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RESEARCH ARTICLE

EFFECT OF THE MAGNETIC FIELD ON ENERGY GAP I IM E)LIGHT DEPENDENT RESISTANCE (LDR) USING – N – IPURITY (F $x-$ Ray tube

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ABSTRACT

This work is devoted to see how the magnetic field flux affects the value of the energy gap of impurity (Fe) Light Dependent resistance (LDR). This effect is studied at different $x-ray$ wavelengths. The variation of the energy gap values with the $x-ray$ wavelengths is also studied.

In this study the dependence of the energy gap on the magnetic field is discussed. We show that the gap width decreases with magnetic field approaching the critical value when a high voltage with minimum value is applied. The decrease in gap width value has been calculated for (5) Light Dependent Resistance (LDR) with different concentration(N_{Fe}). From the results, it's clear that the impurity (Fe) light dependent resistance (LDR) is quite sensitive to the applied magnetic field. Also the results indicate that the energy gap in impurity (Fe) light dependent resistance depends not only on the magnetic field but also on the donor's concentration, and the wave lengths of $x-ray$. The result of this work should provide useful guidance for the optical absorption in semiconductors.

INTRODUCTION

An $x-ray\ tube$ functions as a specific energy converter, receiving the electrical energy and converting into other forms of energy, x-radiation and heat. Heat is considered the undesirable product of this conversion process, therefore x-radiation is very specific energy conversion takes place in the $x-ray\ tube$.

The energy used for this process is provided from the generator, connected by electrical circuit connected to the system. The generator also needs to convert the electrical energy from the power system into the direct current(DC), being the adequate form to be applied to the $x-ray\ tube$.

The quality and the quantity of the $x-radiation$ are controlled by adjusting the electrical parameters (KV – voltage or the potential applied to the tube, Am – current that flows through the tube) and exposure, usually a fraction of a second.

To summarize, $x-rays$ are produced in a standard way, by accelerating electrons with a high voltage and allowing them to collide with the focal spot.

In solid state physics an energy gap, also called a band gap, is an energy range in a solid where no electron states can exist . In graphs of the electronic band structure of solids, the band gap generally refers to the energy difference (in electron volts [eV]) between the top of the valence band and the bottom of the conduction band in insulators and semiconductors. This is equivalent to the energy required to free on outer shell electron from its orbit about the nucleus to become a mobile carrier, able to move freely within the solid material, so the band gap is a major factor determining the electrical conductivity of a solid. Substances with large band gaps are generally insulators, those with smaller band gaps are semiconductors, while conductors either have very small band gap or none, because the valence and conduction bands overlap [1, 2].

Every solid has its own characteristic energy band structure. This variation in band structure is responsible for the wide range of electrical characteristics observed in various materials. In semiconductors and insulators, electrons are confined to a number of bands of energy, and forbidden from other regions. The term "band gap" refers to the energy difference between the top of the valence band and the bottom of the conduction band. Electrons are able to jump from one band to another However, in order for an electron to jump from a valence band

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to a conduction b and, it requires a specific minimum amount of energy for the transition. The required energy differs with different materials. Electrons can gain enough energy to jump to the conduction band by absorbing either a phonon (heat) or a photon (light).

The effect of a magnetic field on the band energy (energy gap) in light dependent resistance (LDR) plays a fundamental role in understanding the optical properties of impurities in semiconductors.

The light dependent resistance (LDR) is a sensor whose resistance decreases when light impinges on it.

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].

Semi conductors (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 texets [4, 5].

