Omdurman Islamic University Journal(OIUJ)
مجلة جامعة أم درمان الاسلامية
https://journal.oiu.edu.sd/index.php/oiuj
https://doi.org/10.52981/oiuj.v17i2.1493
2021; 17(2):1-13
ISSN: 5361-1858

Change in Optical Properties due to Exposure of CdTe Thin Films to Magnetic Field

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To cite this article:
Abdelnabi Ali Elamin, Change in Optical Properties due to Exposure of CdTe Thin Films to Magnetic Field, Omdurman Islamic University Journal, Vol. 17, No. 2, 2021, pp. 1-13, https://doi.org/10.52981/oiuj.v17i2.1493

Received: 05, **10**, 2021; **Accepted**: 7, 20, 2021; Published: 12, 22, 2021.

ABSTRACT

The aim of this research is to study the effect of magnetic fields on the optical properties of CdTe thin films prepared by thermal evaporation techniques. The optical properties of CdTe such as transmittance, absorption, reflectivity, absorption coefficient, extinction coefficient, dielectric constant, and refractive index, have been studied. Experimental results shows that the transmittance, dielectric constant, and refractive index of CdTe samples increase when the intensity of the magnetic field increases, while the absorption, reflectance, absorption coefficient, and extinction coefficient of CdTe samples decrease when the intensity of the magnetic field increases. These effects may be due to change in thickness, morphology, and structure properties for CdTe thin films after exposure to the magnetic field. These results are consistent with theoretical frameworks and mathematical equations. This change can be used in a variety of applications for solar cells.

Keywords: Magnetic Field, Optical Properties, Thin Films

1. Introduction

The magnetic field is used in a variety of applications. It can be used to produce electricity by means of electric generators, in addition to its applications in oil drilling. The magnetic Field is now a day utilized in curing some diseases by a activating cells electrical pulses [1, 2]. This new trend is now known as magnetic therapy. It is also used as a probe for diagnosis using the so called magnetic resonance Imaging (MRI) devices [3].

Nano science and nanotechnology are the study and applications of extremely small tiny particles having dimensions in the range (1-300nm). The physical and chemical properties of matter by changing their nano structure and size[4].

Thus one can control the properties of nano materials to meet the desired needs [5]. This freedom of controlling matter properties opens a new horizon in promoting and producing new technologies in physics, chemistry and biology [6].

The numerous applications of films have led to extensive studies to develop and prepare one of the most popular applications made for thin films used in solar cells. Cadmium telluride (Cd Te) in the form of thin films is one of the most promising polycrystalline for producing solar cells with maximum efficiency [7].

The previous study shows many applications of cadmium telluride thin films [8, 9, 10, and 11]. This motivates to study the effect of the magnetic field on the optical properties of The Cadmium telluride. Thin films with different thicknesses were perpetrated at different annealing temperature then exposed to different magnetic strengths. Experimental works concerning these procedures are exhibited in section 3. Section 2, 4 are devoted for literature review and theoretical background. Section 5 is concerned with findings and discussion while Section 6 is devoted to the conclusion.

1. Literature Review

Few years ago a great deal of work has been done on the effect of magnetic field on thin films. The first work was done by Abdul-Hussein A. et al (2019) about the effect of magnetic field on the thickness of silver (Ag) thin films [12]. They prepared Ag thin films of (84,89, 94 269,290) nm thick at different deposition (10,30,60)s. The crystal structure of the thin films was evaluated by X-ray diffraction (XRD). Atomic force microscopy (AFM) was used for surface morphological studies of the films, and the results showed that the thickness of the films increases with the increase of the magnetic field to 250 Gauss. But when the magnetic field strength is greater than (250 Gauss), the thickness begins to decrease. The results also indicated an increase in the grain size from (144.9 to 276.7) nm and the surface roughness of the films from (0.431 to 22.7) nm.

