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EFFECT OF THE MAGNETIC FIELD ON OPTICAL ABSORPTION IN LIGHT DEPENDENT RESISTANCE DOPED WITH PHOSPHORS (P) AND IRON (FE) LAYER

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ABSTRACT

This work is devoted to see how the magnetic field effect on the optical absorption in Light Dependent Resistance (LDR) doped with phosphors and iron . This effect is studied at different visible light wave lengths and different (x-ray) wave lengths. From the results, it is clear that , when one using (x-ray) , and by changing the direction of the magnetic field ,one can tune the resonance photon energy . This variation occurs when one applied high voltages in the (x-ray) tube, thus the magnitude of the absorption coefficient is very sensitive to the direction of the magnetic field. In particular, one can use the direction of the magnetic field as a tunable parameter in optical transitions .

In this study the dependence of the inter sub band transitions on the magnetic field is discussed. We show that inter sub band optical absorption is the sensitive to the tilt angle .This behavior in the inter sub band optical absorption gives a new degree of freedom in regions of interest device application. From our results , it's clear that the sub band energies and inter sub band optical absorption are quite sensitive to the applied magnetic field .

The result of this work should provide useful guidance for the design of optically pumped quantum well lasers and quantum well infrared photo detectors.

KEYWORDS: Light dependent resistance (LDR) , Layer concentration , The magnetic field ,optical absorption . tilt angle .

INTRODUCTION

The effect of a magnetic field on the optical absorption coefficient plays a fundamental role in understanding the optical absorption properties of impurities in both semiconductor bulk materials, and in hetero structures.

The light dependent resistance (LDR) is a sensor whose resistance decreases when light impinges on it. This kind of sensor is commonly used in light sensor circuits in open areas , to control street lamps for example . Another possible use is in spectroscopic apparatus [1] . In this kind of apparatus, continuous light or pulsed light can be used.

Continuous light is used in common spectroscopic apparatus. The use of lock – in amplifiers made the use of pulsed light in spectroscopy easier, as is commonly used in photo acoustic spectroscopy [2] . Light dependent resistance (LDR) is made of semiconductors as light sensitive materials , on an isolating base . The most common semiconductors in this system are cadmium sulphide, lead sulphide, germanium, silicon and gallium arsenide [3] . Semiconductors (sc) play an important role in our day life. They are widely used in electronic devices like computers, mobiles, televisions, solar cells and sensors. The physics of semi conductors are presented in many standard texts [1,2]. The optical properties of (s. c) is an important factor in understanding the performance of optical sensors and solar cells. These properties are based on the interaction of electromagnetic waves (e.m.w) with matter.

The understanding of the nature of this interaction depends mainly on the models which describe the nature of(e. m) waves as well as matter. In spite of the remarkable successes achieved by modern physics specially the laws of quantum mechanics (q. m) and relativity in describing the nature of matter an (e. m)radiation, there still some problems

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associated with interaction of matter and radiation especially for new amorphous semiconductor materials [3,4,5]. For instance the empirical absorption coefficient and empirical relations which related attenuation coefficient with radiation energy and wave length in not in agreement with the theoretical one [6,7,8,].

THEORETICAL SECTION [THEORETICAL ANALYSIS]

Quantum Mechanical Absorption Coefficient

The absorption coefficient can also be obtained by using the wave function of the photon which takes from [10]

$$\psi = Ae^{i(kx-wt)} \tag{2.1.1}$$

The density of photons is given by:

$$n = |\psi|^2 = \overline{\psi}\psi \tag{2.1.2}$$

Thus the radiation intensity is given by:

$$I = hfnv = |\psi|^2 chf = \overline{\psi}\psi chf = \hbar wc|\psi|^2 \tag{2.1.3}$$

When photons enter matter k is replaced by $\tilde{k}$. As a result the wave function is given by:

$$\psi = Ae^{i(\tilde{k}x-wt)} \tag{2.1.4}$$

The wave vector inside matter can be written as: [10]

$$\tilde{k} = k\left(1+\frac{1}{2}x\right) = k\left(1+\frac{1}{2}x_1+\frac{1}{2}x_2 i\right) \tag{2.1.5}$$

