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Photoacoustic Spectroscopy of ZnBeMgSe Mixed Crystals

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Summary
This paper presents basics of the space selective piezoelectric spectroscopy method. This method is illustrated with the experimental piezoelectric amplitude and phase spectra of ZnBeMgSe(4% Be, 15% Mg) samples. The fitting of theoretical curves to experimental data computed in the piezoelectric space sensitive spectroscopy method indicated the presence of surface states located on both surfaces of the sample. From the fiiting procedure the optical absorption coeff. spectra connected with the surface absorption were determined.

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1. Introduction

Photothermal spectroscopy (PTS) has become lately a very useful tool for investigations of optical and thermal properties of semiconductors [1]. One of the PTS types is a piezoelectric spectroscopy (PES) in which the stress and strain of a sample due to the absorption of electromagnetic radiation is detected by a piezoelectric transducer [2]. The design of the piezoelectric cell (the method of mutual location of the detector and the sample) has a strong impact on the character of the PES signal, both phase and amplitude. For the proper understanding of investigated phenomena, it is necessary to know the temperature distribution in the sample and its influence on the detector's behavior. The model for such kind of interpretation has been proposed lately by Malinski [3, 4]. Recently a new feature of PES was also shown – it was the possibility to investigate the defect states localized on surfaces of a semiconductor sample and then the quality of the surface [5]. The right interpretations of these cases also required the improvement and development of previous models. It was done for the first time for the case of ZnBeMnSe [6].

2. Experimental procedure

ZnBeMgSe crystals were grown from high-purity powder using the high-pressure Bridgman method. The crystal rod was cut into about 1 mm thick samples which were first ground using grinding powder (10 μm diameter), then polished with diamond paste (1 μm), and finally chemically etched. A solution of H_2SO_4 (96%), $K_2Cr_2O_7$, and water was used for etching the samples. After etching, the samples were rinsed in distilled water and then immersed for a few seconds in boiling NaOH. Then the samples were rinsed again in cold water, next in boiling distilled water, and finally in ethyl alcohol. In the piezoelectric (PZE) experiment samples were illuminated with the intensity modulated beam of light of a Xenon lamp (Cermax 300 W) after passing through the prism monochromator. The experimental piezoelectric amplitude spectra of the samples were corrected for the spectrum of the Xenon lamp measured with the the carbon black reference sample. The piezoelectric signal was detected with a lock-in phase selective amplifier (Stanford SR 510). The piezoelectric characteristics of both sides of the samples were measured at room temperature in the rear experimental configuration [7] when the illuminated surface of the sample and the piezoelectric transducer are on the opposite sides of the sample.

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3. Theoretical considerations

The piezoelectric signal, that is analysed, is the result of the periodical temperature fields generated in the sample caused by the absorption of the intensity modulated periodical optical radiation. In general we have one volume absorption type temperature distribution and one of the temperature distributions connected with the surface absorption on one of the surfaces of the sample. The global temperature field is the superposition of the surface absorption and volume absorption temperature fields. These temperature spatial distributions in the sample can be expressed by the formulae (1,2) depending on the location of

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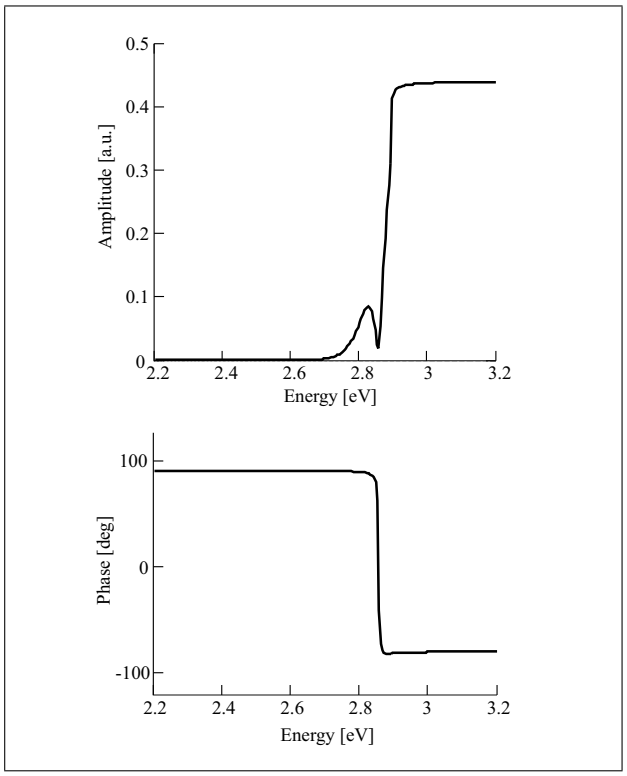

Figure 1. Piezoelectric amplitude (a) and phase (b) photoacoustic spectra of a perfect crystal sample without surface defects.