The second work has been done by Sawsan Abdullzahra [13]. In her work, some electrical and optical properties of ZnO thin films were studied under the influence of magnetic fields of different intensities, which were prepared by spraying DC magnetrons. The films prepared in a DC magnetron spraying system (Edward 306 pumping system) were deposited onto the glass substrate. The structure of the membranes was studied by the X-ray diffraction method. X-ray analysis showed that the prepared films have a hexagonal structure. Increasing the magnetic field intensity leads to an increase in the grain size and sedimentation rate, this increases the thickness of the film. By increasing the magnetic field, the resistance increases because distortion in the crystal arrangement may occur. An increase in the values of carrier concentrations (n) and mobility (μ) was also shown with increasing magnetic field strength. An improvement in crystal structure and homogeneous distribution of the gains was also observed. The optical absorption coefficient (α)decreased with increasing magnetic field intensity but there is a sharp increase in (with a thickness of 450 cm) the film, this may be due to the growth of the directed sample. The dependence of the permeability on the magnetic field is attributed to the change in thickness and morphology of the films. Note that the most suitable magnetic field for films to be used as transmission electrodes in solar cells is 370 Gauss, which has low resistance and high transparency.

Another work done by Roaa Abdul-Azim Ali 2015 [14], on the effect of magnetic field strength on the refractive index of lenses. The phenomenon of change of refraction when a magnetic field passes through the medium is called choral magnetism. Through its results, it was found that there is an empirical relationship between the change in the strength of the magnetic field and the value of the refractive index by measuring the focal length. She confirmed this work using the classical physical laws of paramagnetism. Useful expression for bipolar and electric susceptibility in the presence of a magnetic field is obtained by M. Dirar, et al. The effect of this dependence on the speed of light and the refractive index of the medium was discussed by Dr. Dirar and Sawsan Ahmed Al-Hareem (2013) [15]. Also, some researchers such as M.Dirar and Sawsan Ahmed Elhouri (2013) [16] found that the phenomenon of change in refractive index when light passes through a helical medium placed in an external magnetic field can be derived using the classical laws of Newton and Maxwell's physics. This change was experimentally verified using Newton's ring experiment.

A study was also performed by HBanejad and E Abdosalehi (2009) [17], using magnetic field strengths of zero Tesla (as control), 0.075 Tesla, and 0.1 Tesla, applied to influence water volumes of 4ht/h and 30ht/h. The results using the SAS program showed that changing the magnetic field in the effective amounts of water had significant effects at the 99 percent level in reducing the hardness of the water.

Another work has been done by Ghalib Abdaluhab Ali and Naghem Muhamad Eubayd (2015)[18]. The effect of changing the magnetic field and pulsed laser wavelength on the properties of platinum nanoparticles prepared by laser ablation with different concentrations of different solutions such as deionized double distilled water (DDDW), methanol, and sodium dodecyl sulfate (SDS) at different concentrations has been studied. The absorbance spectra and florescence were displayed and recorded to study the optical properties. Platinum morphology was characterized by scanning electron microscopy (SEM) and transmission electron microscopy. It was noted through his study that when the magnetic field was applied during the ablation method to prepare platinum nanoparticles, it was observed that the magnetic field leads to an increase in the concentration and size of nanoparticles, which leads to an increase in absorption and an increase in the efficiency of dissolution. The highest melting efficiency at a magnetic field strength of 13.5mT.

The objective of this research is to prepare CdTe thin films of different thicknesses at different annealing temperatures and then study the change of optical properties of CdTe thin films before and after exposure to the magnetic field. The materials and methods in Section 3. Section 4 is a theoretical background. Findings, discussion and conclusion in Sections 5 and 6.

3. Experimental Work

The CdTe was prepared first then their optical properties were examined. The CdTe thin film was prepared using thermal evaporation technique which conducted at the laboratories of the faculty of science, department of physics, and university of Taibah in Saudi Arabia Kingdom. The second experiment measured the intensity of total light intensity of light flowing through each sample with magnetic field applied at each time and then the transmittance, absorbance, reflectivity of each sample beside the optical constant were found. This experiment was conducted at the physics laboratory of the faculty of science and technology at Omdurman Islamic University.

3.1 Apparatus and Materials

CdTe thin films, glass slides, two magnetic coils, teslameter, multimeter, photo cell, resistive resistor, and Bulb (HeNe) laser light source of wave length (733) nm were as Shawn in figures (1) and (2).

