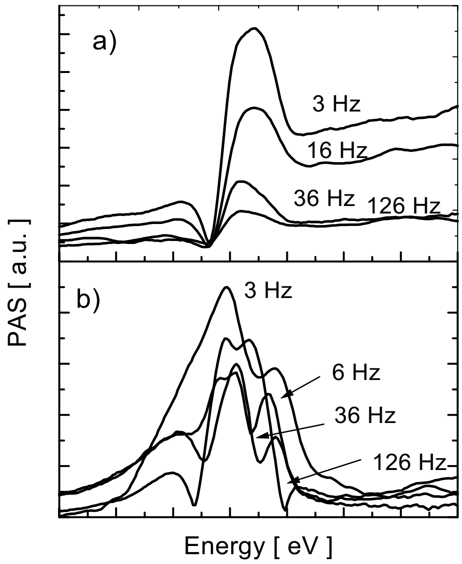

Fig. 1. Photoacoustic spectra of as-grown (a) and annealed (b) $Zn_{0.93}Be_{0.07}Te$ for different frequencies of chopped light

Fig. 2. gives amplitude and phase spectra for as-grown and annealed $Zn_{0.93}Be_{0.07}Te$. In the amplitude spectrum of the as-grown sample the signal of small intensity is observed at low absorption region, which intensity increases for energy value corresponding to band to band transition.

If one considers the PA phase spectra of as-grown and annealed $Zn_{0.93}Be_{0.07}Te$ mixed crystal it can be seen that the changes of phase (characteristic points indicated by vertical dash lines in Fig. 2) are always observed for the same energy values regardless of modulation frequency. Then they must be associated with the same heat sources responsible for PA signal generation, which intensity depends on the modulation frequency. Moreover in the phase spectra of as-grown and annealed $Zn_{0.93}Be_{0.07}Te$ the value of the phase in the high absorption region becomes constant for the same value of energy (vertical solid line in Fig. **2**) corresponding to energy gap value. This feature of PA phase spectra can be used as an alternative method of energy gap determination.

Because of the photoacoustic signal depends on heat diffusion in the sample, it is possible to use the PA method to investigate

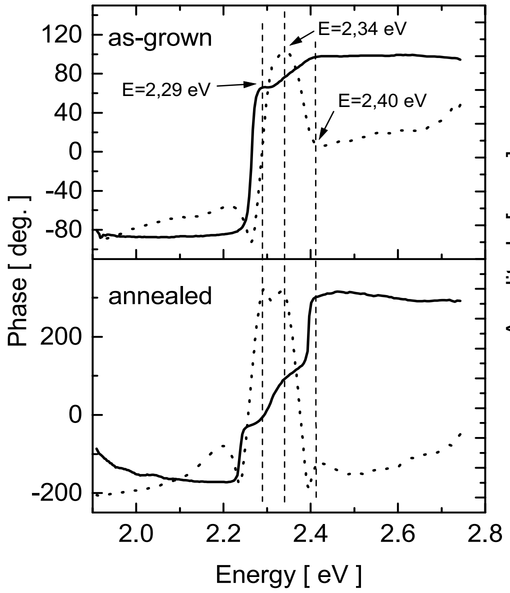

Fig. 2. PA amplitude (dot) and phase (solid) for as-grown and annealed $Zn_{0.93}Be_{0.07}Te$ for chopping frequency 126 Hz

thermal properties of the semiconductors. Thermal diffusivity measures the rate of the heat diffusion in the material and it is unique parameter like the absorption coefficient. Thermal diffusivities of many materials can be accurately measured by the

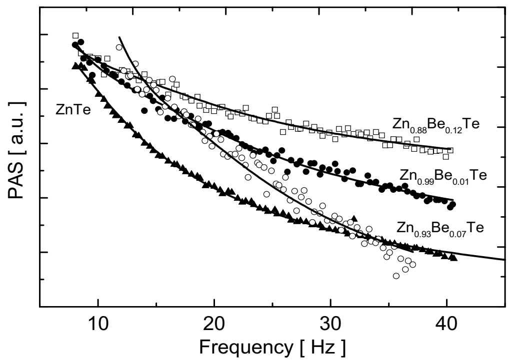

Fig. PA signal as a function of modulation frequency for annealed $Zn_{1-x}Be_xTe$.

photoacoustic method as it was first demonstrated by Adams and Kirkbright [8].The thermal diffusivity values for $Zn_{1-x}Be_xTe$ were determined using photoacoustic amplitude and phase dependence on modulation frequency. The model developed by Blonskij et. al. was applied [9]. These authors averaged the thermal diffusion equations over the area of the

x	**E_g [eV]**	**Thermal diffusivity [cm^2/s]**
0	2.28	0,119
0.006	2.29	0,302
0.065	2.32	0,338
0.121	2.48	0,272

Table 1. The values of thermal diffusivities and energy gaps of annealed $Zn_{1-x}Be_xTe$ mixed crystals for different Be content

sample, solved the thermoelastic problem and gave the analytical expressions for the amplitude and phase. The estimated values of the thermal diffusivities and energy gap values at 300 K of $Zn_{1-x}Be_xTe$ mixed crystals versus Be content derived from the analysis of frequency dependence are presented in the table 1. It has been found that the thermal diffusivity of $Zn_{1-x}Be_xTe$ in the investigated range of composition is almost three times larger than that of ZnTe. This can be associated with additional sources of heat due to the presence of defects in annealed mixed crystals.

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