SINGLE OSCILLATOR PARAMETERS AND OPTICAL ENERGIES OF LASER IRRADIATED Cu DOPED CdS THIN FILMS

C. I. ORIAKU, J. C. OSUWA*, C. H. NJOKU
Department of physics, Michael Okpara University of Agriculture, Umudike, P.M.B. 7267, Umuahia, Abia State, Nigeria

We present in this paper the results of the oscillator parameters and the optical energies for as grown and laser irradiated Cu doped CdS thin films. These parameters were modeled from transmission spectra data measured by spectrophotometry. The as grown thin film compositions were obtained using Rutherford backscattering spectrometry. The refractive index dispersions data of both the as grown and laser irradiated Cu doped CdS thin film obeyed the single oscillator model. The computed oscillator parameters; static refractive index n_s, oscillator strength E_d, spectra moments M_{-1}, and M_{-3} reduced after irradiation while the oscillator energy E_0, increased after irradiation. The absorption pre exponential factor α_0 and Urbach energy E_u were observed to increase after laser irradiation.

(Received March 14, 2011; accepted March 23, 2011)

Keywords: Cu doped CdS, Refractive index dispersion, Optical energies, Oscillator parameters

1. Introduction

Extensive researches carried out on chalcogenide based thin films have shown that they can be used as wide band gap high power devices, surface acoustic devices and as highly sensitive infrared detectors. They behave as semiconductors and exhibit amorphous semiconductor behavior with band gap energy ranging from 1eV to 3eV [1 -3]. Both amorphous and crystalline forms are suitable for applications due to their special properties on interaction with light including infrared transparency and modification of their refractive index [4, 5]. Another interesting property of chalcogenide based glasses is that they exhibit high values of refractive index in the range 2.3- 3.2 eV, making them good candidates for coupling IR light beams into chalcogenide glass waveguides [6]. Cu Doped CdS is a widely studied chalcogenide thin film glass [1, 2, 7- 8]. The thin films of Cu:CdS are known to be sensitive to the absorption of electromagnetic radiation that on exposure to any form of radiation (eg Laser radiation), is capable of exciting electron-hole pairs and can exhibit structural changes [1]. Another effect of electromagnetic radiation such as laser is that it can induce drift of electrons, which can change the refractivity of the materials and as a result, can cause changes in the surface output of the semiconducting crystals [9].

The evaluation of optical dispersions and other optical constants of semiconductors are of considerable importance for applications in integrated optoelectronic devices, where the refractive index of a material is the key parameter for device design [10]. This has proved to be very useful for elucidation of the electronic structure of these materials [8, 10- 11]. In this communication, the effects of He-Ne laser radiation with Cu doped CdS thin films on the oscillator parameters and optical energies are presented.

*Corresponding author:josuwa70@gmail.com

2. Experimental

The deposition of Cu doped CdS thin films was by chemical bath deposition (CBD) method as reported in our earlier works [1, 2]. A sample of the as grown films was irradiated for 20 minutes with He-Ne laser operating at wavelength of 632.8nm placed 1m from the film sample. Rutherfords backscattering Spectrometry (RBS) and Spectrophotometry were employed to obtain the composition and optical transmission data for both the as grown and the laser irradiated thin films respectively.

3. Results and discussion

A tandem accelerator for ion beam analysis equipped with Rutherfords cross section detector showed the elemental compositions for both the soda lime glass substrate and Cu doped CdS (Cu:CdS) as presented in Table 1.

Table 1: Elemental Compositions for Soda Lime Glass substrate and Cu doped CdS thin Film.

----------	Cd	Cu	S	Si	Ca	Al	Na	O
Soda lime glass	--------	---------	----------	0.2000	0.0500	0.1000	0.1000	0.5500
Cu doped CdS	0.4000	0.1100	0.4900	---------	---------	---------	---------	---------

The optical transmission spectra are imperatively used to describe the energy band gap and band structure of amorphous and crystalline materials. As shown in figure1, the spectral transmissions of as grown Cu:CdS(1) thin films show high values greater than 70% at the VIS-NIR region and however dropped to values less than 50% at the band edge after irradiation with laser Cu:CdS(2). The variation in optical transmittance of un-irradiated and laser irradiated thin film samples can be due to changes in surface output of the semiconducting crystals achieved on interaction with laser radiation.

