EFFECTS OF TEMPORAL VARIATIONS IN DEPOSITION ON THE OPTICAL AND SOLID STATE PROPERTIES OF ELECTRO-DEPOSITED CADMIUM TELLURIDE (CdTe) THIN FILMS ON GLASS FTO.

J. C. OSUWA*, N. I. CHIGBO, C. I. ORIAKU
Department of Physics, Michael Okpara University of Agriculture, Umudike, PMB 7267, Abia State, Nigeria

Electro-deposition of cadmium telluride (CdTe) thin films were grown on fluorine-doped tin oxide on glass (glass FTO) at room temperature of 27 ^oC and at the same cathodic voltage, for different deposition times ranging from 30-180 minutes. The effects of temporal variations in deposition on the absorbance and transmittance of the thin films were analyzed with a spectrophotometer (D model Avantes Spec 2048 version 7.0) and were found to occur only in the NIR region of 800-1000 nm wavelength. The results show substantial increase in absorbance and decrease in transmittance with increase in deposition time. Other optical and solid state properties were evaluated using appropriate mathematical relations and excel package and the values obtained are reported in this paper. The energy band gaps, E_g, for direct transitions for all the thin film samples analyzed were found to lie between 1.48-1.50 eV in agreement with E_g of 1.48 eV reported in literature and in conformity with CdTe as one of the leading thin film materials for solar cell fabrication due to the high absorbance associated with its band gap energy.

(Received November 12, 2012; Accepted November 22, 2012)

Keywords: Cadmium telluride, Temporal variations in deposition, Increase in absorbance, Decrease in transmittance, Solar cell fabrication

1. Introduction

Cadmium chalcogenides thin films have received intensive attention in recent times as their band gap lies close to the range of maximum theoretically attainable energy conversion efficiency [1-3]. They can also be used in hetrojunctions, IR detectors, switching devices and optoelectronics. The importance of high quality polycrystalline films of CdTe finds application in high efficiency solar cells [4-7].

As the rapid development in the field of group II-VI semiconductors for their use in photovoltaic devices continues to receive attention, cadmium telluride belonging to the II-VI group is widely used material for CdS/CdTe hetrojunction photovoltaic devices [8-10]. This is due to the fact that CdTe has intermediate energy band gap, reasonable conversion efficiency, stability and low cost [11]. The increasing interest in solar absorption has also created a demand for the characterization of absorbing semiconducting thin film materials in the visible and near infrared range for their application in photovoltaic devices. The band gap, E_g, is the most important parameter in semiconductor Physics. Cadmium Chalcogenide materials have band gaps of $1.4 \leq E_g \leq 2.4$ eV and reasonable overlap with the solar spectrum. Thus, CdTe remains a promising base material for solar cells owing to its nearly optimum energy band gap and high absorption coefficient [1]. In this paper, the effect of variation in deposition time of CdTe thin films on the absorbance, transmittance and other optical and solid state properties have been studied and analyzed.

*Corresponding author: josuwa70@gmail.com

2. Experimental details

2.1 Substrate Preparation

In preparing the substrates the glass/FTO sheets were cut into small sheets of about $4cm^2$ each. Each small substrate was then washed in soap solution in ultrasonic bath for about 15 minutes followed by rinsing with de-ionized water. Methanol, acetone, nitric acid and acetic acid were also used in succession to clean the substrates and rinsing with de-ionized water in between.

2.2 Deposition of cadmium telluride (CdTe) thin films

A conventional three-electrode system consisting of a work electrode, counter electrode, and reference electrode were used for the electro-deposition of CdTe. Each cleaned substrate was dried with nitrogen gas and attached to a graphite rod to serve as the cathode for electro-deposition. The counter electrode is also a graphite rod. In this case of CdTe deposition, a reference electrode is used in addition. The solution for CdTe deposition consists of 800ml aqueous solution of 1M $CdSO_4$ and about 0.001M TeO_2 in 1 liter beaker. All reagents were of analytical grade and were used without further purification. The pH of the solution was finally adjusted to 2.0 after stirring for 24hours.