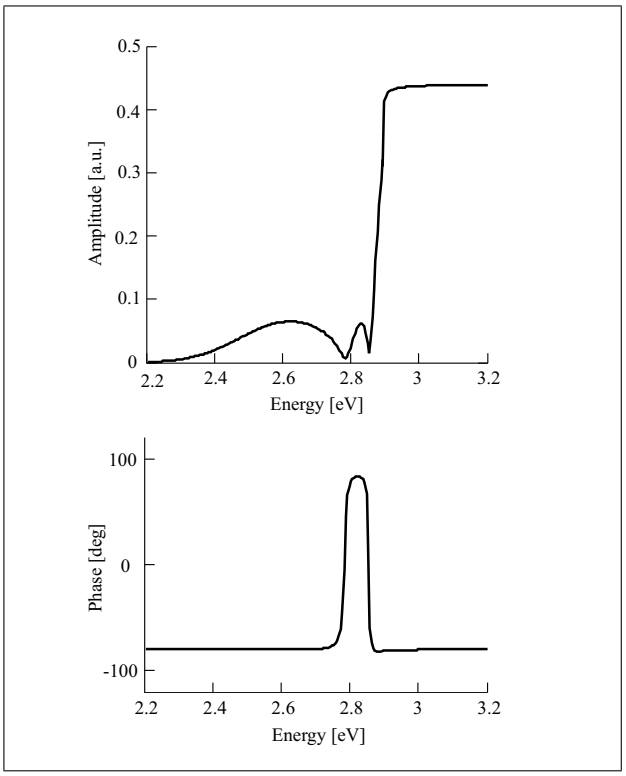

Figure 2. Piezoelectric amplitude (a) and phase (b) photoacoustic spectra of a perfect crystal sample with surface defects located on the illuminated side of the sample.

the surface defects.

$$T_L(x,\beta) = T_{SL}(x,\beta,\alpha,f,l,d) + T_V(x,\beta,\alpha,f,l), \quad (1)$$

$$T_R(x,\beta) = T_{SR}(x,\beta,\alpha,f,l,d) + T_V(x,\beta,\alpha,f,l), \quad (2)$$

where T_{SL} is the temperature distribution connected with the surafce defects located on the illuminated (left) side of the sample, T_{SR} is the analogous distribution but connected with the defects located on the opposite (right) side of the sample, T_V is the temperature distribution connected with the volume absorption of light in the sample, x is the spatial coordinate, β is the optical absorption coefficient, α is the thermal diffusivity of the sample, l is the thickness of the sample, d is the thickness of the layer with surface defects and f is the frequency of modulation. The piezoelectric signal S is expressed by the formula (3) derived by Jackson and Amer for the bulk absorption and which in the rear experimental configuration is the difference of piston and drum contributions.

$$S \simeq -\left(\frac{1}{l}\int_0^l T_{L/R}(x,\beta)\,\mathrm{d}x - \frac{6}{l^2}\int_0^l \left(\frac{l}{2}-x\right)T_{L/R}(x,\beta)\,\mathrm{d}x\right). \quad (3)$$

The computed piezoelectric photoacoustic spectra of a semiconductor sample in the rear experimental configuration in the case of the sample's surface free from any defects are presented in Figure 1. The spectra were computed according to formula (3) for the surface absorption

