

Stoichiometry Determination Across the Face of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ Semiconductors

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Variation of E_1 and $E_1 + \Delta_1$ band gap energies of mercury cadmium telluride with composition x across the face of a number of p -type and n -type samples have been determined. A three-dimensional presentation of these variations has been introduced.

Keywords: $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$; Stoichiometry determination; Electrolyte electro-reflectance spectra.

INTRODUCTION

$\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ belongs to the class of pseudobinary alloys¹ of the form $\text{A}_{1-x}\text{B}_x\text{C}$. The compound, $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ is a valuable infrared detector^{2,3}. There is an increasing interest in studying different chemical and physical properties of the compound^{4–11}. The alloy has two conductive transitions, E_1 and $E_1 + \Delta_1$ in the range of 2.0–4.0 photon energy and has been studied experimentally¹² and theoretically¹³. Their transition energies and band gap energies E_g vary with the composition x , so the stoichiometry and uniformity of the samples have important roles in their qualities. The samples are produced with different techniques such as stoichiometric mixture of the pure tetrahedral compounds¹⁴ HgTe and CdTe , evaporation, laser melting, etc.¹⁵. The uniformity of the prepared semiconductors, especially through their faces, must be determined accurately. One of the most precise and fast methods to do so is the electrolyte electro-reflectance (EER) measurement. The EER technique can also be used in structural studies and in determining the amount of doping in epitaxial layers of semiconductors¹⁶.

EXPERIMENTAL

The experimental settings are similar to as previously described¹⁷ and shown briefly in Fig. 1. A monochromatic light, in the z -direction and in the range of 2.0–4.0 eV, is focussed on the face of the sample. The sample compartment consists of a quartz cell filled with an electrolyte, which is inert to the sample, *i.e.*, one part concentrated nitric acid to 5000 parts methanol solution¹⁸. The sample, inner electrolyte and inner platinum electrode, whole together, can be moved with the aid of two sero-motors in the x - and y -directions. Edges of the sample are covered with wax to let the electric current between the two Pt electrodes to cross only through the sample and build up the electric field on the sample face.

The reflected light, at an angle of 45° to the incident light, is collected by an appropriate detector such as photomultiplier, phototube, etc. Then the signal is amplified and displayed on a recorder and at the same time it is stored in a computer.

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The electric field is provided by a D.C. Bias oscillator, which generates a square or rectangular electric wave, giving an opportunity to measure the signals in the presence and absence of the electric field. The setting is done in such a way that the reflectance is measured in the presence of the electric field (R') and in the absence of the electric field (R). Then using the ratio of $(R' - R)/R$ which is presented by $\Delta R/R$ and is called electrolyte electro-reflectance (EER), the signal for the incident photon is calculated.

In order to reduce the noise level for each photon energy, the desired number of EER measurements can be carried out and saved in a computer and by averaging, the randomly occurring noise level can be reduced considerably. Automation, movements of the sample in x and y -directions, frequency settings, synchronization, data recording and averaging are all done with great accuracy by the aid of a computer.