Hence the wave function takes the form:

$$\psi = Ae^{i[k(1+x_1)x-wt]}e^{-\frac{kx_2}{2}x} \tag{2.1.6}$$

$$\overline{\psi} = Ae^{-\frac{kx_2}{2}x}e^{-i[k(1+x_1)x-wt]} \tag{2.1.7}$$

Therefore the intensity is given by:

$$I = A^2Ce^{-kx_2x} = I_0e^{-kx_2x} \tag{2.1.8}$$

But since:

$$I = I_0e^{-\alpha x}$$

It follows that the absorption coefficient is given by:

$$\alpha = kx_2 \tag{2.1.9}$$

In view of relations $a = \frac{F_\circ}{x_\circ}\omega^2 m$, $b = \omega(\mu_r - Be) and\ x_2 = -\frac{be^2N}{a^2+b^2}$ one gets:[10]

$$x_2 = -\frac{be^2N}{a^2+b^2} = \frac{e^2N(Be-\mu r)w}{\left(\frac{F_0}{x_0}-w^2m\right)^2+w^2(\mu_r-Be)^2} \tag{2.1.10}$$

In view of equation $N = \int_0^k n(k)dk = \frac{4\pi}{3}N_\circ(\frac{\beta}{2\pi m})^{\frac{3}{2}}\ \hbar^2k^2$ the above equation reads:

$$x_2 = \frac{CC_2e^2k^4(Be-\mu r)}{\left(\frac{F_0}{x_0}-C^2k^2m\right)^2+C^2k^2(Be-\mu_r)^2} \tag{2.1.11}$$

Where:

$$C_2 = \frac{4\pi N_0}{3}\left(\frac{\beta}{2\pi m}\right)^{3/2}\hbar^2 \tag{2.1.12}$$

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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Thus the absorption coefficient is given by:

$$\alpha = \frac{CC_2 e^2 (Be - \mu r) k^5}{\left(F_0 / x_0 - C^2 k^2 m\right)^2 + C^2 k^2 (Be - \mu r)} \qquad (2.1.13)$$

In the case when (B) , ($F_{0)}$ and (μ_r)are small, equation (4.13) becomes:

$$\alpha = \frac{C_2 e^2 (Be - \mu r)}{C^3 m^2}.k \qquad (2.1.14)$$

Absorption Coefficient in the presence of magnetic field

The conductivity and absorption coefficient γ are related, according to the relation[10]

$$\alpha = \frac{C\mu\sigma}{n_1} \qquad (2.2.1)$$

$$\sigma = \frac{ne^2\tau}{m^*} \qquad (2.2.2)$$

Where μ stands for the magnetic permeability, σ represents the conductivity while n_1 is the refractive index. The photo conductivity is thus expressed in terms of the relaxation time and effective mass, according to the relation (2.2.2). The absorption coefficient is thus given by

$$\alpha = \frac{c\mu ne^2\tau}{m^* n_1} \qquad (2.2.3)$$

Where the relative magnetic permittivity satisfies the relation :

$\mu = \mu_r \, \mu_\circ$ (2.2.4)

In view of (2.2.4) , the equation (2.2.3) reads :

$\alpha = {cne^2\tau \, \mu_r \, \mu_\circ}/{m^* \, n_1}$ (2.2.5)

Then the absorption coefficient is affected by magnetic material via μ, where:

$\alpha \approx \mu$ (2.2.6)

The effect of the magnetic properties on the a absorption coefficient can also be obtained with the aid of equations $\alpha = k_2 = \frac{\omega}{c} n_2, and\ n_2 = \frac{c^2\mu}{2n_1}$ $(4\pi\chi_2)$ to get : [10]

$$\alpha = \frac{2\pi\mu c\chi_2\omega}{n_1} \qquad (2.2.7)$$

Bearing in mind Langven expression for Larmer frequency [10,27]

$$\omega_L = \omega = \frac{Be}{2m} \qquad (2.2.8)$$

The absorption coefficient takes the form

$$\alpha = \frac{2\mu c\chi_2}{n_1}\frac{Be}{2m} \qquad (2.2.9)$$

The effect of spin and orbital angular moment ion can be incorporated via the atomic magnetic moment beside the magnetization vector M which is given according to quantum paramagnetic theory as [19]

$$M = \frac{ng^2 m_s^2 \mu_\circ^2}{kT} \quad H = \chi H \qquad (2.2.10)$$

Thus the absorption coefficient is related to the spin quantum number m_s via the magnetic susceptibility . Where g is the splitting factor and μ_B is called Bohr agneton .