Theoretical Section [Theoretical Analysis]

Energy Gap Calculation Using the Relation between Temperature and Current

In this part one can calculate the value of energy gap for the sample using the relation between temperature and current when the voltage is kept constant. The current is given by [6,7]:

$$I = I_0\left(e^{eV/kT} - 1\right) \approx I_0 e^{eV/kT} \qquad (1)$$

But

$$I_0 = Ae^{-eV_g/kT} \qquad (2)$$

Hence

$$I = Ae^{\frac{e(V-V_g)}{kT}} = Ae^{\frac{eV_L}{kT}} \qquad (3)$$

Thus when V is kept constant and the current I changes with T, in this case:

$$\ln I = \ln A + \frac{e}{k}(V - V_g)\left(\frac{1}{T}\right) \qquad (4)$$

Let:

$$\ln I = Y ...,...x = \frac{1}{T}...,...b = \ln A \qquad (5)$$

$$a = \frac{e}{k}(V - V_g) \qquad (6)$$

Drawing the relation between

$Y = \ln I ...and...x = \frac{1}{T}$ Are finds from the graph that

$$b = \ln A \qquad (7)$$

$$slope = \tan^{-} = \frac{e}{kT}(V - V_g)$$

Thus, $V_g = V - \frac{kT}{e}\tan^{-}$

$$V - V_g = \frac{kT}{e}\tan^{-} \qquad (8)$$

Hence the energy gap is given by:

$$E_g = eV_g \qquad (9)$$

Energy Gap Calculation Using the Relation between the Voltage and Current

In this part one can calculate the value of energy gap for sample using the relation between the voltage and current when the temperature is kept constant. From equation (4) one find [8,9]:

$$\ln I = \ln A - \frac{eV_g}{kT} + \frac{e}{kT}V \qquad (1)$$

$$\ln = \frac{e}{kT}V + \ln A - \frac{eV_g}{kT} \qquad (2)$$

If one gets: $Y = \ln I ... x = V$

$$a = \frac{e}{kT}............b = \ln A - \frac{eV_g}{kT} \qquad (3)$$

$$Slope = \tan^{-} = a = e/kT \qquad (4)$$

$$b = \ln A - \frac{eV_g}{kT} \qquad (5)$$

$$\frac{e}{kT}V_g = \ln A - b$$

$$V_g = \frac{kT}{e}(\ln A - b) \qquad (6)$$

$$V_g = \frac{1}{a}(\ln A - b) \qquad (7)$$

Using the relation (2.2.7) for ln A V_g can again be found. Thus the energy gap again by:

$$E_g = eV_g \qquad (8)$$

Nature of $X - ray$

$X - rays$ with energies ranging from about $100\ eV\ to\ 10Me$ are classified as electromagnetic waves, which are only different from the radio waves, light, and gamma rays in wavelength and energy . $X - rays$ show wave nature with wavelength ranging from about $10^{-3} nm$. According to the quantum theory, the electromagnetic wave can be treated as particles called photons or light quanta. The essential characteristics of photons such as energy, momentum, etc., are summarized as follows [10].

The propagation velocity (c) of electromagnetic wave

(Velocity of photon) with frequency (f) and wavelength (λ) is given by the relation .

$$c = f\lambda \qquad (ms^{-1}) \qquad (1)$$

The velocity of light in the vacuum is a universal constant given as (c=299792m/s). Each photon has anenergy(E), which is proportional to its frequency.

$$E = hf = {}^{hc}/_{\lambda} \qquad (J) \qquad (2)$$

Where (h) is the Planck constant$(6.626 \times 10^{-34} J.s)$. With (E) expressed in (keV), and $(\lambda\ in\ nm)$, the following relation is obtained :

$$E(keV) = {}^{1.24}/_{\lambda(nm)} \qquad (2.3.3)$$

The momentum(p) is given by(mv), the product of the mass (m), and its velocity (v). The de Broglie relation for material wave relates wavelength to momentum.

$$\lambda = {}^{h}/_{p} = {}^{h}/_{mv} \qquad (4)$$

Production of $X - ray$

When a high voltage with several tens of (kV) is applied between two electrodes, the high-speed electrons with sufficient kinetic energy, drawn out from the cathode, collide with the anode (metallic target). The electrons rapidly slow down and lose kinetic energy. Since the slowing down patterns (method of loosing kinetic energy) vary with electrons, continuous$(\times -ray)$ with various wavelength are generated. When as an electron loses all its energy in a single collision, the generated $(\times -ray)$ has the maximum energy (or the shortest wavelength =λ_{SWL}). The value of the shortest wavelength limit can be estimated from the accelerating voltage (V) between electrodes.

$$eV = hf_{max} \qquad (1)$$

$$\lambda_{SWL} = {}^{c}/_{f_{max}} = {}^{hc}/_{eV} \qquad (2)$$

$$\lambda_{SWL} = {}^{12.398 \times 10^{3}}/_{V} \qquad (3)$$

Where:
e= electron charge $(1.6 \times 10^{-19} c)$
V = applied voltage (high voltage)
c = velocity of light.