A wire was connected from the negative pole of the D.C power supply to common of the ammeter while the positive pole was connected to the counter electrode (graphite electrode). Another wire was connected from the positive pole of the ammeter to the work electrode (glass/FTO substrate). The positive of the voltmeter was connected to the counter electrode, while the common of the voltmeter was connected to the reference electrode. Next, the three electrodes were immersed into the electrolyte which contains a solution of the metal salt to be plated i.e $CdSO_4$ and TeO_2

The voltage of the DC power supply and current in the ammeter were 5V and 0.01A respectively. The samples were electro-deposited at the same cathodic voltage for different durations of 60 min, 30 min, 90 min, 120 min, 150 min and 180 min successively. After deposition, the films were rinsed with copious amounts of distilled water, dried in air under ambient condition and kept in an air tight container to avoid contamination. The reaction processes are as follows;

Reduction of Tellurium

$$HTeO_2^+{}_{(aq)} + 3H_{(aq)}^+ + 4e^- \rightarrow Te_{(s)}^{4+} + 2H_2O$$

Deposition of Tellurium with the Cd^{2+} ions

$$Te_{(s)} + Cd^{2+}{}_{(aq)} + + 2e^- \rightarrow CdTe_{(s)}$$

Generally, the overall cathode reaction is

$$Cd^{2+}{}_{(aq)} + HTeO_2^+{}_{(aq)} + 3H_{(aq)}^+ + 6e^- \rightarrow CdTe_{(s)}^{4+} + 2H_2O$$

Similarly, anode reaction is

$$4OH- \rightarrow O_2 + 4e^- + 2H_2O$$

3. Results and discussion

Spectral measurements with spectrophotometer which occurred in the NIR region of 800-1000 nm wavelength are shown in figs. 3.1-3.3 for absorbance, transmittance and reflectance. Figure 3.1 shows a steady increase in absorbance from 0.25 t0 0.9 for samples deposited from 30-180 minutes. The trend is reversed for the transmittance of fig. 3.2 with steady decrease in transmittance from 70 percent at 1000 nm down to 12 percent at 800 nm wavelength for the sample deposited for 180 minutes . Figure 3.3 shows that samples deposited for more than 90 minutes have negative reflectance at 800 nm wavelength while all samples exhibit low reflectance of between 5-25 percent in the entire NIR range, thus making them good anti-reflectance materials .

Higher absorbance with longer deposition time is further confirmed by the absorption coefficient shown in fig. 3.4. As shown in fig.3.5, the energy band gap obtained from the well known Tauc's relation [12-13]

$$(\alpha h\upsilon) = A(h\upsilon - E_g)^n \tag{3.1}$$

all lie between 1.48 – 1.50 eV for all the samples for the direct allowed transition with n=1/2. Figures 3.6 – 3.10 depict the trends of the extinction coefficient , refractive index, real and imaginary dielectric constants and optical conductivity. Except for the refractive index, all other quantities show increased values with increase in deposition time. The refractive index shown in fig. 3.7 has values of less than 1.0 for CdTe thin films deposited for more than 90 minutes at photon energy of about 1.58 eV , while all samples have refractive index between 1.2 and 1.7 in the entire NIR range.