Figure 1. Apparatus and Materials

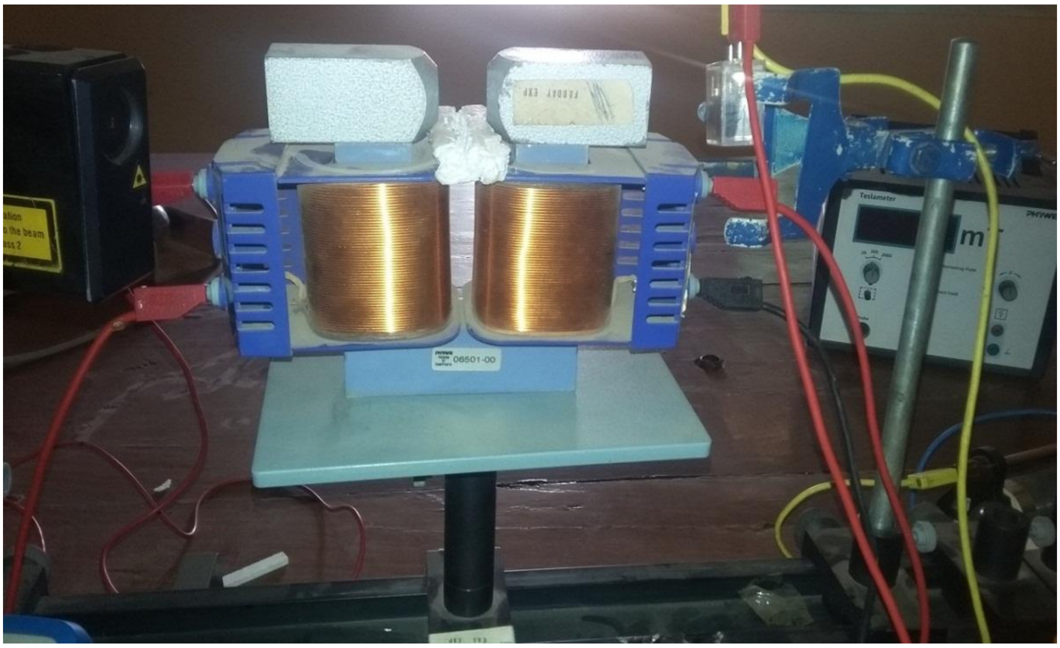


Figure2. Apparatus and Materials

3.2 Preparation Thin Films

CdTe thin film was prepared by a vacuum coating unit. Pure CdTe was used as the source for evaporation. The material was placed in a molybdenum boat with a small dimple in the center to serve as a point source. Clean glass slides were used as a substrate. The source substrate distance was kept at 13.5 cm. The rotary motor was used to obtain a uniform coating. The evaporation rate was maintained at 1.4A°/sec under a pressure of 1x 10^{-5} mbar. The films were prepared at different temperatures ranging from 100^0C up to 250^0C substrate temp. Rate of evaporation and thickness were measured using digital thickness monitor fixed to the unit. All the samples were prepared for different thickness and the samples were labeled in this experiment as S_1 , S_2 , S_3 , S_4 at different annealing temperatures and different thicknesses as shown in the figure 3 and, table(1).

Figure 3.CdTe Thin Films

3.3 Determination of the Samples Thicknesses

The Thickness of thin films can be found according to the relation [10]:

$$t = \frac{\Delta m}{A.\rho} \qquad (1)$$

with t standing for the thickness, (A) area of the substrate, (ρ) density of the material and, (Δm) is the mass of the film measured by digital electronic balance before and after coating.

4. Change of the Optical Properties with Magnetic Field Strength

The objective of this experiment was studied the change of optical properties such as absorbance [19], reflectance [20], transmittance[21], absorption coefficient[22,23]extinction coefficient[24], refraction index[25] and dielectric constant when a magnetic field is applied.

