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NONLINEAR TEMPERATURE DEPENDENCE OF THE BAND GAP IN $Hg_{1-x-y}Cd_xMn_yTe$ AND $Hg_{1-x}Cd_xTe$ ALLOYS*

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The temperature dependence of the band gap for HgCdTe and HgCdMnTe has been experimentally investigated in the temperature range of 7–250 K. The distinct nonlinear dependence has been observed in the low temperature range. It was shown that the lattice dilatation contribution calculated for HgCdTe is a significant part (about 30%) of the total temperature shift of the energy gap.

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1. Introduction

The temperature dependence of the energy gap in $Hg_{1-x}Cd_xTe$ (HCT) and other similar narrow-gap alloys has been the subject of numerous investigations. Most of the experiments has been done in the temperature range of 77–300 K. The widely used, empirical expression for the $E_g(x,T)$ in HCT [1] contains the temperature independent dE_g/dT coefficient. There are however some, not numerous, experimental data on the nonlinear temperature dependence of the energy gap in HgTe [2, 3] and HCT [4, 5] in the liquid helium temperature range. In this paper we present the results of the new experimental investigations of this effect in HCT and, for the first time, in HgCdMnTe (HCMT) alloys and we try to link the nonlinear behaviour of the $E_g(T)$ function with crystal lattice dilatation.

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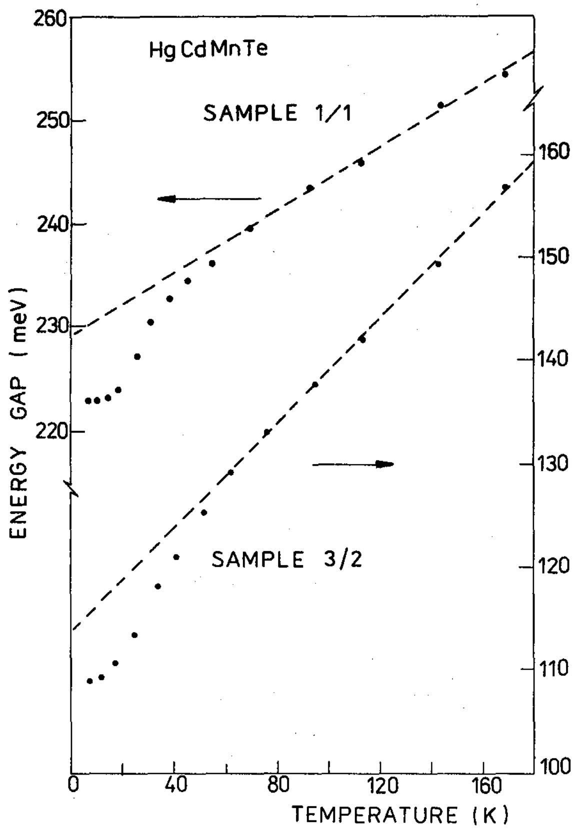

Fig. 1. Energy gap versus temperature for two HCMT samples. The dashed lines present the linear part of the $E_g(T)$ dependence.

2. Experimental

The experimental investigations were performed on one HCT ($x = 0.35$) and two HCMT epitaxial layers with narrow open gaps (109 and 223 meV at 7 K) with the Mn concentrations y < 0.02. The layers were grown by isothermal vapour phase epitaxy. CdTe and CdMnTe crystals were used as a substrate for HCT and HCMT layers, respectively. The variations of the energy gap of HCT with temperature have been determined from absorption measurements in the temperature range of 7–300 K. For HCMT the measurements of the photovoltaic (PV) effect in the temperature range of 7–200 K have been performed. The position of the band gap has been exactly localised on the PV edge at 7 K using the E_g values determined directly from PV oscillations in quantizing magnetic field [6].

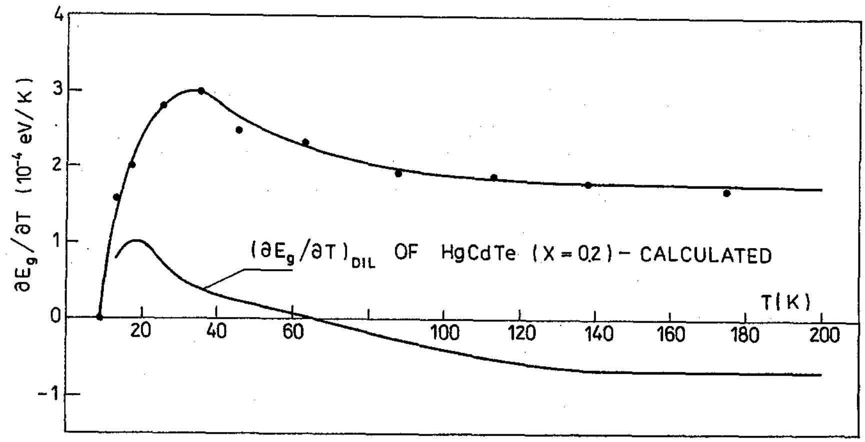

Fig. 2. Temperature coefficient of the energy gap (dE_g/dT) versus temperature for HCT. The lower curve presents the calculated dilatation contribution to the dE_g/dT coefficient.

3. Results and discussion

The $E_g(T)$ curves derived from the measurements for two HCMT samples are presented in Fig. 1. The $E_g(T)$ dependence for HCT is qualitatively similar. All the measured $E_g(T)$ curves exhibit a distinct nonlinear behaviour in the low temperature range. The energy gap is nearly temperature independent below 15 K. Above this temperature an increase of E_g starts to be observable and above 80 K E_g increases with increasing temperature with the constant slope (a little smaller than that reported in [7]). Our measurements are the first experimental statement of nonlinear $E_g(T)$ dependence in HCMT. In the case of HCT the nonlinear $E_g(T)$ dependence for $x = 0.24$ has recently been reported in [4]. Figure 2 shows the temperature dependence of the dE_g/dT coefficient, exemplary for HCT sample. The dilatation contribution to the value of dE_g/dT has been calculated from the well-known formula:

$$(\partial E/\partial T)_{\mathrm{Dil}} = -3\alpha C_e (\partial E_g/\partial P)_T$$

and shown in Fig. 2. The thermal coefficient of linear dilatation α, the elasticity coefficient C_e and the pressure coefficient of the energy gap $(\partial E_g/\partial P)_T$ for HCT have been taken from experimental data reported in [8], [9, 10] and [11], respectively. As seen (Fig. 2) the dilatation contribution is quite large (about 30% of the total value) and can modulate the temperature dependence of the total dE_g/dT coefficient in the significant way (particulary in low temperature range). It is worth noticing that the contribution of the lattice dilatation to the temperature shift of the energy gap of HCT ($x = 0.3$) has been calculated in [12] but, because of the lacking data for HCT, the values of α used in [12] were averaged between the values for CdTe and HgTe. In the later paper [8] it was shown that at about 20 K the values of α for HCT alloys ($x = 0.201$ and $x = 0.303$) exceed nearly by a factor of 2 the values of α for the alloy components. This result is very important and suggests, for instance that it would be worth to know what the dilatation contribution to the particularities observed in $E_g(T)$ dependence for large-gap semimagnetic semiconductors in low temperature range [13, 14] is. It should be noted that our experimental results on $E_g(T)$ dependence cannot be described in terms of Varshni phenomenological formula proposed in [15, 2, 3] for a number of elemental semiconductors and semiconducting compounds. The temperature dependence of the $\mathrm{d}E_g/\mathrm{d}T$ coefficient derived from Varshni formula has no maximum which we observe in our semiconducting alloys (Fig. 2).

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