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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CALCULATION METHODS AND EXPERIMENTAL TECHNIQUES

Introduction

This work is devoted to see how the magnetic field effects on the optical absorption coefficient of Light Dependent resistance (LDR) doping with phosphors (p) and iron (Fe). This effect is studied at different visible light wave lengths and different x-ray wave lengths. The variation of the absorption coefficient with the wave number and temperature is also studied .

Sample Preparation

The effect of Doping process (P), impurities (Fe) ,beside the wave number in addition to temperature on the absorption coefficient is determined for (15) Light Dependent resistance (LDR). Which are doped semi conductors.(5) These semi conductors are doped by phosphor p, which have (5) valence electrons in his outer most shell. Thus one expect p to increase free electrons Ten of these samples also have Fe impurities which one expect to affect the magnetic properties of these samples. The concentration of (P) and (Fe) in these samples are found by using (XRF) (x-ray fluorescence) spectral technique. To simplify experimental treatments the commercial code of these samples is replaced by a simple one arranged in a following order.

Table (3.3) Concentration of Impurities in (LDR) Samples:

No	Simple code	Commercial code	Additional impurities	Ratio of the impurities (in ppm)
1	Sn_1	PR-A_1	P	1014
2	Sn_2	PR-A_2	P	983
3	$Sn_{3\ ...}$	PR-$A_{7\ S}$	P	632
4	Sn_4	PR-$A_{8\ Z}$	P	129
5	Sn_5	PR-A_{28}	P	90
6	Sn_6	Ph TR TFm	Fe	138
7	Sn_7	$Ph_{S\ 27}$	Fe	480
8	Sn_8	PhZ_1	Fe	448
9	Sn_9	Phs_1	Fe	1824
10	Sn_{10}	Ph P_1	Fe	6091
11	Sn_{11}	Ph S_2	Fe	815
12	Sn_{12}	TR TFms	Fe	25699
13	Sn_{13}	Ph P_2	Fe	19619
14	Sn_{14}	037 A	Fe	17225
15	Sn_{15}	Ph K 2 C	Fe	2182

Determination of Concentration

The concentration of P and Fe for the (15) samples is found by using (x-ray) Fluorescence spectral technique .In this technique the sample is irradiated by x-ray photons. This causes atoms in the sample to be exited and then return back to their stable state after emitting a characteristic photon.

The energy of this characteristic photon is equal to the difference between two energy levels in the inner most shell. As far as each element has a certain characterize energy levels, one then expects each element to emit a photon of certain energy which is different energies from all other elements. Thus the energies of the emitted photons, from the sample can be utilized to knew the elements existing in it. The large number of atoms for a certain element the larger the emitted photons. Thus the concentration of each element is proportial to the height of the spectral beak which represents the number of emitted photons.

The (XRF) device has a software and a display unit which directly detect the existence of P and Fe and gives their concentration in (PPm) (part per million of from gramme) .The concentration of P and Fe for all samples are shown in appendix (B) (sample results).

Determination of the Absorption Coefficient

Due to the lack of sophisticated and advanced devices, the absorption coefficient x is found by using a number of experiments and a number of mathematical techniques.

The absorption coefficient is found from the famous relation

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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$$I = I_o\, e^{-\alpha\, z} \qquad (3.5.1)$$

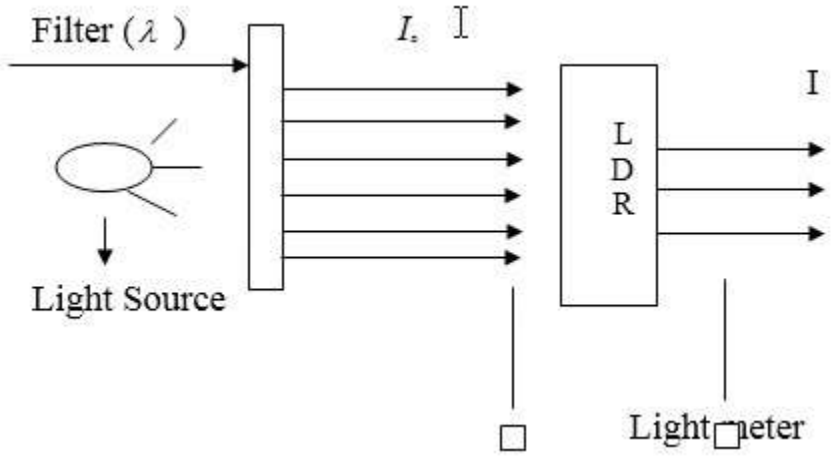

Fig (3.5.1) : The Optical Absorption Experiment

Where the numerical value of α is given by

$$\alpha = \frac{d\,I}{I\,dz} = \frac{\Delta I}{I\,\Delta z} = \frac{h\,f\,\Delta n c}{I\,\tau c} \qquad (3.5.2)$$

