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Simultaneous determination of the thermal diffusivity and a drum factor for CdBeMnTe crystals with the photoacoustic method

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ABSTRACT

The paper presents results of photoacoustic studies of the thermal diffusivity of CdTe and $Cd_{1-x-y}Be_xMn_yTe$ crystals. The drum effect strongly influences the photoacoustic characteristics that have been measured. The values of the thermal diffusivity of the crystals have been extracted from the amplitude and phase frequency characteristics measured in reflection and transmission configurations in the Sf/Sr and Phase-Lag method. This paper presents that it is possible to extract simultaneously the thermal diffusivity and a drum factor *B* from photoacoustic frequency measurements.

1. Introduction

Diluted magnetic semiconductors (DMS) are materials with magnetic ions implemented into the crystal structure. These materials are interesting because of a potential application in optoelectronics and spintronics [1]. DMS based on mixed crystals of II–VI compounds with the manganese are very promising materials for spintronics due to unique magneto-optical properties [2]. In the case of a quaternary diluted magnetic semiconductor the magnetic properties do not change with the variation of lattice parameters when the second non magnetic component of the alloy is incorporated. Very interesting are tellurium based II–VI compounds with a partial cationic substitution by Be atoms. Beryllium as a component, improves material properties inducing noticeable lattice strengthening because of a dominant covalent bonding and a high cohesive energy of BeSe or BeTe. Photothermal methods have been widely applied to estimate thermal or transport properties of solid samples using contact photopyroelectric method [3–6] and noncontact methods such photothermal infrared radiometry [7–9] and photoacoustic spectroscopy [10–12]. Thermal diffusivity is one of the basic thermal parameters used in photoacoustics. Correctness of its determination influences calculations of other parameters which can be extracted from photoacoustic experiments [13,14]. Thermal diffusivity can be determined from the frequency dependence of the amplitude or phase of the photoacoustic signal as it depends on the thermal diffusion length μ of the thermal wave which is a function of the thermal diffusivity and the frequency of modulation of the intensity of light illuminating the sample, see Formula (5). The presence of the temperature gradient is the reason of the bending of the sample what is called a Drum effect which has been described elsewhere [15–17]. This effect causes additional contribution to the photoacoustic signal which cannot be neglected and must be taken into account in calculations. The Sf/Sr and Phase-Lag methods are very practical for determination of the thermal diffusivity as they do not depend on the experimental apparatus frequency characteristics. In other methods the experimental apparatus characteristics must be measured in the independent experiments. Sf means the amplitude of the photoacoustic signal in the front experimental configuration called in some papers the reflection configuration. Sr means the amplitude of the photoacoustic signal in the rear experimental configuration called in some papers the transmission configuration. They were applied for determination of the changes of the thermal diffusivity with the composition of the mixed crystals Si_xGe_{1-x} [18]. For thermally thin samples the drum effect can be neglected. For thermally thick samples this effect must be however considered. The sample is thermally thin or thick when the diffusion length μ of the thermal wave is bigger or smaller than the thickness *d* of the sample respectively. This paper shows that for

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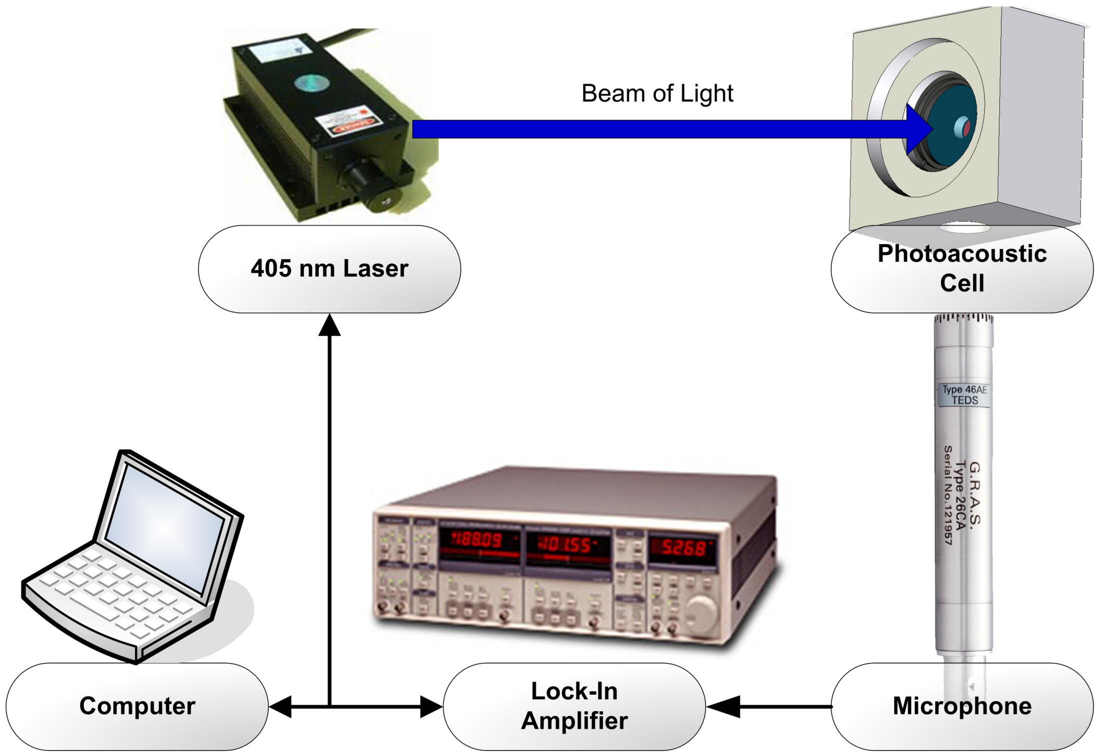