These properties can be determined by Beer's law.

$$I = I_{\circ} e^{-\alpha t} \qquad (2)$$

$$\mathrm{Ln}\left(\frac{I}{I_{\circ}}\right) = -\alpha t$$

With I, I0, α, and t are standing for intensity, initial intensity, absorption coefficient and thickness respectively. Taking the log of both sides gives

$$t\alpha = 2.303 \log\left(\frac{I_{\circ}}{I}\right) \qquad (3)$$

denoting the absorbance A by

$$\log\left(\frac{I_{\circ}}{I}\right) = A$$

Thus

$$\alpha = \frac{2.303A}{t} \quad (4)$$

The transmittance is thus given by

$$T = \frac{I}{I_\circ} = e^{-\propto t} = e^{-2.303A} \quad (5)$$

$$\frac{I_\circ}{I} = e^{2.303A}$$

A= - log T

The reflectance R can bé obtained from the relation

$$A + T + R = 1 \quad (6)$$

$$R = 1 - A - T \quad (7)$$

The extinction coefficient (K), refractive index (n), and dielectric constant (ϵ) are given by the formula [26, 27]

$$K = \frac{\propto\lambda}{4\pi} \quad (8)$$

$$n = \sqrt{\frac{(1+R)^2}{(1-R)^2}} - \sqrt{K^2} + 1 + \frac{1+R}{1-R} \quad (9)$$

$$\in = n^2 - K^2 \quad (10)$$

Sawsan Al-Houry et al. (2015) derived theoretically the relationship between the refractive index and magnetic field strength (H) using the classical physical laws of parametric magnets. The refractive index is given by

$$n = c\sqrt{\varepsilon_0}(1+\beta^2) + c\sqrt{}\varepsilon_0\left(\frac{\beta^2}{2}\left(\frac{\beta^2 H^2}{KT^2}\right)\right) \quad (11)$$

$$n = c_1 + c_2 H^2 \quad (12)$$

Where $c1 = c\sqrt{\varepsilon_0}(1+\beta^2)$, $c_2 = c\sqrt{}\varepsilon_0\left(\frac{\beta^2}{2}\left(\frac{\beta^2 H^2}{K^2T^2}\right)\right)$

Where c, ε_0, β, K, T are standing for vacuum speed of light, vacuum permittivity dielectric constant, Bohar magneton, Boltzmann constant and temperature respectively [28].

According to equation (12)

$$n \propto H^2 \quad (13)$$

From equations (10) and (12), the extinction coefficient (K) and dielectric constant (∈) are related according to the relation

$$\in = c_1 + c_2 H^2 - K^2 \quad (14)$$

The magnetic field strength (H) and magnetic induction (B), in vacuum, are related by the equation

$$B = \mu_0 H \quad (15)$$

Where μ_0 is the vacuum magnetic permeability.

Thus

$$\in \propto B^2 \quad (16)$$

Also

$$\in \propto -K^2 \quad (17)$$

There fore

$$B^2 \propto -K^2 \quad (18)$$

Using equations (4), (8), (14) and (18), the absorption coefficient and absorbance are given by

$$\alpha^2 = \frac{16\pi^2(c_1 + c_2 H^2 - \in)}{\lambda^2} \quad (19)$$

$$A = \sqrt{\frac{16\pi^2 t^2 (c_1 + c_2 H^2 - \in)}{2.303\lambda^2}} \quad (20)$$

Hence

$$B^2 \propto -\alpha^2 \quad (21)$$

And

$B^2 \propto -A^2$ (22)

The relation between the magnetic field intensity and reflectance and the transmittance were found by equations (6) and (22) to be.

$B^2 \propto -R^2$ (23)

$B^2 \propto T^2$ (24)

5. Result and Discussion

The results of thickness measured for thin films and optical characterizations of the cadmium telluride thin films before and after exposure of the magnetic field were recorded and displayed graphically in this section.

5.1 Result Thickness for CdTe Thin Films

From Table (1) it clear that the thickness of samples changes for different annealing temperature ranging from 100 ^{0}C to 250 ^{0}C.

Table 1. Thickness of CdTe Thin Films

Samples	annealing temperatures(C°)	Average of Thickness (nm)
S_1	$250C^{\circ}$	85nm
S_2	$250C^{\circ}$	90 nm
S_3	$200C^{\circ}$	174 nm
S_4	$100\ C^{\circ}$	190 nm

5.2. Changes in Transmittance due to Magnetic Field

From figure (4) it is clear that the transmittance for all samples increased when the magnetic field intensity was increased. According to equation (24) the transmittance increases with the increase of magnetic field. The increase in transmittance may be due to the increase in the number of gaps which increases the number of photons transmits through medium that due to crystalline defects.