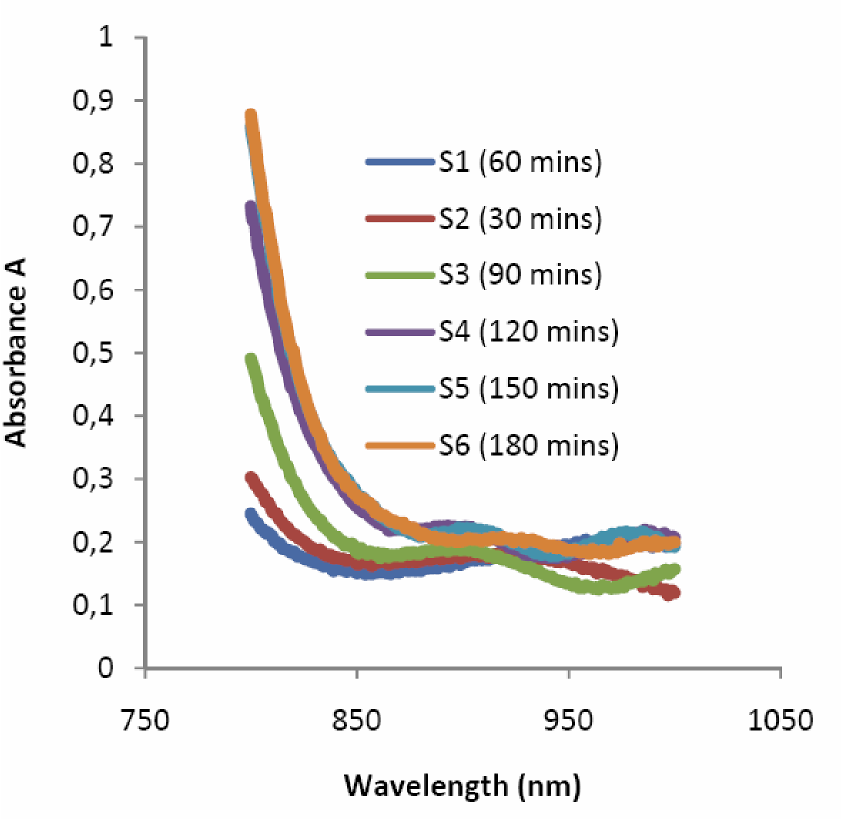

Fig. 3.1 Absorbance as a function of wavelength for CdTe at different deposition time.

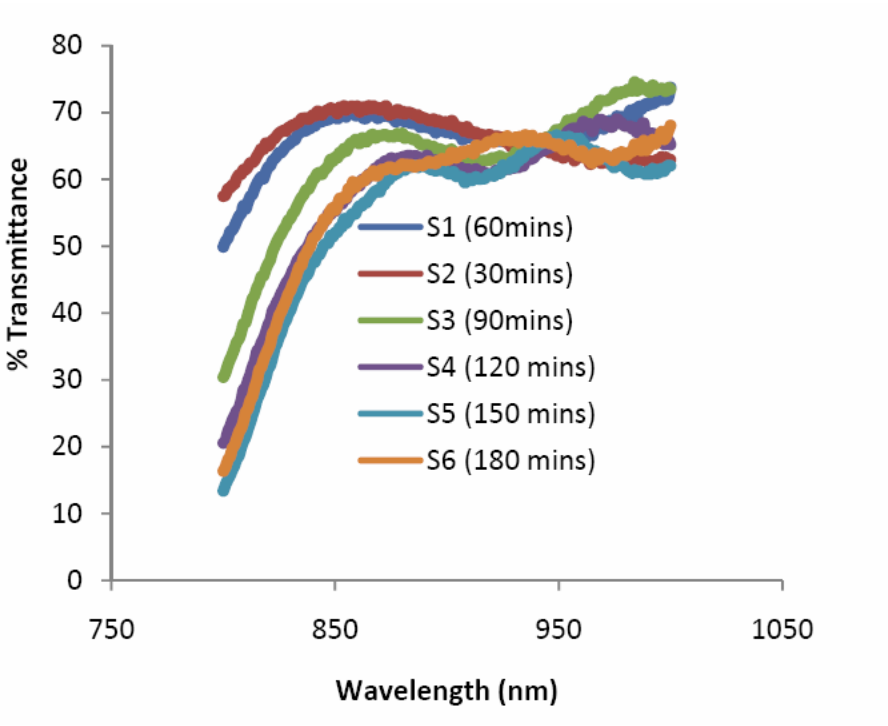

Fig.3.2 % Transmittance as a function of wavelength for CdTe at different deposition time