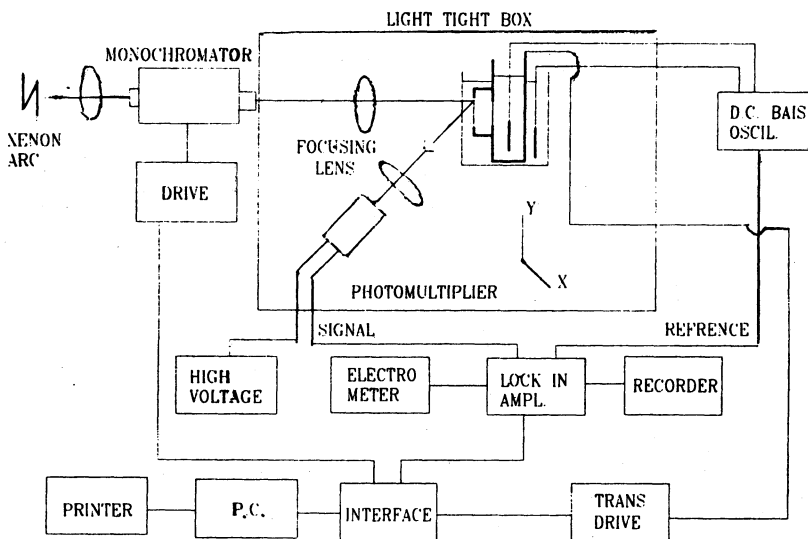


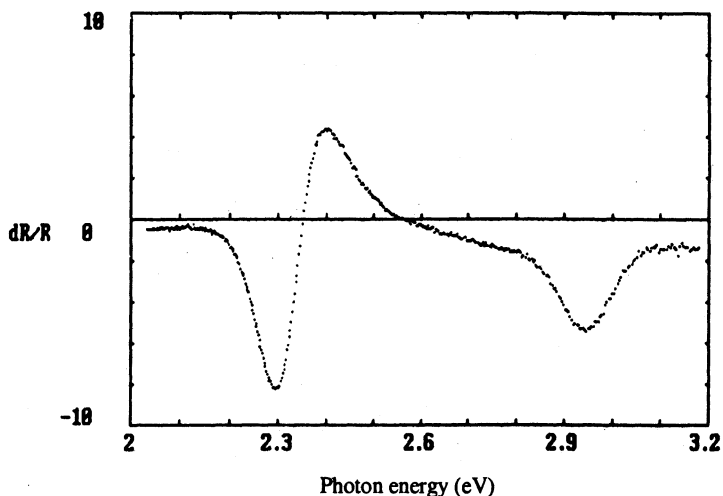
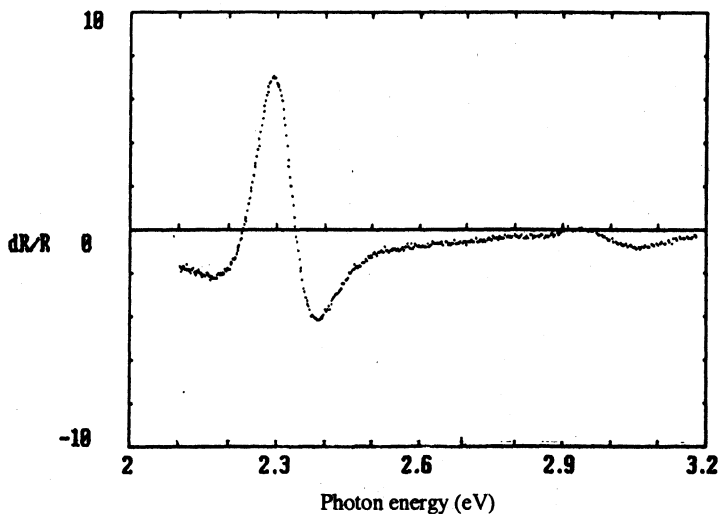
Fig. 1. The experimental arrangement for EER measurements

E_1 and $E_1 + \Delta_1$ band gap energies of HgTe are 2.15 and 2.8 eV respectively and the same band gap energies of CdTe are 3.35 and 4.0 eV. By mixing these two with different composition, x , a new semiconductor $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$ can be produced. Naturally E_1 and $E_1 + \Delta_1$ band gap energies can vary between the two parents. For two extreme cases, we have

$$\Delta E_1 = E_1(\text{CdTe}, x = 1) - E_1(\text{HgTe}, x = 0) = 1.2$$

which corresponds to $\Delta x = 1.0$, therefore variation in E_1 band gap energy of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}_x$ is quadratically proportional to the variation in composition x . For relative measurements and in the small range of the variations in x value it is reasonable to approximate ΔE_1 is directly proportional to Δx by a factor of 1.2.

The flexibility and varying band gap energies give an incredible advantage and a powerful usage, satisfying considerable demands of industries. An n -type and a p -type EER spectra of semiconductors have been shown in Figs. 2 and 3 respectively.

HgCdTe #11 spectrum, $S = 30$ mV, $T_c = 3$ sec, $P = 60$ Fig. 2. An *n*-type EER spectrum in the photon energy range of 2.0–3.2 eVHgCdTe #p182-10 substrate spectrum, $S = 30$ mV, $T_c = 3$ sec, $P = 60$ Fig. 3. A *p*-type EER spectrum in the photon energy range of 2.0–3.2 eV

Reflectance of light from the surface of a sample is not a mirror type reflection and the light is diffused through these samples by about one micron. A light spot has a definite size; therefore the taken spectrum presents an average composition x of this volume. To reduce this volume, nothing can be done about the diffusion. However, a correct setting can reduce the size of the light spot.