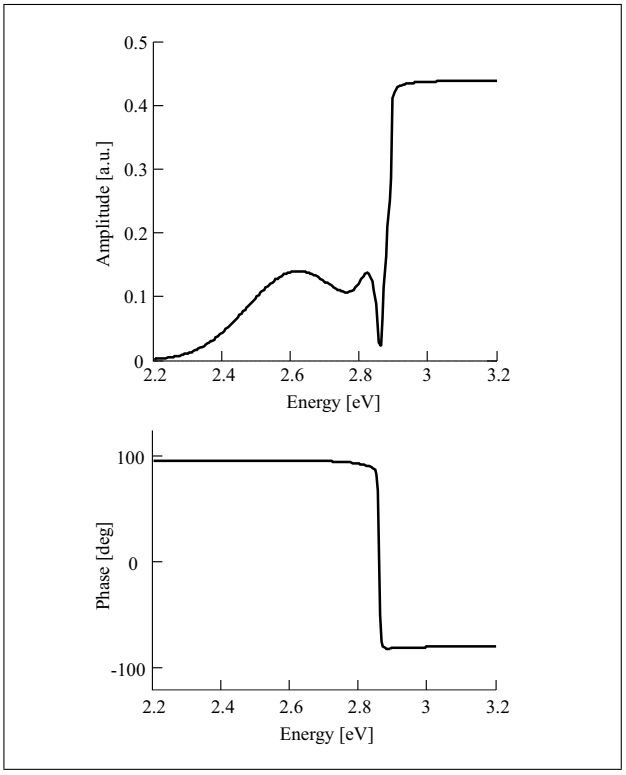

Figure 3. Piezoelectric amplitude a) and phase b) photoacoustic spectra of a perfect crystal sample with surface defects located on the nonilluminated side of the sample.

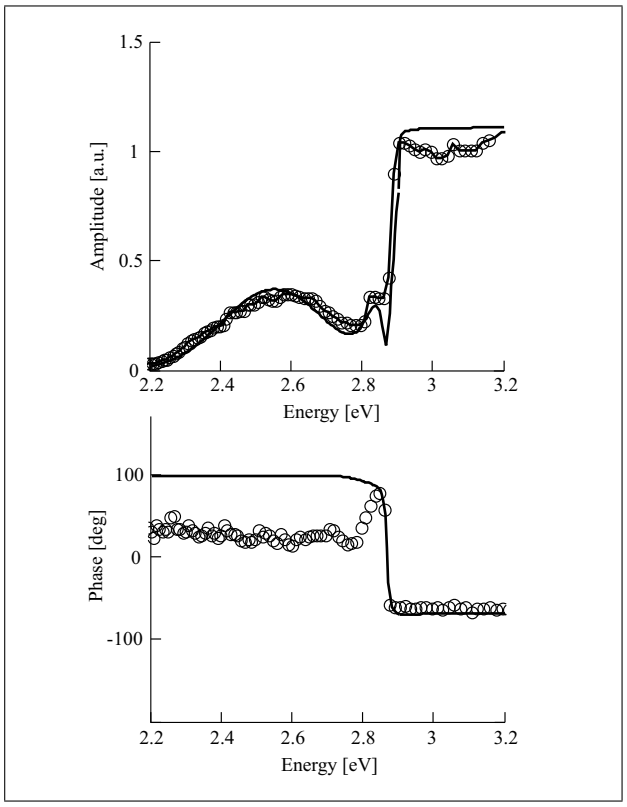

Figure 4. Piezoelectric amplitude (a) and phase (b) spectra of ZnBeMgSe sample (left side) at $f = 36$ Hz. Circles are experimental data, solid lines are theoretical curves.

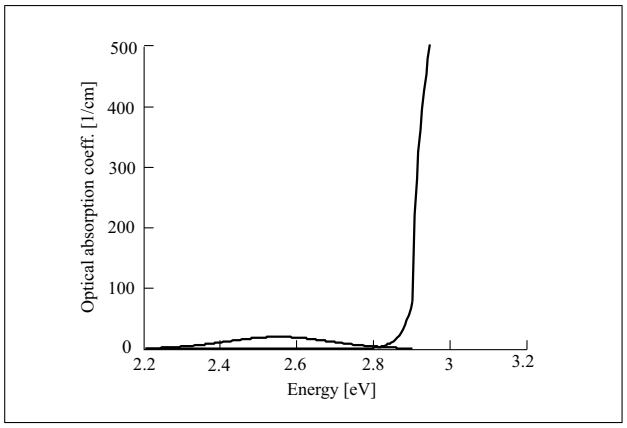

Figure 5. Optical absorption coefficient spectrum computed from the fitting procedure to the PZE spectra of the left side of the sample.

equal to zero and the set of parameters: $f = 126$ Hz, $E_g = 2.9$ eV, $l = 0.1$ cm, $\alpha = 0.04$ cm^2/s. E_g means the value of the energy gap of a semiconductor.

When the surface defects exhibiting the absorption band with the maximum of the absorption band at $E_d = 2.6$ eV and its halfwidth (HW) about HW = 0.2 eV are located on the illuminated (left) side of the sample then the following piezoelectric spectra, presented in Figure 2, are expected.