With [10]

$$\Delta\, I = h\,f\,\Delta\, n c \qquad \Delta\, z = \tau c \qquad (3.5.3)$$

$\Delta\, n$ = change in the number of photons
= change in the number of free electrons
$h\ f$ = photon energy
τ = recombination time
$= 1.22\times10^{-12}$ sec
c = $3\times10^{8} m s^{-1}$ = speed of light

The frequency of the photon f is found from the colour of the light by using certain light filters. The frequency of x- ray is found from the relation

$$f = \frac{e\,V}{h} \qquad (3.5.4)$$

Where V is the operating voltage

The change $\Delta\, n$ in electron concentration is found from the Hall experiment by utilizing the relation

$$R_{0_H} = \frac{1}{n_0 e} \quad \text{(In darkness)} \qquad (3.5.5)$$

$$R_H = \frac{1}{ne} \quad \text{(Inlight)} \qquad (3.5.6)$$

$$\therefore n_0 = \frac{1}{R_{0_H} e} \ldots\ldots; n = \frac{1}{\mathrm{Re}} \qquad (3.5.7)$$

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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$$\therefore \Delta n = n - n_0 = \frac{1}{(R_H - R_{0_H})e} \qquad (3.5.8)$$

The hall resistance R_{0_H} is found in darkness. Thus

$$R_{0_H} = \frac{1}{n_o e} \qquad (3.5.9)$$

When the sample is lighted R_H is again determined, 1.e

$$R_H = \frac{1}{ne} \qquad (3.5.10)$$

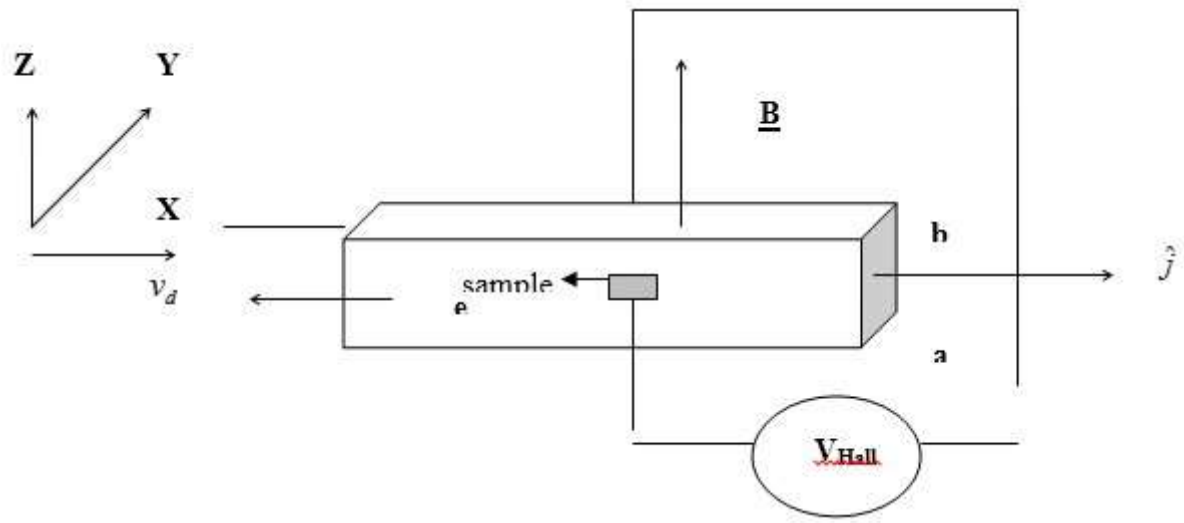
Hence

$$\Delta n = n - n_o = \frac{1}{(R_H - R_o H)} \qquad (3.5.11)$$

The intensity of light is found by using the light meter with sensitivity (0.1 W/m^2) ranging from (1 – 100 W/m^2).the absorption coefficient is found by determining I, ΔI, ΔZ from (3.5.2), (3.5.3) and (3.5.8)

Experimental Design to Find Hall Resistance

To find Hall Resistance for each sample, a voltmeter having sensitivity 0.1 m V and range (200 mV- 100 V) together with an ammeter having sensitivity (0.1 μ A) and range (200 μA – 200 m A) are concerted with the sample as shown in Fig(3.6.1).



