

Photoconductivity study as a function of thickness and composition of Zn-Te thin films for different illumination conditions at room temperature

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Thin films of Zn-Te compound of varying compositions and thicknesses have been formed on glass substrates employing three temperature method. The photoconductivity study was made at dark and illuminated conditions. The spectral response of photocurrent as a function of certain wavelength of incident radiations, maximum photocurrent is developed at about 520 nm irrespective of composition and thickness. For the same composition of Zn and Te, photocurrent is function of applied bias voltage and the incident light intensity. The maximum photocurrent was developed at about thickness of 500 nm irrespective of composition and also stoichiometric ZnTe films irrespective of thickness at room temperature.

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1. Introduction

The Zinc –Tellurium is a II-VI semi conducting material of direct band gap 2.26 eV at room temperature, for the fabrication of high efficiency solar cells and other optoelectronic devices [1]. The Zn-Te films grown at room temperature and high temperature substrate are found to be polycrystalline in nature [2].

Optical and thermal activation processes in ZnTe thin films show variation of photo current density for different applied bias voltages and wavelengths [3]. At different concentrations of Zn, when it was mixed with Te the structural and optical properties changes [4]. Thermally stimulated current of ZnTe thin films for different dc bias voltages show $I \propto V^2$ at room temperature [5].

The spectral photo response of ZnTe crystal as a function of wavelength and temperature shows sharp peak at particular wavelength [6]. Mott and Davis [7] looked at the photoconductive response in amorphous semiconductors and presented equations to explain the observed behavior of these materials. Webb and Brodie [8] reported the photoconductivity of amorphous ZnTe have been measured both as a function of temperature and light intensity. The recombination mechanism was observed to change from monomolecular recombination at high temperature and low light intensity to bimolecular recombination at low temperature and high light intensity.

From the survey of literature it is found that few attempts had been made to study the optical properties of Zn-Te system over entire range of composition. Therefore we have taken the investigation of photoconductivity study as an optical property for Zn-Te

films of varying composition and thickness. The spectral response of photocurrent depends on a function of dark and illuminated conditions, applied bias voltage and incident light intensity for the same films.

2. Experimental details

Thin films of Zn-Te for photoconductivity measurement were prepared by the three temperature method [9-13]. Zn-Te films of different compositions and different thicknesses were prepared by vacuum deposition of the constituent elements Zn (99.999% pure) and Te (99.99% pure). Zinc and tellurium powders were evaporated from two different preheated conical mica baskets which in turn heated externally by nichrome wire. The films were prepared mostly on glass substrate kept at room temperature in a vacuum of the order of 10^{-5} torr with an IBP TORR-120 vacuum unit. After adjusting the flux rates from two sources by varying the source current, films of varying thicknesses and compositions were obtained by overcoming the experimental difficulties in adjusting and maintaining evaporation rates of the individual components. The films obtained were annealed at ~ 423 °K for 6 to 8 hours for the purpose of uniform distribution of the components of the deposits. The method employed to determine the composition of the film were similar to those reported earlier [11-13]. The composition of Zn from Zn-Te films was determined by employing absorption spectroscopy [14] at 350 nm.

The film thickness (d) was measured by multiple beam interferometry [15] and gravimetric method [11-13] using the relation,

$$d=M/(g A) \text{ cm}$$

where

- A - Surface area of the film
- M - Mass of the film
- g - The density of the film material, expressed as

$$g = x_1 g_1 + x_2 g_2$$

where g_1, g_2 and x_1, x_2 are densities and atomic fractions of Zn & Te elements respectively.

The spectral response of photocurrent of Zn-Te films were measured at different wavelengths of light, bias voltage, intensity of light, thickness of the film, and at wt. % of Zn at room temperature. The intensity of incident light was measured with Luxmeter (Model 5200, Kyoritsu, Electrical Instruments works Ltd. Japan)

3. Results and discussion

Zn-Te films of different compositions and thicknesses are used for dark and illuminated photoconductivity studies under different conditions of measurements. The exposed area for illumination of such radiation intensities was $\sim 3 \text{ cm}^2$. The photo response of the films were recorded for different radiation energies at room temperature and under different applied bias voltages.