Calculation Methods and Experimental Techniques

Introduction

This work is devoted to see how the magnetic field effects on the energy gap in Light Dependent resistance (LDR) doping with iron (Fe). This effect is studied at different $(\times -ray)$ wave lengths (a high voltage with several tens of (kV) is applied).

Sample Preparation

The effect of magnetic field on the energy gap in light dependent resistance (LDR) is determined for (5) samples (LDR). These samples have (Fe) impurities which one expect to affect the magnetic properties of these samples. The concentration of (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 [11].

Table 1 Concentration of Impurities in (LDR) Samples

No	Simple code	Commercial code	Additional impurities	Ratio of the impurities (in ppm)
1	Sn_{11}	Ph P_1	Fe	138
2	Sn_{12}	Ph S_2	Fe	480
3	Sn_{13}	TR TFms	Fe	648
4	Sn_{14}	Ph P_2	Fe	1824
5	Sn_{15}	037 A	Fe	6091

Determination of Concentration

The concentration of (Fe) for the (5) 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 proportional 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 existance of P and Fe and gives their concentration in (PPm) (part per million of from gramme).

Experimental set up to Determine Current and Voltage Variation with X-Ray wavelengths

To find current and voltage with respect to $(\times -ray)$ wavelengths in different (LDR) samples. Each sample is connected as shown in Fig (3-4-1) using Digital multimeter (range 200 mV-1000 V and Digital ohmmeter (range: 200 Ω - 200 M Ω.) .

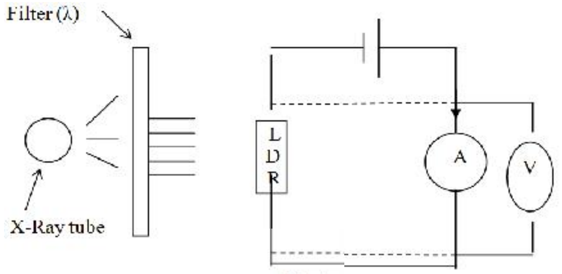

Fig 1 The circuit of LDR to measure Photocurrent and voltage at different $(\times -ray)$ wavelengths

Variation of I with ± experiment the resistance R is measured directly by using ohm meter .The conductivity $\pm_o$ in dark, and when the sample is exposed to light of different intensities, ± , is found from the relation

$$\pm_o = \frac{L}{R_o A} \qquad \pm = \frac{L}{R A} \tag{1}$$

The reading of voltage and current were taking for different (LDR),with different concentration (N_{Fe}).

$$n_o = \frac{m \pm_o}{2 e^2} \qquad n = \frac{m \pm}{2 e^2} \tag{2}$$

Where:-

m = electron maces = $9.1 \times 10^{-31} Kg$

e = electron charge = $1.6 \times 10^{-19} Coul$

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

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

Thus Δn is calculated from the relation

$$\Delta n = n - n_0 \tag{3}$$

Thus the energy gap is found from relation (8) for different (LDR) samples as shown in tables.

The wavelengths of $x - ray$ are found from relation (3) for high voltage with several tens of(kV).