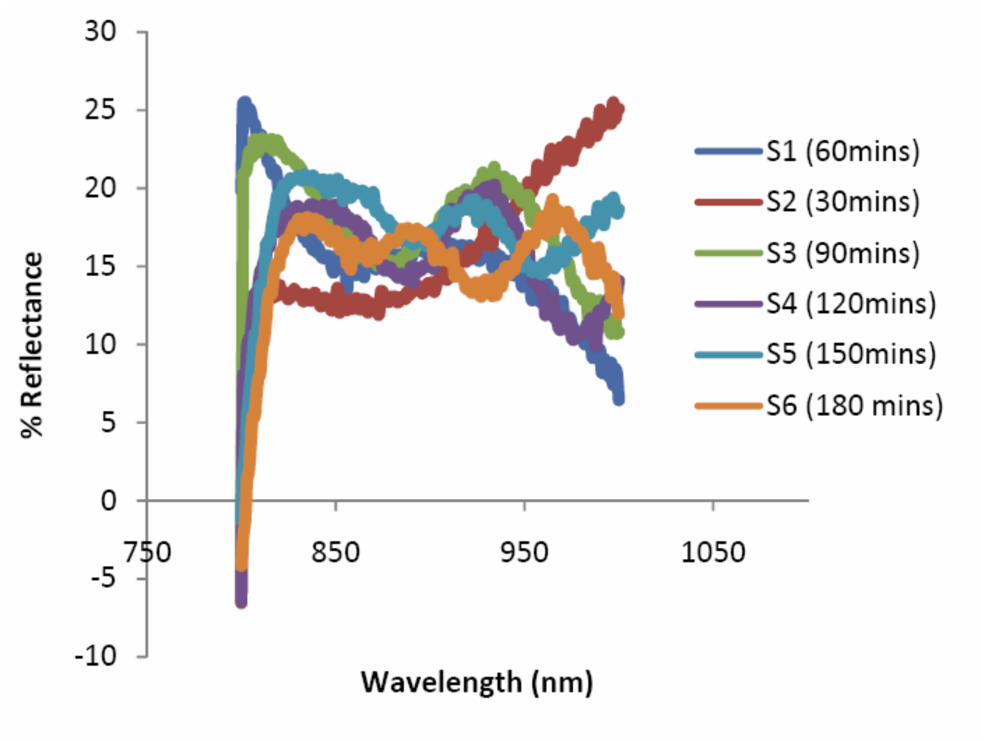

Fig. 3.3 % Reflectance as a function of wavelength for CdTe thin film at different deposition time

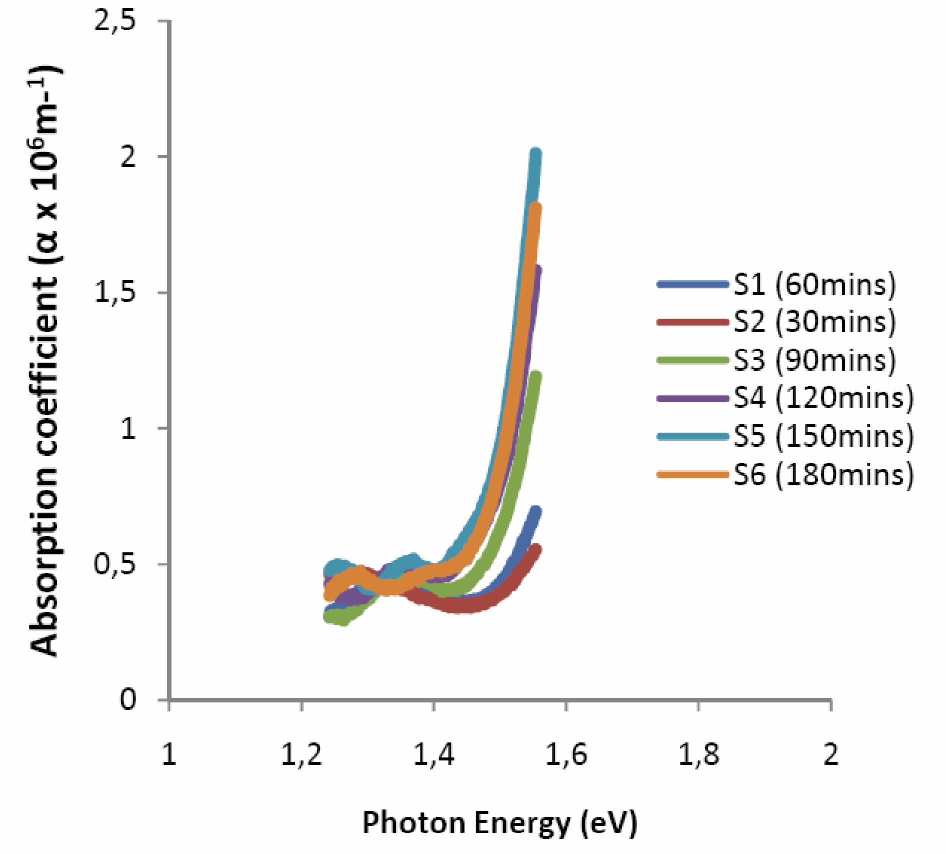

Fig.3.4 Absorption coefficient as a function of photon energy of CdTe thin film at different deposition time