Fig(3.6.1): Hull effect experiment

A magnetic filed from a pair of coils are generated so as to be perpendicular to the direction of the current flow. The magnetic field strength is found by using Tesla meter, sensitivity (0.1 mT), (range:200 mA- 200 μA) .The voltage and current are found by using the voltmeter and the ammeter respectively and R_H is found from the relation

$$R_H = \frac{V}{I} \qquad (3.6.1)$$

And Δn is calculated from eq. (3.5.8) . The tables for Δn for each sample and wave lengthwise recorded

ISSN: 2277-9655
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Experimental Set up to Determine α Variation with d_1

To find the relation between α, Temp.T,wave number k, and impurity concentration , E each sample is connected as shown in Fig(3.7.1) using Digital multimeter (range 200 mV-1000 V and Digital ohmmeter (range: 200 Ω - 200 M Ω.)

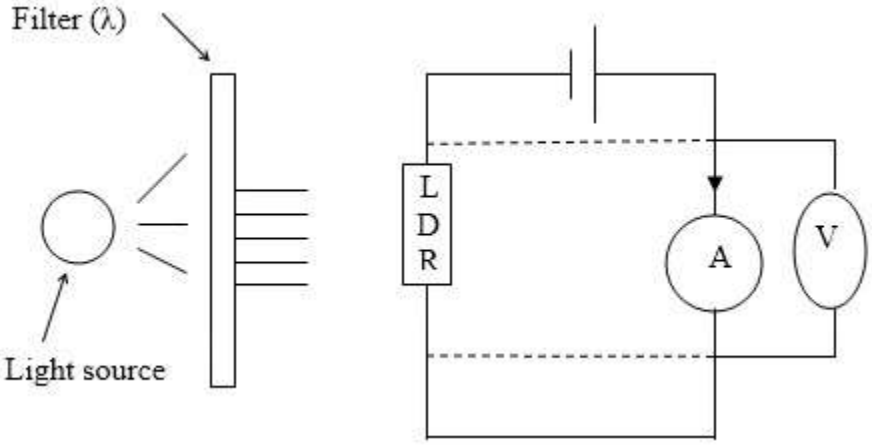

Fig (3.6.1) : The circuit of LDR to measure photocurrent at different illuminations

Variation of I with σ experiment the resistance R is measured directly by using ohm meter .The conductivity σ_o in dark, and when the sample is exposed to light of different intensities, σ , is found from the relation [3]

$$\sigma_o = \frac{L}{R_o A} \qquad \sigma = \frac{L}{R A} \tag{3.7.1}$$

The concentrations n_o and n are found from the relation

$$n_o = \frac{m\ \sigma_o}{\tau\ e^2} \qquad n = \frac{m\ \sigma}{\tau\ e^2} \tag{3.7.2}$$

Where [10]

m = electron maces = $9.1\times10^{-31} Kg$

e = electron charge = $1.6\times10^{-19} Coul$

τ = relaxation time = 1.22×10^{-12} sec

= 1.22×10^{-12} sec from the texts [3]

Thus Δn is calculated from the relation

$$\Delta n = n - n_0 \tag{3.7.3}$$

Thus α is found from relation (3.5.2) for different values of I , T, B , K, N_P and N_F as shown by the figures .

RESULTS AND DISCUSSION

In our numerical simulations, the thickness of (LDR) structure is ($L = 80\ nm$) . The calculation were done for the temperature ($T = 300K$) . The boundary conditions are Ψ(0) = Ψ(L) = 0 .The effective mass of the electron has been taken as (m^*=0.067m_o) $m_o$being the free electron mass . In Figure (1) present the variation of the absorption

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(ISRA), Impact Factor: 2.114

coefficient (α) as a function of the incident photon energy of ($x-ray$) for different magnetic field intensities. As seen in this figure the absorption coefficient increases as the magnetic field intensity increases.