Fig. 1. Schematic diagram of the experimental set-up used in the measurements.

thermally thick samples it is possible to determine values of the thermal diffusivity and a drum factor from the simultaneous fitting of the theoretical Sf/Sr and Phase-Lag frequency characteristics to the experimental ones.

2. Materials preparations and experimental methods

2.1. Materials

Mixed $Cd_{1-x-y}Be_xMnTe$ crystals have been obtained by the high pressure Bridgman method under an argon overpressure of 11 MPa. The intentional beryllium content ranged from 0.00 up to 0.15, whereas the manganese content was 0.10 for all investigated samples. Produced crystal rods were cut perpendicular to the growth axis into about 1 mm thick plates and ground with a standard grounding powder (10 μm). Next samples were polished using Al_2O_3 polishing powder (1 μm) until obtained surface was of a good quality. After such preparation specimens were cleaned applying an ultrasonic washer.

2.2. Experimental set-up

Experimental set-up used for investigations is presented in Fig. 1. The thermal waves were exited using a laser diode with a beam size smaller than 1 mm, the output power of 200 mW and a photon energy of 3.06 eV corresponding to the operating wavelength $\lambda = 405$ nm. The lock-in amplifier SR830 has been used for phase sensitive measurements and for the modulation of the intensity of the laser beam. Self designed photoacoustic cell with G.R.A.S. microphone (type 26AK) has been used as a detector of the photoacoustic signal. Modeling and designing of such a type of the Helmholtz resonator have been detailly described elsewhere [19,20]. Measurements were performed in the range of frequencies of modulation from $f = 1$ Hz to $f = 100$ Hz. Measurements were fully automated and computer controlled. Investigations have been performed in the room temperature.

Thermal diffusivity has been extracted from the photoacustic characteristics measured in two different operating modes presented in the figures below.

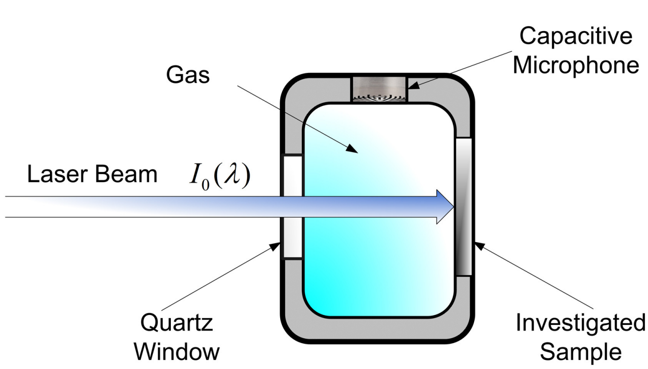

Fig. 2. Schematic diagram of the sample mounted in the photoacoustic cell in the reflection configuration.

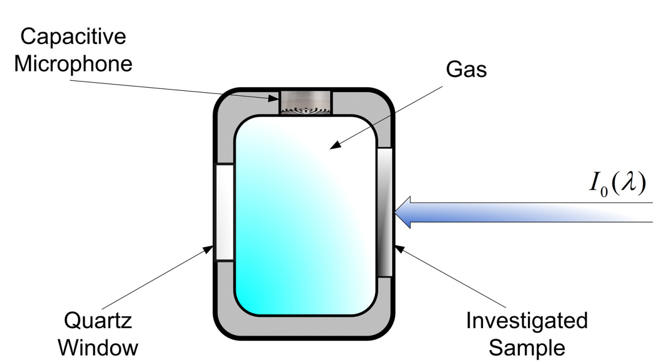

Fig. 3. Schematic diagram of the sample mounted in the photoacoustic cell in the transmission configuration.