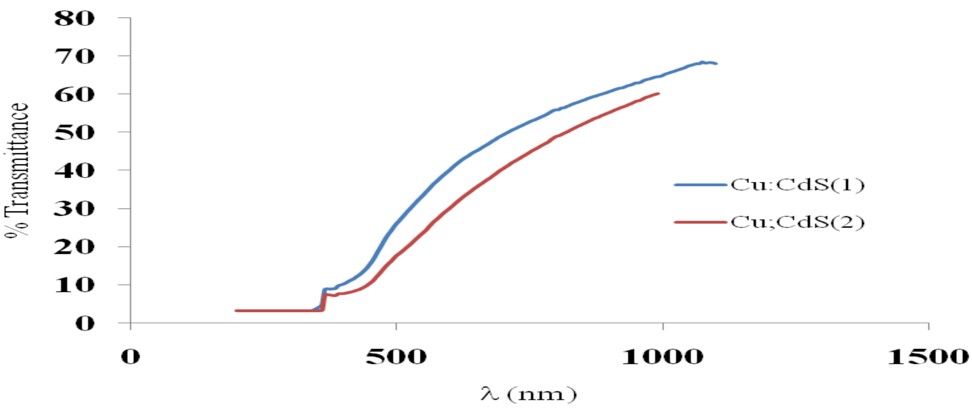

Fig. 1: Transmittance Spectra Un-irradiated and laser Irradiated

The oscillator parameters were calculated using the single oscillator model [8, 10], proposed by Wemple and Di Domenico viz;

$$n^2 = 1 + \frac{E_0 E_d}{E_0^2 - (h\nu)^2} \quad (1)$$

Where n is the refractive index, E_o is the oscillator energy, E_d is the oscillator strength and $h\nu$ is the incident photon energy. The refractive index can be obtained directly from the transmission using some well known mathematical relations in literature [12]. Equation (1) can be simplified as follows;

$$(n^2-1)^{-1} = \frac{E_o}{E_d} - \frac{(h\nu)^2}{E_o E_d} \qquad (2)$$

To evaluate the oscillator parameters, a graph of $(n^2-1)^{-1}$ against $(h\nu)^2$ was plotted in figure 2. From the plot (E_o/E_d), represents the intercept on the vertical axis and $(E_o E_d)^{-1}$ is the slope, hence, E_o,E_d can be evaluated. The moments of the dispersion spectra M_{-1} and M_{-3}, can be evaluated using the relationships:

$$E_d^2 = \frac{M_{-1}^3}{M_{-3}} \qquad (3)$$

$$E_o^2 = \frac{M_{-1}}{M_{-3}} \qquad (4)$$

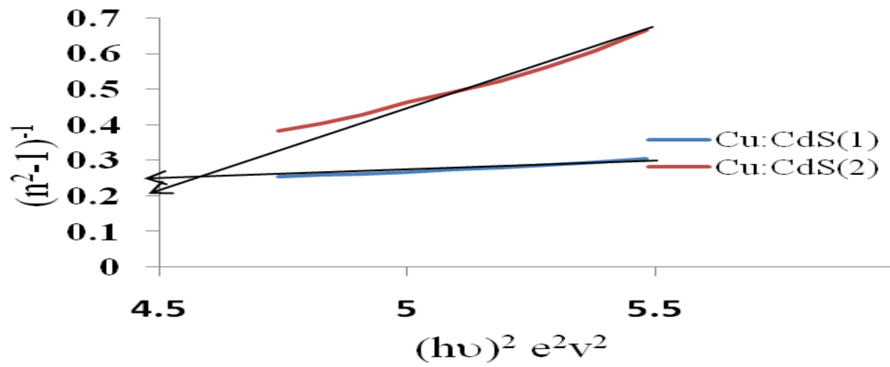

Fig. 2: Plot of $(n^2-1)^{-1}$ versus $(h\upsilon)^2$ (a)Un-irradiated, (b) laser Irradiated

The plot of the refractive index n against photon wavelength is shown in the fig.3. It is clearly observed that the refractive index tends to decrease for both films as we approach the longer wavelength. The refractive index was found to decrease after irradiation with laser.

