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PECULIARITIES OF COMPOSITION AND TEMPERATURE DEPENDENCE OF ENERGY-BAND PARAMETERS OF $\mathrm{Zn}_x\mathrm{Cd}_y\mathrm{Hg}_{1-x-y}\mathrm{Te}$

A.M. ANDRUKHIV[a], V.I. IVANOV-OMSKII[b], J. POLIT[c] AND E.M. SHEREGII[a,c]

[a]I. Franko Drogobich Pedagogical University, Drogobich, Ukraine
[b]A. Ioffe Physico-Technical Institute of Russian Academy of Science
St.-Petersburg, Russia
[c]Institute of Physics, Pedagogical University, Rejtana 16a, 35-959 Rzeszów, Poland

The influence of addition of Zn on band parameters of $\mathrm{Zn}_x\mathrm{Cd}_y\mathrm{Hg}_{1-x-y}\mathrm{Te}$ solid solution at different temperatures (4.2–200 K) was investigated. The cyclotron resonance at 4.2 K and magnetophonon resonance at 77–200 K were used to determine band structure parameters. The temperature dependence of band structure parameters (energy gap, effective mass of electron) for the composition of series of epilayers (x varied in 0.08–0.20 range and y — 0.07–0.12) was obtained. It is found that band structure parameters for some compositions (for example $x = 0.17$, $y = 0.08$) are almost independent from temperature and equal: $\gamma_1^{\mathrm{L}} = 19.55$, $\gamma_2^{\mathrm{L}} = \gamma_3^{\mathrm{L}} = 8.5$, $K^{\mathrm{L}} = 6.48$, $F = -0.5$, $E_{\mathrm{g}} = 0.35$ eV, $E_{\mathrm{p}} = 17.9$ eV. The effective mass of electrons was found to be greater with addition of Zn while the effective mass of heavy holes is left unchanged.

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The objective of this work is to investigate the influence of addition of Zn on band parameters of $\mathrm{Zn}_x\mathrm{Cd}_y\mathrm{Hg}_{1-x-y}\mathrm{Te}$ (ZMCT) at different temperatures (4.2–200 K).

Three compositions of epitaxial layers of ZMCT obtained on CdZnTe substrates are studied. The thickness of homogeneous layer was ≈ 4 μm. The other dimensions of specimens prepared for measurements were 1×5 mm^2. The data of the samples are presented in Table I.

Second derivation of transverse magnetoresistance $\partial^2\rho_{xx}/\partial B^2$ as a function of magnetic field B was registered up to 6.5 T at different temperatures in the range 77–200 K.

Cyclotron resonance has been studied using the technique of registration of the changes in photoconductivity in the magnetic field up to 6.5 T at 4.2 K under radiation.

TABLE I

Data of the specimens $Zn_xCd_yHg_{1-x-y}Te$.

Sample	$\lambda_{1/2}$ [μm]	x	y	n [cm^{-3}]	μ $\left[\frac{cm^2}{V\cdot s}\right]$
I	6.9	0.08	0.11	4×10^{15}	9×10^4
II	4	0.12	0.10	5×10^{15}	5×10^4
III	3.6	0.17	0.08	2×10^{15}	2×10^4

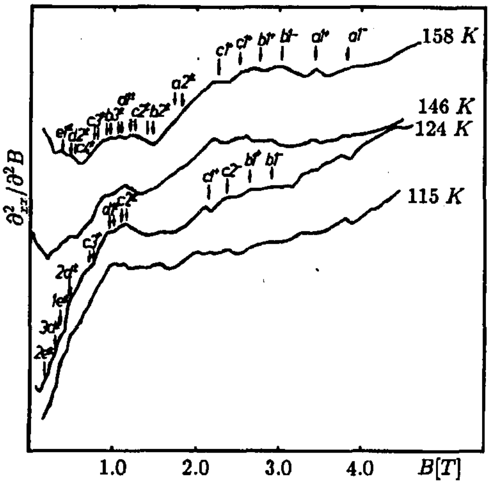

Fig. 1. Experimental records of $\partial^2 \rho_{xx}(B)/\partial B^2$ for sample I. The arrows show theoretical positions of corresponding transitions.

The experimental plots of $\partial^2 \rho_{xx}/\partial B^2$ for sample I, measured at three different temperatures are shown in Fig. 1. When the temperature increases above 124 K, a group of strong peaks appears in the range from 2.0 to 3.0 T, to which their harmonics correspond at 1.0–1.5 T and 0.4–0.7 T. These three series of peaks a, b, c can be interpreted as ordinary magnetophonon resonance (MPR) with the participation of LO phonons of ZnTe-like, CdTe-like and HgTe-like lattices respectively. The strongest and the most distinguishable at $T \geq 124$ K peak (1c) provided by absorption of LO phonon in HgTe-like lattice due to the transition from 0^+ Landau level to 1^+ was used for determination of the band structure parameters under the first approximation, since the energy of LO (HgTe) phonon for solid solution MCT is known and hardly changes [1] with the composition of Cd (probability of Zn also for $x + y \leq 0.3$ in ZMCT).