When the surface defects are located on the nonilluminated (right) side of the sample then the following spectra,

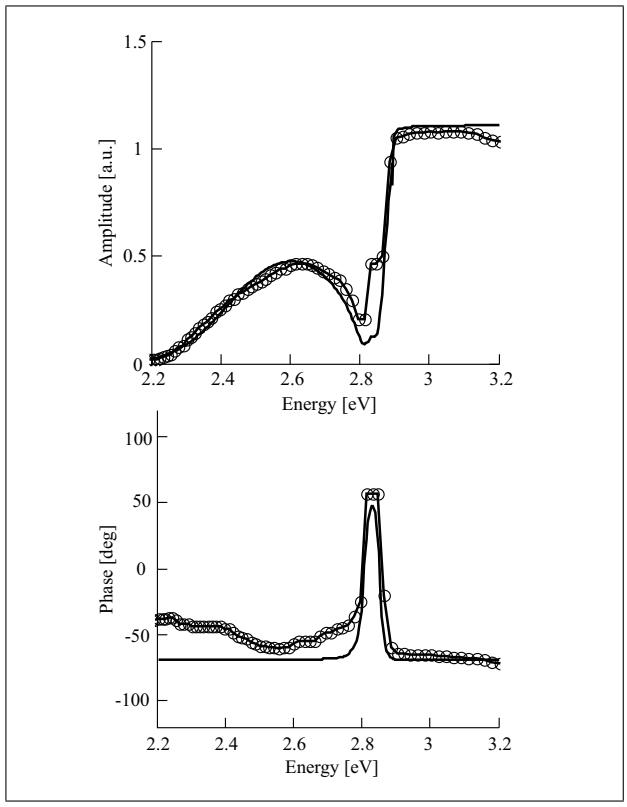

Figure 6. Piezoelectric amplitude a) and phase b) spectra of ZnBeMgSe sample (right side) f=36 Hz. Circles are experimental data, solid lines are theoretical curves.

computed for the same set of parameters, presented in Figure 3, are expected.

The character of both amplitude and phase spectra strictly depends on the location of the defects on the surfaces of the sample. It is clearly shown that especially the phase spectra indicate the location of the defect states on one of the surfaces of the sample.

4. Numerical analysis of the experimental spectra

Figure 4 a) and b) show experimental piezoelectric spectra of the left side of the sample ZnBeMgSe (4% Be, 15% Mg) measured at $f = 36$ Hz and theoretical curves computed in the model of surface states.

The optical absorption coefficient spectrum computed from the piezoelectric (PZE) spectra presented in Figure 4 is shown in Figure 5. The deffect states have their absorption maximum at about $E_d = 2.55$ eV, the halfwidth HW = 0.22 eV and the absorption coefficient $A = 20$ cm^{-1}.

The PZE spectra of the right side of the sample measured at $f = 36$ Hz are presented in Figure 6.

The PZE phase spectra of the sample, presented above, indicated that similar surface defects were located also on the right side of the sample but the concentration of them was approximately 2.5 times higher what is illustrated in Figure 7. The parameters of the optical absorption coeff. spectrum connected with the surface defects were ex-

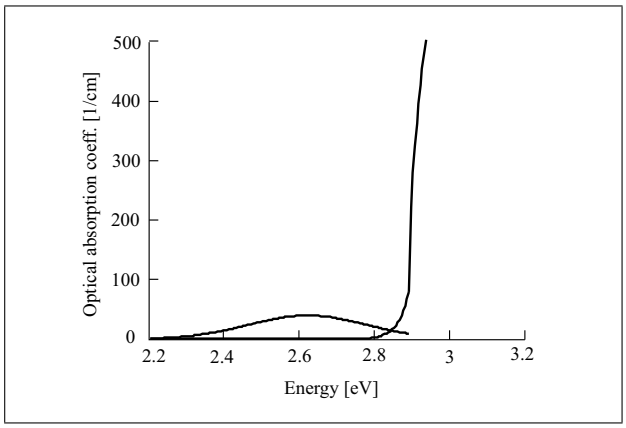

Figure 7. Optical absorption coefficient spectrum computed from the fitting procedure to the PZE spectra of the right side of the sample.