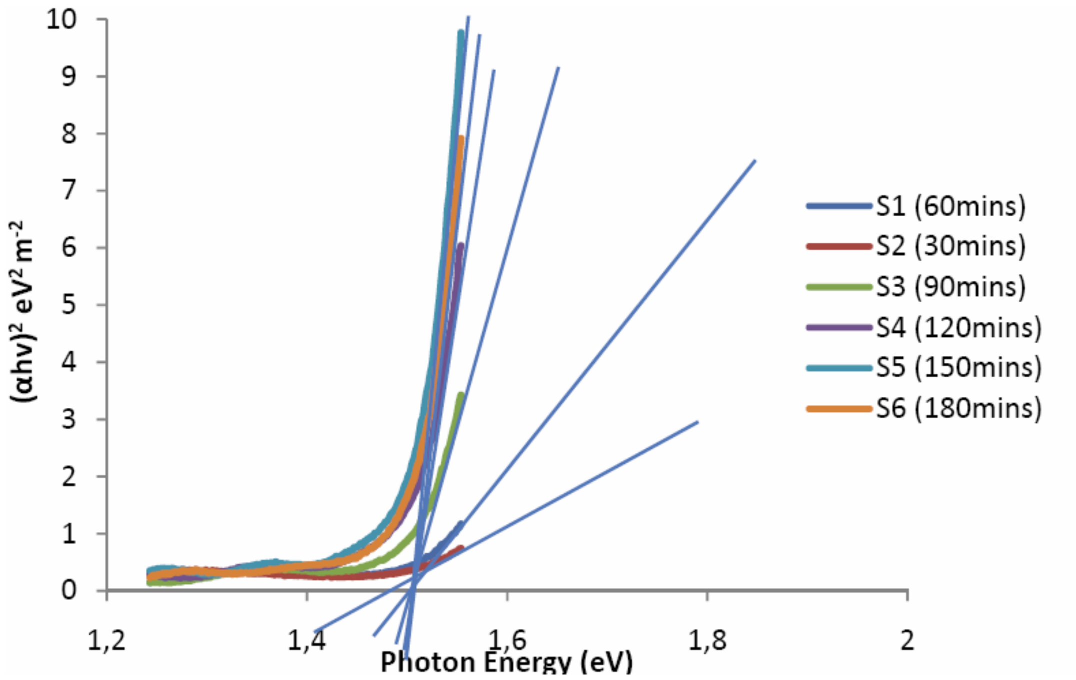

Fig. 3.5: Plot of $(\alpha h\nu)^2$ as a function of photon energy of CdTe thin film at different deposition time

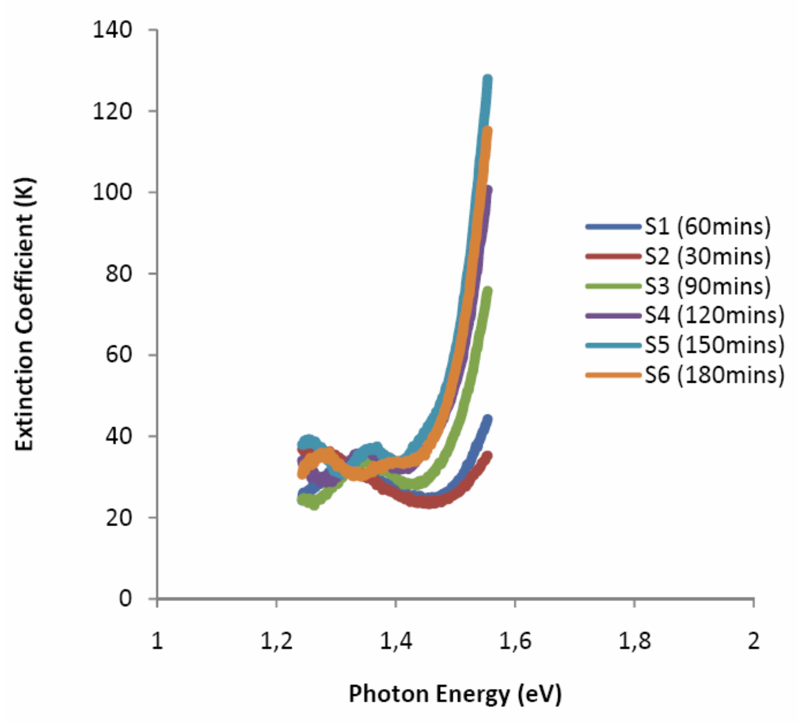

Fig. 3.6 Extinction Coefficient as a function of photon energy of CdTe thin film at different deposition time