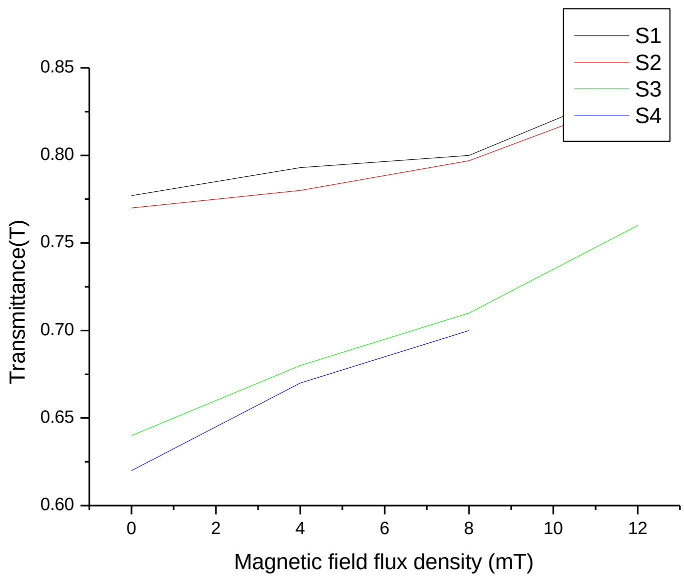


Figure 4.The Relation between Transmittance (T) and magnetic fieldintensity

5.3. Effect of Magnetic Field on Absorption for CdTe

From figure 5 and equation (22) it is important to note that the absorption is reduced by increasing the magnetic field strength. This reduced in absorption for all thickness of CdTe sample smay be attributed to the increase in granular size, which provides many absorption casesThis result has been Compatible with Abduhussian [7].

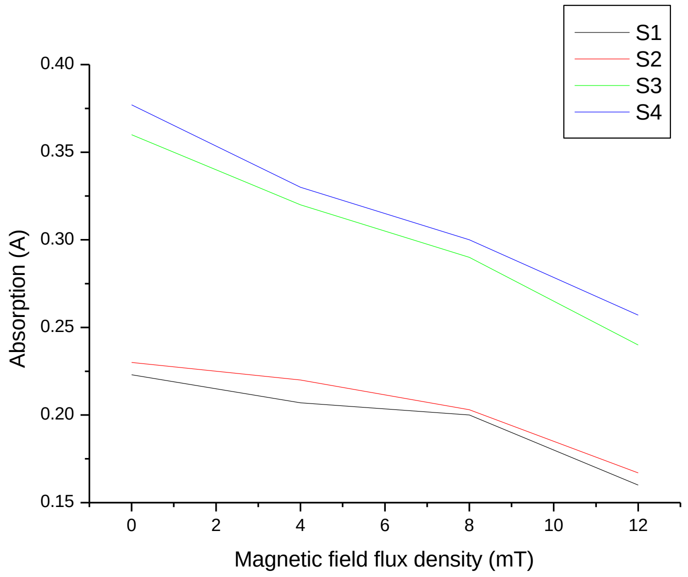


Figure 5. The Relation between Absorption (A) and magnetic field amplification

5.4 Effect of Magnetic Field on Reflectivity(R)

Note that the behavior of the reflection curve as shown in figure (6) is the same for all samples where it begins to decrease with the increase of the magnetic field, because the absorption is week in this range at photon energies less than the Energy gap.