RESULTS AND DISCUSSION

In our numerical simulations, the thickness of (L D R) structure is($L = 80\ nm$). The calculation were done for the temperature ($T = 300K$). Tables (1), (2), (3), (4) and (5) shows the (LDR) voltage and current as functions of the wave lengths of $x - ray$, with different concentration (N_{Fe}) , while the tables (6) , (7) , (8) , (9) and (10) shows the (LDR) voltage and current as functions of the wave lengths of $x - ray$ under the effect of the magnetic field . As seen in this tables the voltage and current has a linear behavior with concentration (Fe) and the wave lengths of $x - ray$. Table (11) shows the energy gap as function of the wave lengths of $x - ray$ and concentration (Fe) in the (LDR), while table (12) shows energy gap as function of the wave lengths of $x - ray$ (high voltage) and concentration (Fe) in the (LDR), under the effect of the magnetic field, at ($T =$ 300°K). The experimental values of tables (11) and (12) present the effect of the magnetic field on the energy gap in (LDR). As seen in this tables the values of the energy gap in table (12) less than the values of the energy gap in table (11). This means that the gap width decreases when one applied the magnetic field In table (12), by changing the direction of the magnetic field we present the variation of the energy gap as a function of the incident photon energy of $x - ray$ for different magnetic field. As seen in this table the energy gap decreases as the magnetic field intensity increases. In view of the empirical relation in tables (11) and (12), it is clear that the energy gap in (LDR) is affected by the magnetic field.

Table 1 Voltage and Current variation, using (the magnetic $x - ray$) with high voltage (50 KV) , [λ_1] [Using (LDR) with different concentration (N_{Fe})] ($T =$ 300°K)

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.027	0.00265
Sn_{12}	1.034	0.00274
Sn_{13}	1.039	0.00278
Sn_{14}	1.046	0.00289
Sn_{15}	1.054	0.00297

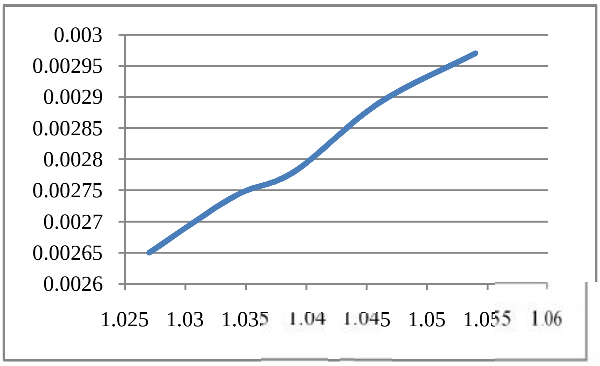

Table 2 Voltage and Current variation using ($x - ray$) with high voltage (100 KV) , [λ_2][Using (LDR) with different concentration (N_{Fe})] ($T =$ 300°K)

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.018	0.00246
Sn_{12}	1.025	0.00253
Sn_{13}	1.033	0.00261
Sn_{14}	1.049	0.00270
Sn_{15}	1.051	0.00283

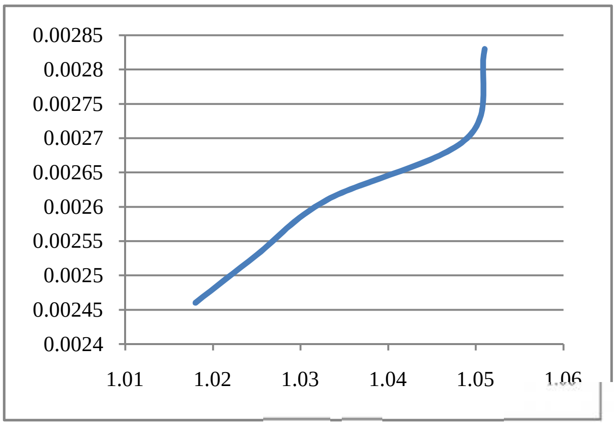

Chart (2) of Table (2) Voltage vs. Current

Table 3 Voltage and Current variation using ($x - ray$) with high voltage (150 KV) , [λ_3] [Using (LDR) with different concentration (N_{Fe})] ($T =$ 300°K)

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.016	0.00225
Sn_{12}	1.021	0.00232
Sn_{13}	1.029	0.00239
Sn_{14}	1.034	0.00246
Sn_{15}	1.044	0.00257