In figure (2) , by changing the direction of the magnetic field we present the variation of the absorption coefficient (α) as a function of the incident photon energy of ($x-ray$) for different magnetic field intensities . As seen in this figure the absorption coefficient (α) increases as the tilt angle of the magnetic field increases . The magnitude of the absorption coefficient becomes larger with large title angle values. In Figure (3) present the variation of the absorption coefficient (α) as a function of the incident photon energy of visible light (using violet ,blue , yellow , orange and red light) for different magnetic field . As seen in this figure the absorption coefficient(α) increases as the magnetic field intensity increases . We should point out that the effect of the magnetic field on the absorption coefficient by using ($x-ray$) is similar to that of the visible light effect . In view of the empirical relation in figures (1) , (2) and (3) , it is clear that the absorption coefficient (α) is affected by the magnetic field . These empirical relations are displayed in equations (2.1.14) , (2.2.5) , (2.2.6) , (2.2.7) , (2.2.8) and (2.2.9) .Finally ,when one comparing these figures with theoretical relations , it is clear that the empirical relations and theoretical relations are in conformity with each other

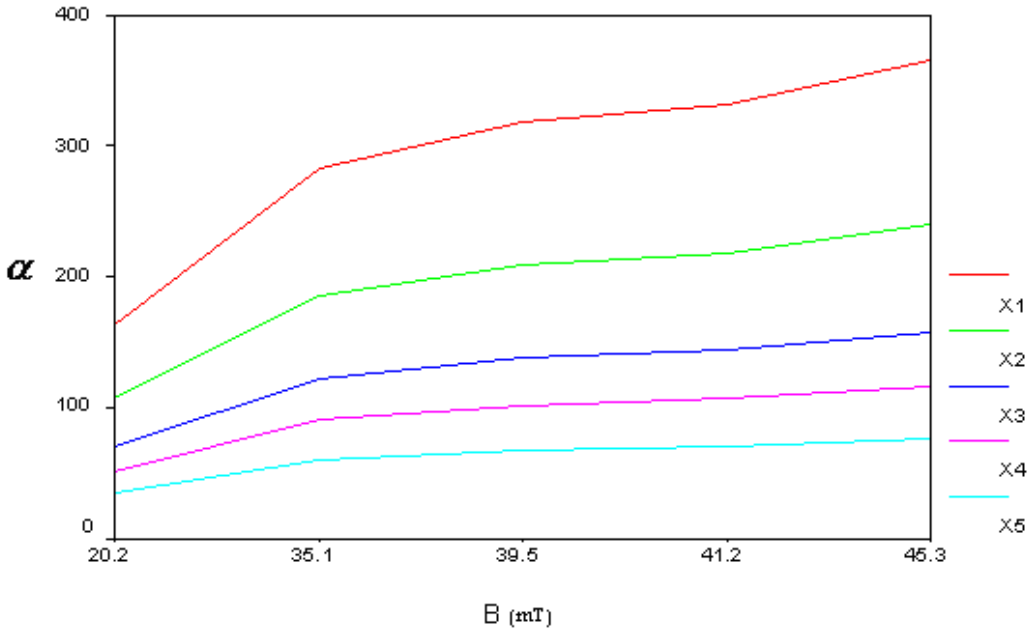
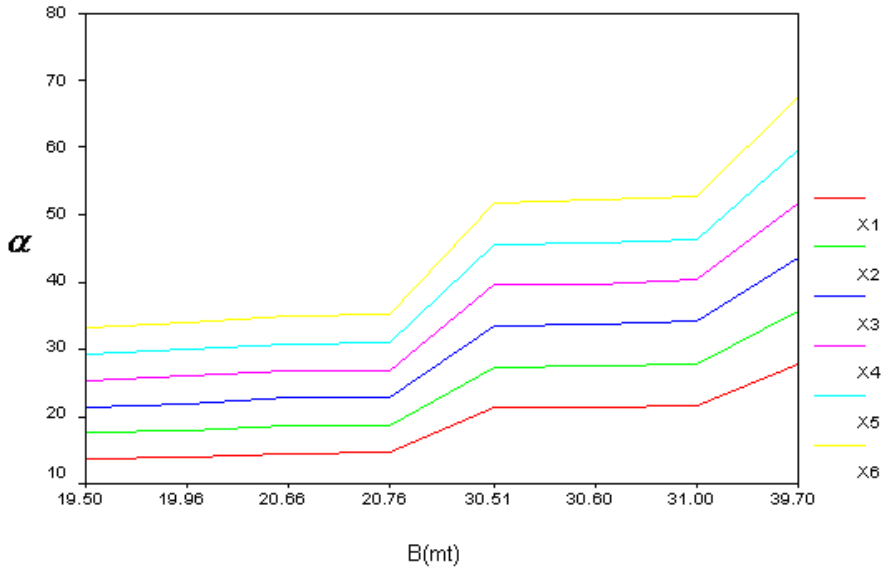