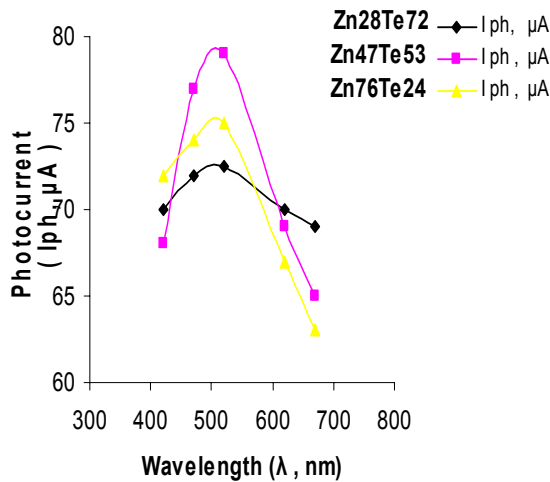


Fig. 1. Plot of Photocurrent ($I_{ph, \mu A}$) versus wavelength ($\lambda, \text{ nm}$) of Zn-Te films at room temperature.

The spectral response of photocurrent (I_{ph}) as a function of wavelength (λ) of incident radiations is shown in Fig. 1. At a certain wavelength maximum photocurrent I_{ph} was observed irrespective of thickness and composition of the film. The maximum photocurrent was developed at about $\lambda=520\text{nm}$, corresponding to energy of

incident radiations $\sim 2.4\text{eV}$. This energy of λ_{max} radiation would correspond to energy of activation. It was observed by previous researchers earlier [16-17]

The position of peak is same for all curves irrespective of thickness and composition of the deposits. This indicates the fundamental band edge is an intrinsic property of the material.

A close analysis of Fig.1 indicates that at a short wavelength the photocurrent rises exponentially to reach maximum value corresponds to $\lambda=520\text{nm}$. It falls at longer wavelength side from the peak position due to carriers from defects and impurity levels. The fall of photocurrent on the high energy side (short wavelength) arises from bimolecular recombination.

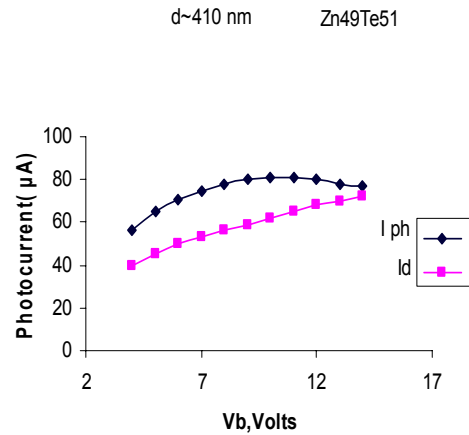


Fig. 2. Plot of photocurrent (I_{ph}) at versus applied bias voltage (V_b) of Zn-Te films at room temperature.

The spectral distribution of Zn-Te films of a fixed composition and fixed thickness at different voltages is shown in Fig. 2. The photocurrent shows the same behavior for all applied potentials, it is observed from the curves that there is no effect from the applied bias voltage except for making an upward shift to the peak for $I_{t \sim 1000}$ Lux and at dark conditions. An increase of photocurrent under the influence of increasing light intensity may be due to the generation of new charge carriers liberated from trap centers due to absorption of incident radiation.

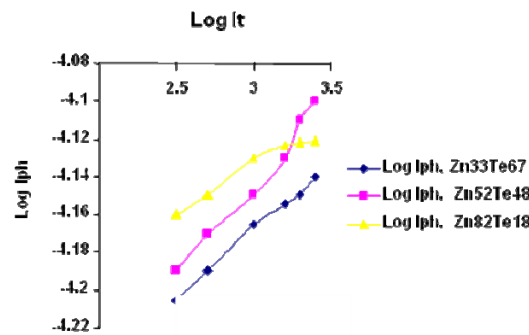


Fig. 3. Plot of $\log I_{ph}$ versus $\log I_t$ of Zn-Te films of thickness $d \sim 450 \text{ nm}$, at room temperature.

The plot of (log I_{ph}) verses incident light intensity (log I_i) for a representative samples of Zn -Te films at room temperature shown in Fig. 3, it follows an equation of the form I_{ph} α I_iⁿ . It can be seen that at high light intensity levels the photoconductivity is proportional to the square root of the light intensity (n ~ 0.5) and the recombination of the photo excited carriers as has been reported by previous workers earlier [8] .

It is evident that at low light intensity the photoconductivity is linearly proportional to intensity of incident radiations suggesting monomolecular recombination of the photo excited carriers (n ~ 1). In a bimolecular recombination, the number of thermally generated carriers is much less than the number of photo excited carriers and in monomolecular recombination the number of thermally generated carriers is much greater than the number of photo excited carriers.