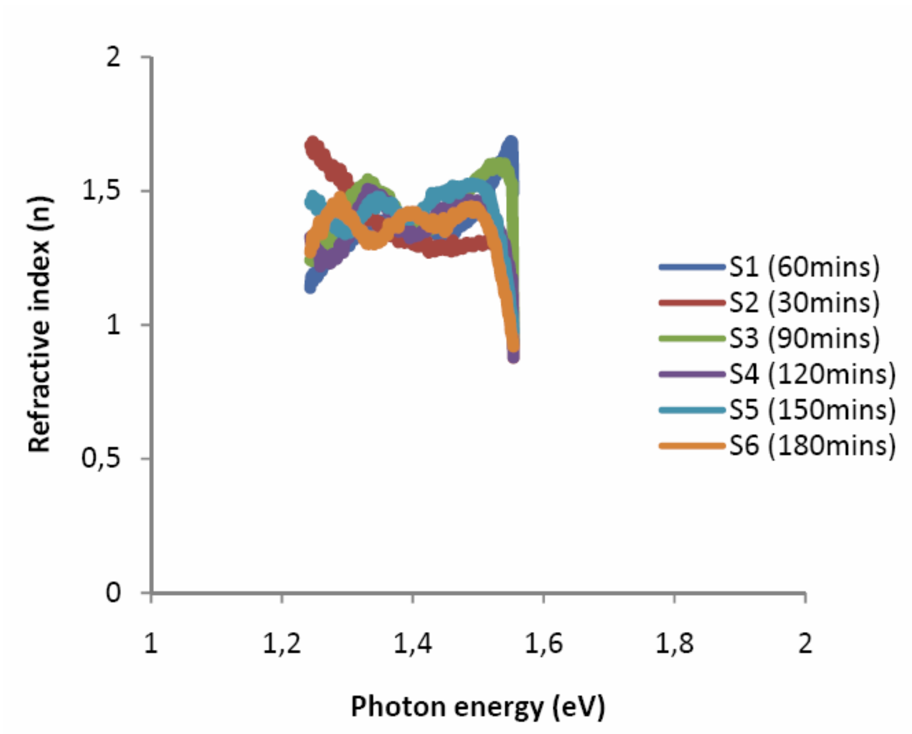

Fig.3. 7: Refractive index as a function of photon energy for CdTe thin film at different deposition time

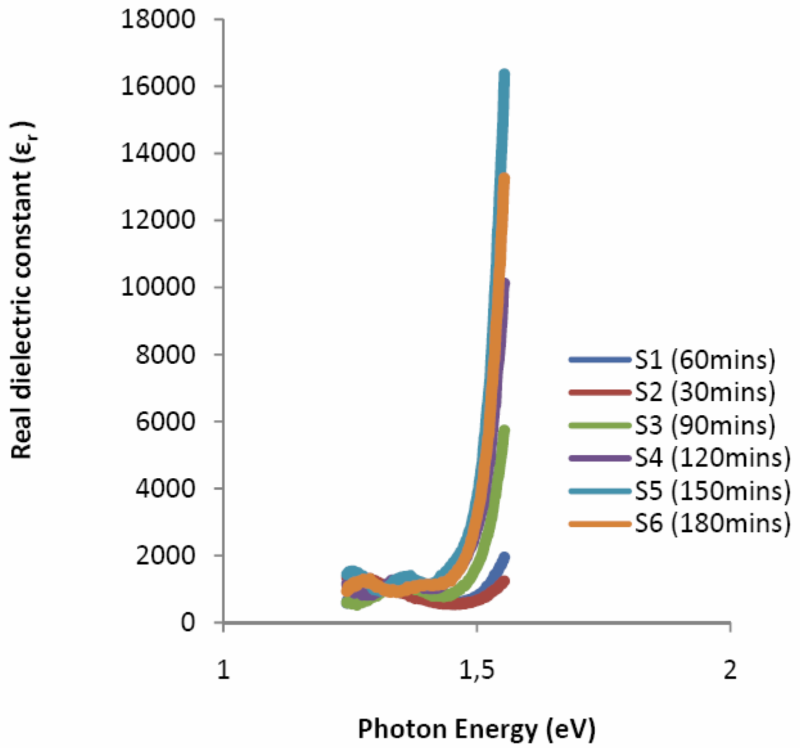

Fig. 3.8: Real Dielectric constant as a function of photon energy for CdTe thin film at different deposition time