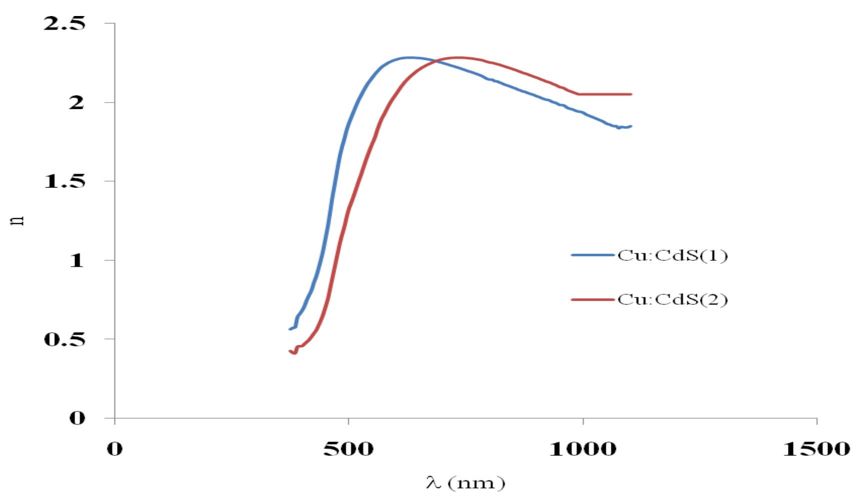

Fig. 3: Plot of Refractive Index (n) versus Photon Wavelength Un-Irradiated and laser irradiated films.

In both amorphous and crystalline materials, some useful information can be deduced from absorption edge measurements [12]. The edge in amorphous phase is less sharp than in crystalline phase. This is in line with our findings here. The edge in the laser irradiated sample (crystalline) is sharper than the as grown sample (amorphous phase). For many amorphous and crystalline materials, an exponential dependence of the absorption coefficient on photon energy hν is found to hold over wide range and takes the form [12];

$$\alpha = \alpha_0 \exp\left(\frac{h\nu}{E_u}\right) \qquad (5)$$

Where α_o is the pre-exponential factor, E_u is known as the Urbach energy which is the width of the localized state. Taking the natural logarithm of equation (5) gives

$$\ln\alpha = \ln\alpha_0 + \frac{h\nu}{E_u} \qquad (6)$$

By plotting $\ln\alpha(\nu)$ against photon energy $h\nu$ and extrapolating a straight line as in figure 4, the Urbach energy E_u was determined directly from the slope E_u^{-1} while the pre-exponential factor α_o was determined from the intercept $\ln\alpha_o$ on the vertical axis. The values of the Urbach energy E_u and the pre-exponential factor α_o are observed to increase after laser irradiation.

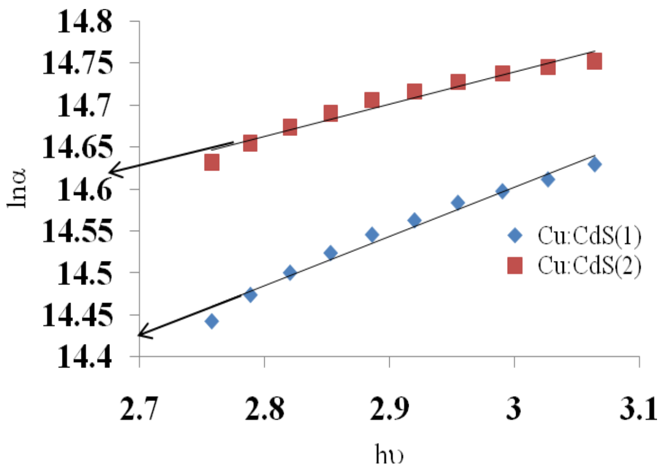

Fig.4: Plot of lnα versus photon energy of un-irradiated and laser Irradiated films.

Also, the absorption coefficient (α) is related to the incident photon energy ($h\nu$) by the following equation;

$$[(\alpha h\nu)]^{(1/n)} = A(h\nu - E_g) \qquad (7)$$

Where A is a constant, h is Plank constant, n is the index which depends on the type of transition. The values of n for allowed direct, allowed indirect, forbidden direct and forbidden indirect transitions are 1/2,2,3/2,and 3, respectively [3-8]. Cu;CdS is a direct band gap material, so putting n=1/2, equation 7, becomes;

$$[(\alpha h\nu)]^{2} = A(h\nu - E_g) \qquad (8)$$

To obtain the optical bandgap E_g, the graph of $(\alpha h\nu)^2$ versus $h\nu$ was plotted, as shown in Figure 5. As determined from figure 5, the bandgap E_g decreases from 2.48 to 2.30 eV after laser irradiation.