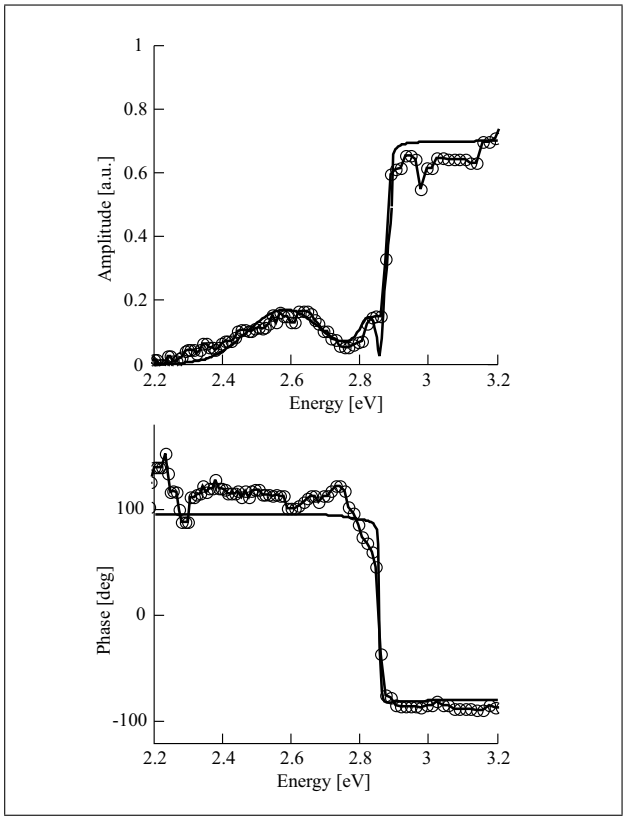

Figure 8. Piezoelectric amplitude (a) and phase (b) spectra of ZnBeMgSe sample (left side) $f = 126\,\mathrm{Hz}$. Circles are experimental data, solid lines are theoretical curves.

tracted from the fitting procedure of theoretical curves to experimental spectra and were: $E_d = 2.6\,\mathrm{eV}$, $A = 50\,\mathrm{cm}^{-1}$, $\mathrm{HW} = 0.22\,\mathrm{eV}$.

Similar experimental PZE spectra were also measured and computed for $f = 126\,\mathrm{Hz}$ and the same optical absorption parameters . They confirm the conclusion drawn from the PZE spectra obtained for $f = 36\,\mathrm{Hz}$. They are shown in Figures 8 and 9.

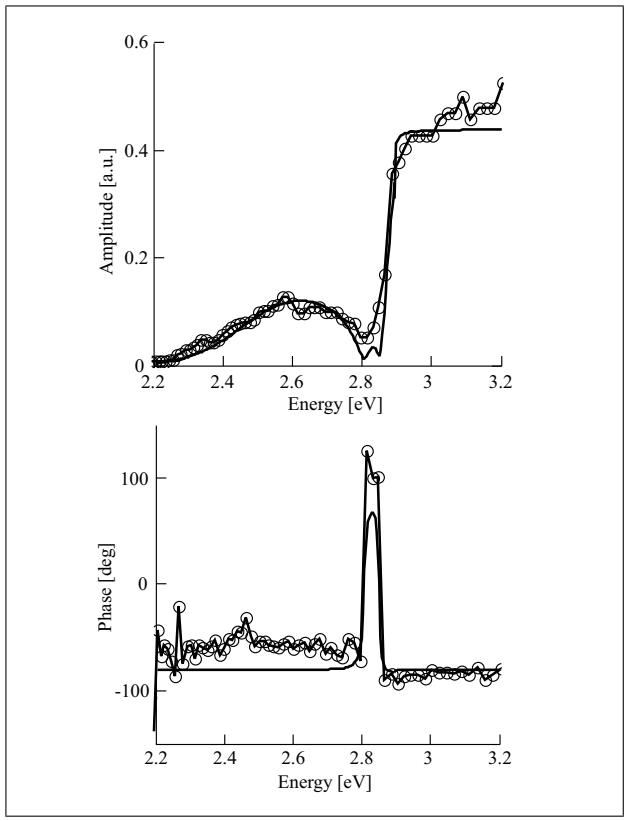

Figure 9. Piezoelectric amplitude a) and phase b) spectra of ZnBeMgSe sample (right side) f=126 Hz. Circles are experimental data, solid lines are theoretical curves.

5. Conclusions

Application of a space selective piezoelectric photoacoustic spectroscopy method enabled to detect surface states on the surfaces of the investigated samples, determine their optical surface absorption parameters and locate them on the surfaces of the sample. These conclusions could not be drawn from conventional transmission measurements which give only total information about absorption coefficient and the information about location of absorbing centers is missing.

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References

[1] A. Rosencwaig, A. Gersho. J. Appl. Phys. **47** (1976) 64–74.
[2] W. Jackson, N. M. Amer. J. Appl. Phys. **51** (1980) 3343–3353.
[3] M. Maliński. Phys. Stat. Sol. (a) **198** (2003) 169–176.
[4] M. Maliński. Archives of Acoustics **28** (2003) 43–55.
[5] M. Maliński, J. Zakrzewski. The European Physical Journal (2007) in press.
[6] M. Maliński, J. Zakrzewski, K. Strzałkowski. Intern. J. of Thermophysics **28** (2007) 299–316.
[7] M. Maliński. Journal de Physique IV France **109** (2003) 43–48.