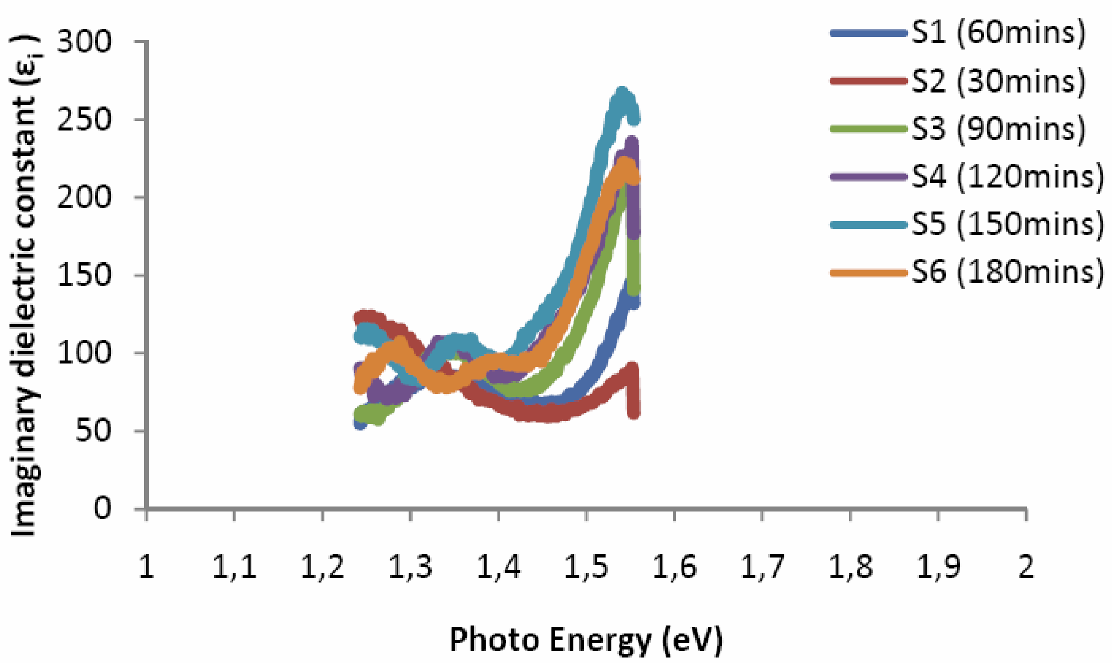

Fig. 3.9: Imaginary Dielectric constant as a function of photon energy for CdTe thin films at different deposition time