The above observed recombination kinetics of photo excited carriers can be explained on the basis of the DM-model for amorphous materials. It has been shown by Mott and Davis earlier [7] that the photoconductivity can be given by

$$\Delta P \text{ (bimolecular)} = (G/b)^{1/2} * (1 + \Delta E_v / KT) \exp(-\Delta E_v / KT)$$

$$\Delta P \text{ (monomolecular)} = [G / 2bAK^2 T^2] * (1 + \Delta E_v / KT) * \exp [(E_A - E_F) / KT] * \exp (-\Delta E_v / KT)$$

where ΔP is the excess carrier density, ‘b’ is the recombination constant. G is the bulk generation rate, A is constant, E_A is the energy at the conduction band edge, and the other symbols have their usual meaning. The photocurrent will result from carriers excited to energies below E_v in the case of P- type conduction as in a-ZnTe.

From the above discussion it is said that in Zn-Te films a defect band of localized states, extending over a narrow range of energies, exists near the centre of the mobility gap, pinning the Fermi level. Both the conduction and valence bands exhibit tails of localized states extending into the mobility gap, however, tailing is not extensive enough for overlap to occur.

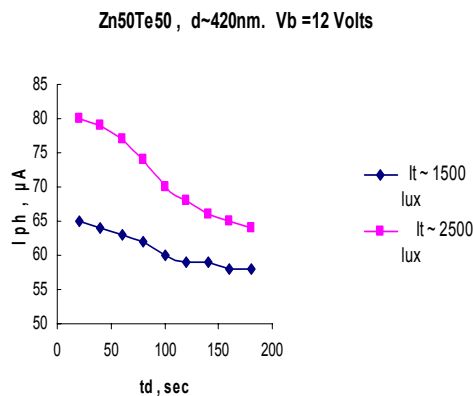


Fig. 4. Plot of Photocurrent (I_{ph}) verses time delay (t_d) of ZnTe films at room temperature.

The decay of I_{ph} as a function of time for constant composition and constant thickness at different light intensities shown in Fig. 4. It can be seen that, the decay rate at high intensity curve exceeds its value compared to lower intensity curve. This could be because at low light intensity, recombination through traps manifests itself and thereby decay rate decreases.

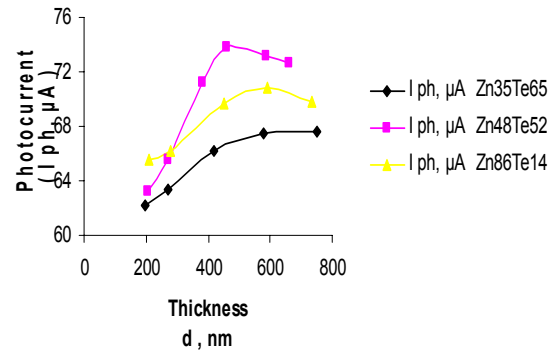


Fig. 5. Plot of photocurrent (I_{ph}) verses thickness (d) of Zn-Te films at room temperature.

Variation of photocurrent with thickness of the film having different compositions shown in fig.5. It is seen that photocurrent increases with increase of thickness irrespective of composition of Zn-Te films, probably due to lesser density of defects in thicker films.

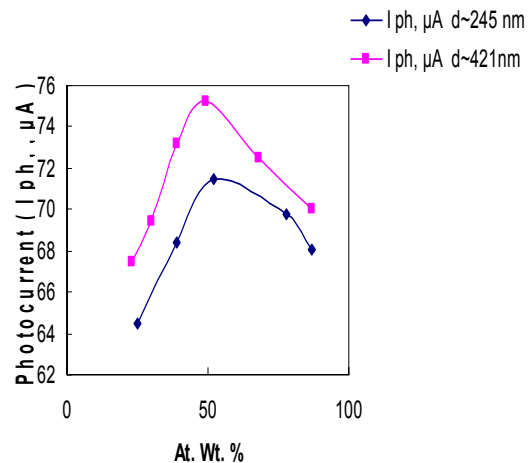


Fig. 6. Plot of photocurrent (I_{ph}) verses At. W. % of Zn in Zn-Te films at room temperature.

Variation of photocurrent with composition of the film shown Fig. 6. It has been revealed from the figure that photocurrent increases with increases of Zn content in the films reaches to maximum at about 50 at. wt. % of Zn and then further decreases with increases of Zn, clearly indicating that maximum photocurrent is developed in a stoichiometric ZnTe films. This has been observed for all film thicknesses.

4. Conclusions

The maximum photocurrent was developed at about thickness of 500 nm irrespective of composition and also stoichiometric ZnTe films irrespective of thickness at room temperature.

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