In sample preparation, uniformity across the face of the samples plays an important role. Besides, uniformity determination must be done by an accurate method. The EER measurement is one of the most accurate and fast ways to do it

and by that the sample remains undisturbed. The best part of the EER spectrum is the sharp zero crossing area, *i.e.*, 2.4–2.5 eV as shown in Fig. 2. Zero crossing point is proportional to the concerned gap energy which is determined by the composition x across the face of the sample. In Fig. 4, the topological presentation of such experiments has been presented for available samples. Three-dimensional presen-

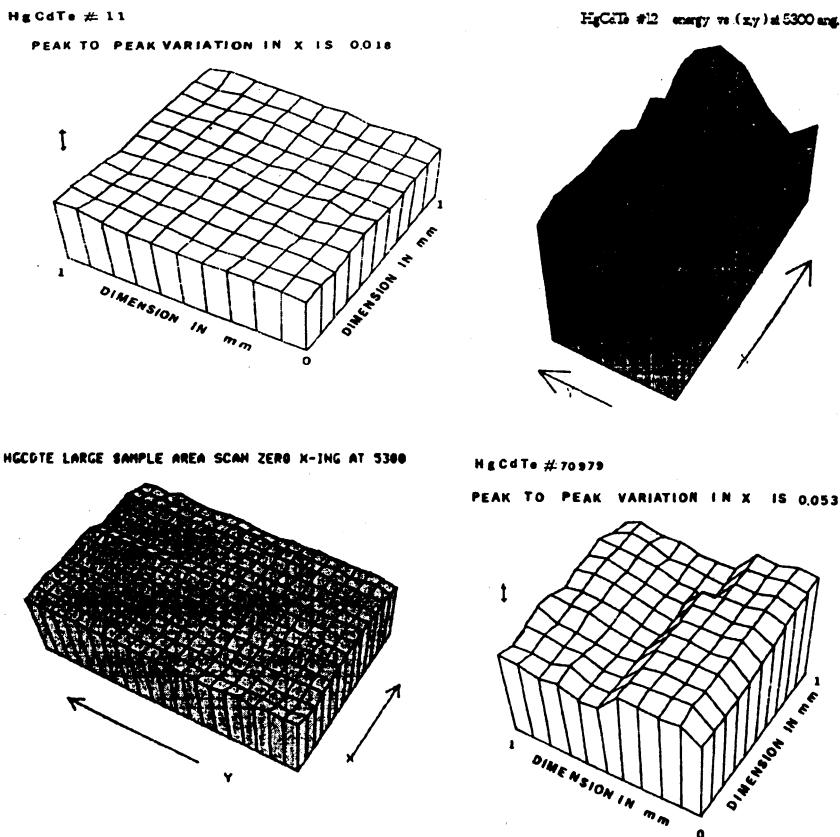


Fig. 4. Three-dimensional presentations of relative variation of composition, x , across the face of $\text{Hg}_{1-x}\text{Cd}_x\text{Te}$.

tations are constructed on an imaginary plane whose one edge is lifted up. The zero crossing point energies are put vertically on the plane and then the end points of these lines are connected to each other, resulting in relative variations on the chosen area.

For a number of samples variations in the composition x have been determined and listed in Table-1. For instance, in the chosen area of sample no. 3; it is found that the maximum deviation in composition x , $\Delta x = 0.0043$ and for sample no. 8 the largest deviation of $\Delta x = 0.0260$.

Conclusion

1. The EER measurement is one of the most accurate methods to determine the uniformity of a sample face from its variation in composition x .

2. By this method, the sample is not damaged and can be used again for other purposes.
3. Automation provides accurate and fast experimental settings.
4. A three-dimensional presentation of band gap energy variations can be presented for a visual control of the uniformity.

TABLE-1
RELATIVE VARIATIONS OF THE COMPOSITION, x , ACROSS THE FACE OF
 $Hg_{1-x}Cd_xTe$ WITH $x = 0.42$ FOR A NUMBER OF SAMPLES

Sample No	Zero crossing (eV)		E_1 (eV)		Maximum Deviation	
	Max.	Min.	Max.	Min.	ΔE_1	Δx
1.	2.3834	2.3644	2.3934	2.3747	0.0191	0.0159
2.	2.3560	2.3511	2.3658	2.3610	0.0048	0.0040
3.	2.3733	2.3682	2.3833	2.3781	0.0052	0.0043
4.	2.3801	2.3704	2.3901	2.3804	0.0097	0.0081
5.	2.3821	2.3528	2.3921	2.3627	0.0294	0.0245
6.	2.3957	2.3751	2.4058	2.3851	0.0207	0.0173
7.	2.3837	2.3613	2.3937	2.3712	0.0225	0.0188
8.	2.3961	2.3651	2.4062	2.3750	0.0312	0.0260
9.	2.4144	2.3991	2.4245	2.4092	0.0153	0.0128
10.	2.3442	2.3285	2.3540	2.3383	0.0157	0.0131
11.	2.3439	2.3362	2.3537	2.3460	0.0077	0.0064
12.	2.3245	2.2448	2.3546	2.3343	0.0203	0.0169

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