Figure (1) : The variation of the absorption coefficient (α) as a function of the photon energy for different applied magnetic field intensities (using (x-ray)) . [ ]

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 2.114



Figure(2): The variation of the absorption coefficient (α) as a function of the photon energy for different applied magnetic field intensities (using ($x-ray$) , for several tilt angles of magnetic field) , by changing the direction of the magnetic field , at [$T = 300K^{\circ}$] .

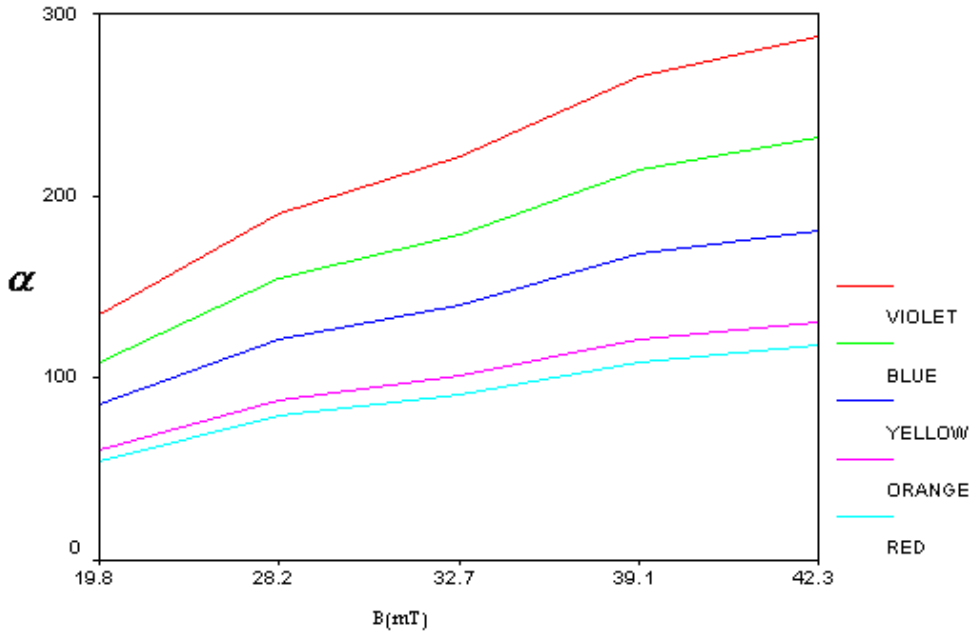


Figure (3): The variation of the absorption coefficient (α) as a function of the photon energy for different applied magnetic field intensities (usig violet ,blue ,yellow ,orange and red light)) , at [ ].

CONCLUSION

In conclusion optical absorption coefficient in light dependent resistance (LDR) has been studied under an external magnetic field . We show that the effect of the direction of the magnetic field on the optical absorption coefficient is similar to change in the dimension of the structure , thus this behavior can be used to study these systems in regions of interest , with the need for different samples . From our results ,it is clear that the sub band energies and inter sub band optical absorption is quite sensitive to the applied magnetic field. From our result , it is clear that , when one

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Scientific Journal Impact Factor: 3.449
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applied lower voltages in the (x-ray) tube ,the magnitude of the absorption coefficient is not very sensitive to the direction of the magnetic field , but the resonance photon energy increases with tilt angle of the magnetic field. Also our results indicate that the optical absorption depends not only on the magnetic field but also on the doping layer concentration . At last the results obtained show that Light Dependent Resistance (LDR) could be used as a sensor of light in optical absorption , and our results show that the (LDR) is quite sensitive to the applied magnetic field .

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