Spectra of photoconductivity of specimen III for different wavelengths have been shown in Fig. 2. In spectra one bright line can be noticed. Extrapolation to $B = 0$ shows that in the given case we observe transitions of intraband conductivity.

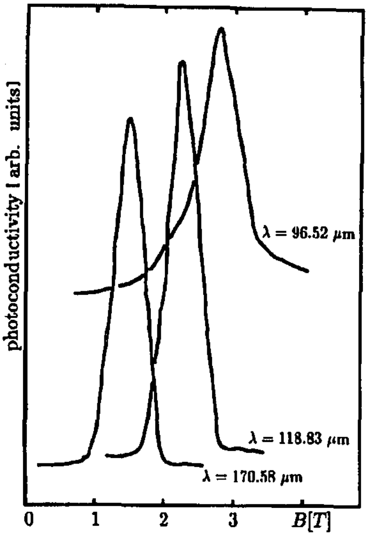

Fig. 2. Spectrum of photoconductivity of the specimen III, obtained in the magnetic field at $T = 4.2$ K.

The energy gap was estimated in first approximation corresponding to photoluminescence data [2]. Band structure parameters were calculated according to the Pidgeon–Brown model [3] in R.R. Aggarwal's [4] version. The experience of authors [5–7] for determination of the band structures parameters in MCT was used when values for γ_1^{L}, γ_2^{L}, γ_3^{L}, K and F parameters were chosen. Therefore we take the following:

$$\gamma_1^{\mathrm{L}} = \frac{E_{\mathrm{P}}}{3E_{\mathrm{g}}} + 2.5, \qquad \gamma_2^{\mathrm{L}} = \gamma_3^{\mathrm{L}} = \frac{E_{\mathrm{P}}}{6E_{\mathrm{g}}}.$$

We assumed that $E_{\mathrm{P}} = 17.9$ eV and $\Delta = 1.0$ eV [5] and they do not depend on temperature and composition [8]. For other parameters, according to [9]:

$$K = \gamma_3 - \frac{1}{3}\gamma_1 + \frac{2}{3}\gamma_2 - \frac{2}{3} - \frac{5}{4}\delta_{\mathrm{exch}}$$

(δ_{exch} — the correction caused by the nonlocality of the potential and equal to 0.4 for MCT [10]) and for F we refer to the value determined by Weiler et al. [6], therefore $F = -0.5$. Having obtained band parameters in this manner, a correction was done by best fit procedure to the experimentally obtained positions of peaks in series c^+, c^--MPR with the participation of LO(HgTe)-phonon with transitions from $0^{\pm}$ levels to $1^{\pm}$, $2^{\pm}$ Landau levels. Band parameters obtained in this way have been presented in Table II ($T = 77$ K).

Temperature dependence of $E_{\mathrm{g}}(T)$ and $m_{\mathrm{e}}(T)$ calculated with the help of the temperature shift of MPR peaks and from data of cyclotron resonance (for sample III) are shown in Fig. 3. The value of the coefficient $\mathrm{d}E_{\mathrm{g}}/\mathrm{d}T$ (equal to 0.136 meV/K for sample I and 0.11 meV/K for sample III) was obtained from the dependence of $E_{\mathrm{g}}(T)$ in Fig. 3. It is smaller than that calculated with the use of the temperature shift of the photoluminescence band (0.18 meV/K for sample III).

TABLE II

Band-structure parameters at $T = 77$ K.

Specimens	E_g [eV]	E_p [eV]	γ_1	$\gamma_2 = \gamma_3$	K	F
I	0.18	17.9	35.65	16.55	14.53	0
II	0.31	17.9	21.75	9.6	7.58	-0.2
III	0.35	17.9	19.55	8.5	6.48	-0.5

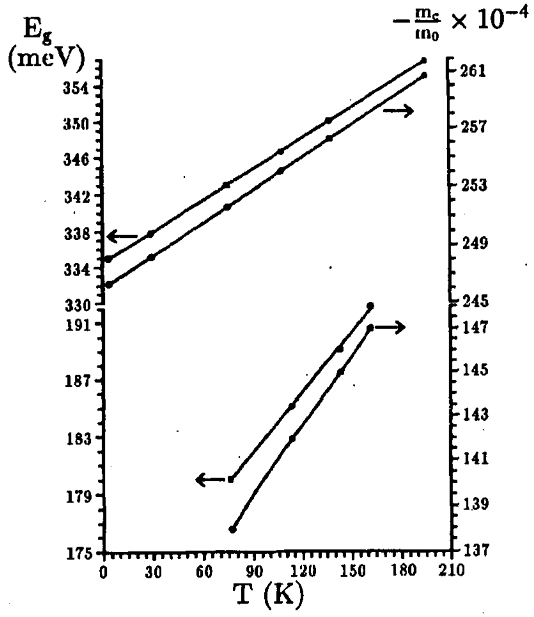

Fig. 3. Temperature dependence of energy gap $E(T)$ and electron effective mass on edge of conduction band $m^*(T)$ for sample I — lower curves, and sample III — upper curves.

It is assumed that the effective mass of heavy holes equal to $m_{hh} = (\gamma_1 - 2\gamma_2)^{-1}$ does not depend on temperature, which agrees with the experiment for CdHgTe [5].

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