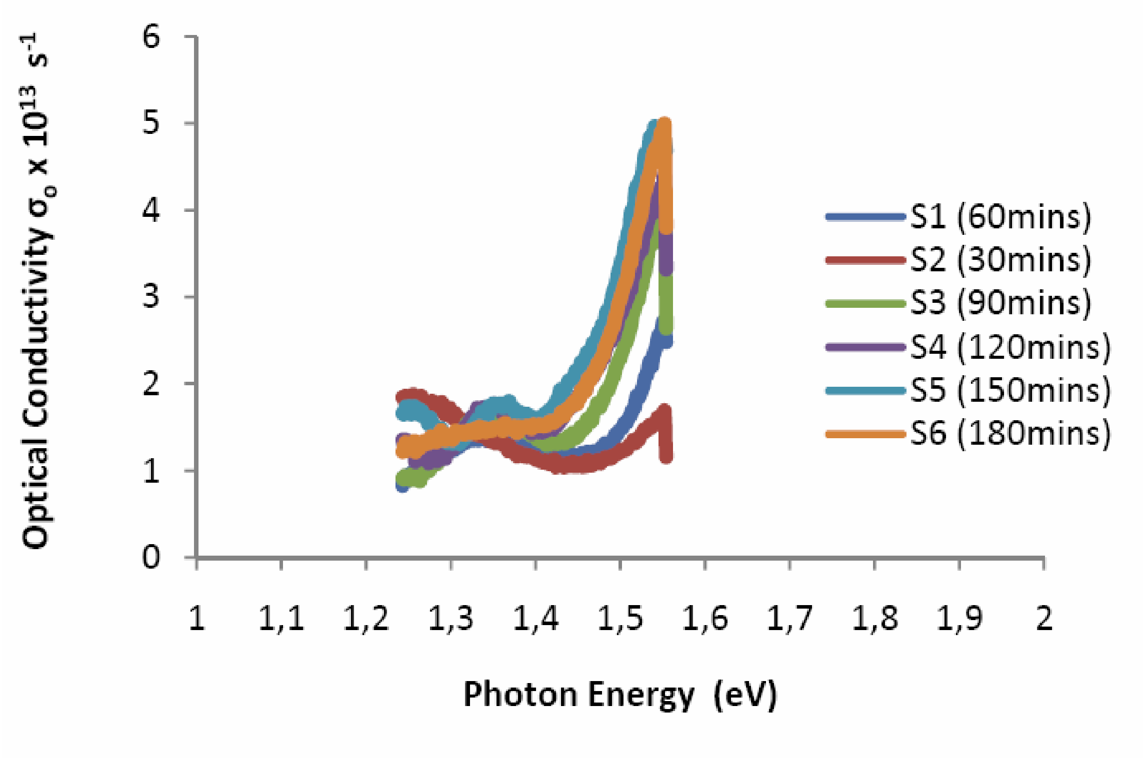

Fig. 3.10: Optical conductivity as a function of photon energy for CdTe thin films at different deposition time

4. Conclusions

Electro-deposition of cadmium telluride (CdTe) thin films were synthesized at the same cathode voltage on fluorine-doped glass (glass FTO) for different deposition times. Spectrophotometer measurements revealed increase in absorbance and decrease in transmittance and reflectance with increase in deposition time. Pronounced changes in all optical and solid state properties of the CdTe thin films including the absorption coefficient, extinction coefficient, refractive index, real and imaginary dielectric constants and optical conductivity, occurred for deposition times of 90 minutes and above as reported in this paper. The direct transition energy band gap of all the film samples analyzed lie between 1.48-1.50 eV in agreement with values reported in literature and in conformity with CdTe thin films as one of the leading nano-materials for fabrication of photovoltaic devices

The above results also provide basis for improved performance of CdTe thin films in other areas of its application such as infrared detectors, switching devices, hetrojunctions and in optoelectronics.

References

[1] K.Vipin, J.K. Gaur, M. K. Sharma, T. P. Sharma, Chalcogenide Letters, **5**(8), 171-176 (2008)
[2] M. Hädrich, C. Kraft, C. Löffler, H. Metzner, U. Reislöhner and W. Witthuhn, Thin Solid Films **517**(7), 2285 (2009)
[3] D. K. Kulkarni, Bull. Mater Sci **29**(2):165-168 (2006)
[4] S. Marsillac, V. Y.Parikh and A.D. Compaan, Solar Energy Materials and Solar Cells, **91**, 1394-1402 (2007)
[5] I. M.Dharmadasa and J. Haigh, Electrochem Soc. **153**(1):47-52 (2006)

[6] B. Habibe and E. Cigdem, Journal of Physics **22**,441-451 (1998)
[7] T. L. Chu and S. S. Chu, Solid State Electron .,**38**(3) 533-549 (1995)
[8] S. Dennison, Mater J. Chem **4**(1), 41-16 (1994)
[9] T. Gruszeski and B. Holmstrom, Solar Energy Materials and Solar Cells, (31) 227 (1993)
[10] P. Bhattacharya, D. N.Bose, Semiconductor Science and technology **6**(5) (1991)
[11] W. J. Danahar and L. E. Lyons, Aust. J. Chem **37**(70689-701 (1984)
[12] S. M. U.Ishiwu, M.N. Nnabuchi and C. N Eze, Chalcogenide Letters, **8**(1): 59-64 (2011)
[13] J. C. Osuwa, C. I. Oriaku and O. I. Uko, Chalcogenide Letters, **7**(7) 449-453 (2010)