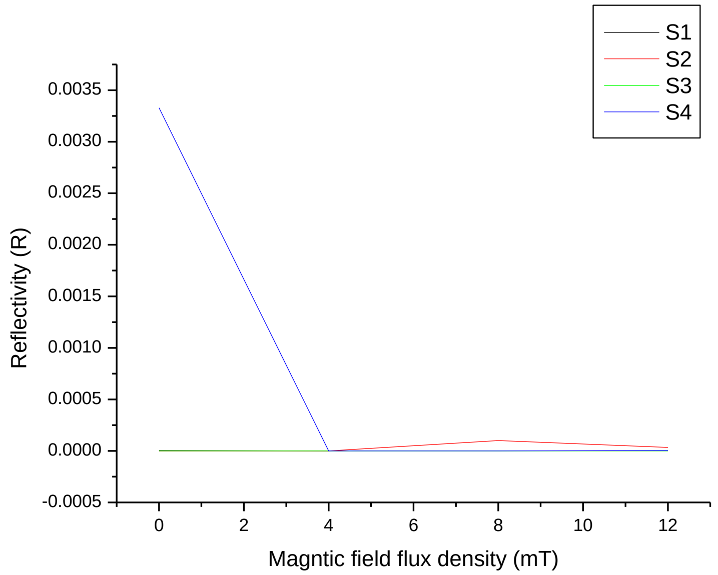


Figure 6. The Relation between Reflectivity of each sample and amplitude of the magnetic field.

The reflectance curve shows sharp decrease up on increasing magnetic field intensity after 4 mT, the reflectance become almost constant. This result has been observed by Mekhaiel [29] and Rodina[30].

5.5 Effect of Magnetic Field on Absorption Coefficient (α) for CdTe

Absorption coefficient plays an important role in the limitation of the type of transition. According equation (21) and figure (7) a decrease in the absorption coefficient with the increase of the magnetic field is observe. This is due to the increase of glass electrical permeability with in this range. This corresponds to Rodina work [30].

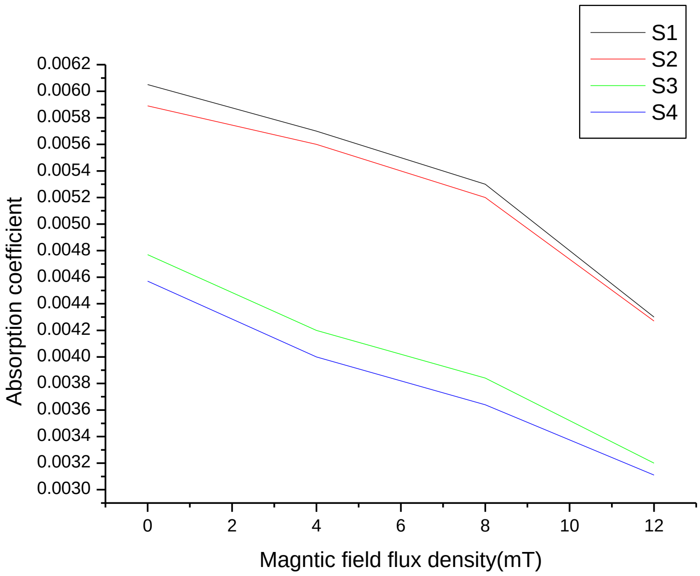


Figure 7. The relation of Absorption coefficient (α) with magnetic field

5.6 Effect of Magnetic Field on Extinction Coefficient(k) for CdTe

From equation (18) figure (8) one observes a decrease in the extinction coefficient with the increase of the magnetic field. From this results one observe a decrease in the extinction coefficient with the increase of the magnetic field strength cause that . The is decrease due to the behavior of the extinction coefficient which is similar to that of the absorption coefficient according to the correlation between (α) and (K) by relationship (8).

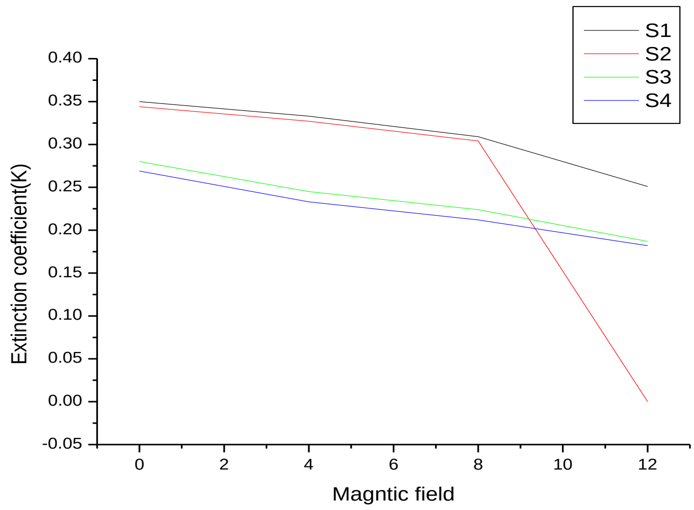


Figure 8. The relation between Extinction Coefficient (k) and magnetic field.