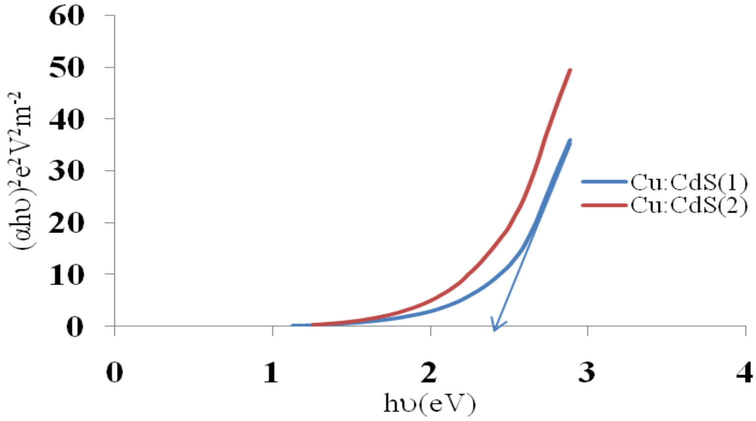

Fig. 5: Plot of $(\alpha h\upsilon)^2$ versus Photon Energy Un-irradiated and laser irradiated films.

The values of the Urbach energy, dispersion parameters and band gaps are presented in table 2.

Table 2: values of dispersion parameters and energy band gap of un-irradiated and laser irradiated Cu:CdS films.

Cu:CdS	n_s	$E_o(eV)$	$E_d(eV)$	M_{-1}	$M_{-3}(eV)^2$	$\alpha_0\,(m^{-1})$	$E_u(eV)$
Un-irradiated	2.269	1.671	6.934	4.149	1.486	327748	1.613
irradiated	2.031	2.146	6.706	3.125	0.679	729416	2.421

The values of oscillator energy, E_o, the pre-exponential factor α_0 and urbach energy E_u increased after irradiating Cu:CdS with laser, while the optical spectra moments M_{-1}, M_{-3}, the static refractive index n_s and the oscillator strength E_d decreased after irradiation with laser. The substantial changes in these parameters within the optical regime usually associated with the evolution of the thin film microstructure from a near amorphous phase to a more ordered phase [13], will be considered useful in probing further the optoelectronic structure of these materials for device fabrication.

4. Conclusions

Spectrophotometric measurements of transmission spectra data of both laser irradiated and un-irradiated Cu doped CdS thin films have been characterized to obtain the dispersion parameters and optical energies of the samples. The results show remarkable shifts in the values of the transmittance, refractive index, energy band gap, urbach energy, spectra moments and oscillator strength between the irradiated and un-irradiated samples. These constitute important factors in possible areas of application of Cu doped CdS thin films.

References

[1] J.C.Osuwa, C.I Oriaku, Journal of Non-oxide Glasses, **2**, Iss.1, (2010).
[2] J.C.Osuwa, C.I Oriaku, C.M. Atuloma, Chalcogenide letters, **6**, Iss. 6, (2010).
[3] A.Abu El-Fadl, Galal A.Mohamad, A.B.Abdl El-Moiz, M.Rashad physica B 366. (2005)
[4] J. Singh, K. Shimakawa, Advances in Amorphous Semiconductors, Taylor and Francis, (2003).
[5] A. Lorinczi, F. Sava, A. Anghel, J. opt. Adv. Mater. **6**(1), 349 (2004).
[6] D. Savastru, S. Miclos, R. Savastru, J. Opt. Adv. Mater. **8**(3), 1165 (2006).
[7] J.C.Osuwa, C.I Oriaku, O.I Uko, Chalcogenide letters, **7**, no7, 2010.

[8] S.ILican, Y.Caglar, Physica Macodonica, **56**, 43, (2006).
[9] M.M Krupa, A.M Korostil, Yu. V. Skirta, I. Vuzoz, Radio Fizika, Russ. **158**, 674 (2005).
[10] C. I. Oriaku, J.C Osuwa, Journal of Ovonic Research, **5**, no.6 (2009).
[11] F. Yakuupanoglu, S. Ilican, M. Caglar, Y. Caglar, J. Opt. Adv. Mater, **9**, 2180, (2007).
[12] D. Ghoneim, K. H. Marzouka, S. N. El-Sayed, N. A. Mohsen, A. M. A. Mahmoud Chalcogenide Letters **7**(5), 313 (2010).
[13] N.K. Sahoo, S. Thakur, R.B. Tokas, Applied Surface Science, (2006).