Reduced absorption and extinction coefficient values mean that the film's ability to dampen the falling wavelengths is lower.

5.7 Effect of Magnetic Field on Refractive Index (n)forCdTd

The refractive index is gradually increases with the increase of the thickness of the film. According equation(12) and the figure (9) are observe that increases rapidly up on the refractive index increasing the magnetic field strength in all samples.

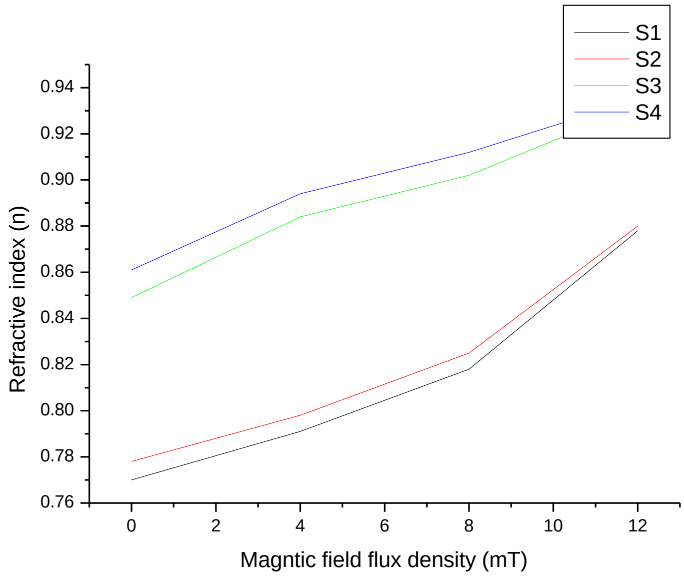
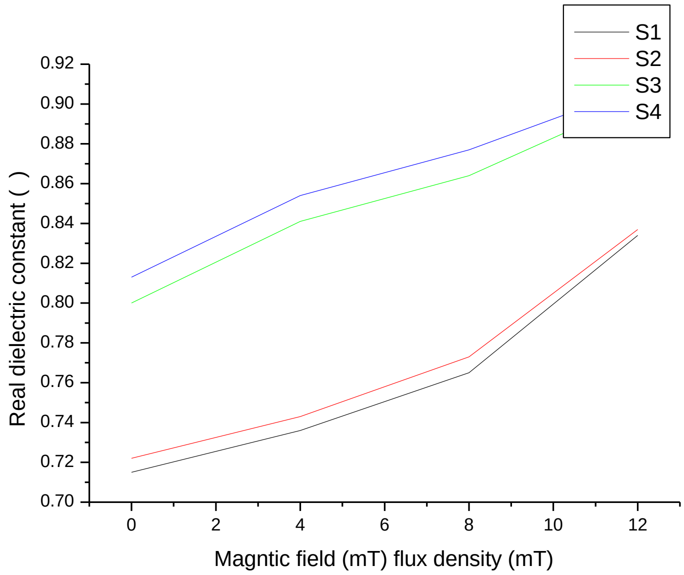


Figure 9. The relation between Refractive Index (n) and Magnetic Field

5.8 Change in Real Dielectric Constant (∈) due to Effect of Magnetic Field on for CdTe

The real dielectric constant (∈) of the material increases with the increase of the thickness of films as shown in figure (10). From equation (14) and figure (10) it is clear that dielectric constant (∈) are increased up on increasing the magnetic field strength. This may be related to the increase of electric polarity. This result conforms to Rodina study [23].



Figure(10).The relation of Real Dielectric constant (∈) and magnetic field.

6. Conclusions

The impacts of magnetic field on optical properties of CdTe thin film indicates that there is a change in optical properties such as transmittance, absorption, reflectivity, absorption coefficient, extinction coefficient, refractive index and dialectic constant due to intensity of magnetic field. The transmittance and refractive index and dielectric constant of CdTe samples increase when the intensity of magnetic field increases. The absorption and reflectance and absorption coefficients and extinction coefficient of CdTe samples decreases when the intensity of magnetic field increases.

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