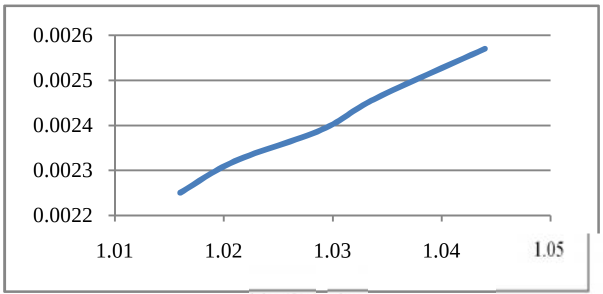

Chart (3) of Table (3) Voltage vs. Current

Table 4 Voltage and Current variation using $(x - ray)$ with high voltage $(200\ KV)$, $[\lambda_4]$. [Using (LDR) with different concentration (N_{Fe})]. ($T = 300^{\circ}$K)

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.001	0.00215
Sn_{12}	1.009	0.00222
Sn_{13}	1.013	0.00230
Sn_{14}	1.019	0.00241
Sn_{15}	1.026	0.00252

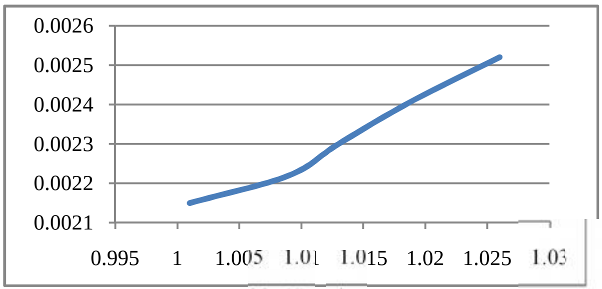

Chart (4) of Table (4) Voltage vs. Current

Table 5 Voltage and Current variation using $(x - ray)$ with high voltage $(250\ KV)$, $[\lambda_5]$. [Using (LDR) with different concentration (N_{Fe})]. ($T = 300^{\circ}$K)

Sample code	Voltage (V)	Current (A)
Sn_{11}	0.902	0.00182
Sn_{12}	0.910	0.00190
Sn_{13}	0.919	0.00200
Sn_{14}	0.927	0.00208
Sn_{15}	0.938	0.00212

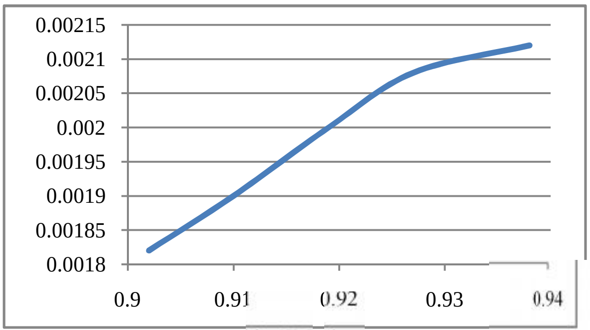

Chart (5) of Table (5) Voltage vs. Current

Table 6 Voltage and Current variation using $(x - ray)$ with high voltage$(50\ KV)$, $[\lambda_7]$, under the effect of Magnetic field. [Using (LDR) with different concentration (N_{Fe})]. ($T = 300^{\circ}$K).

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.042	0.00270
Sn_{12}	1.050	0.00283
Sn_{13}	1.059	0.00292
Sn_{14}	1.067	0.00300
Sn_{15}	1.070	0.00309

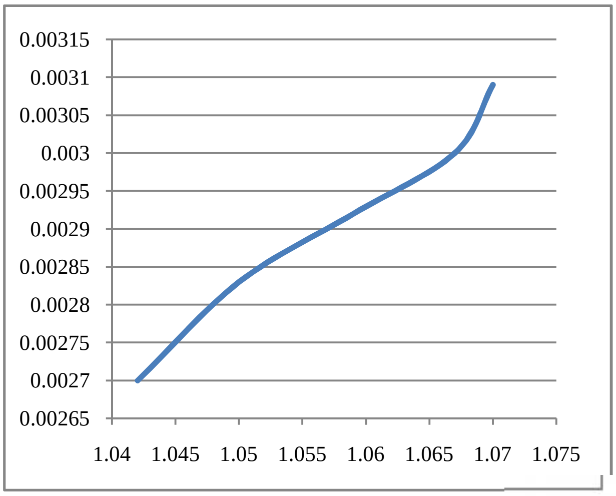

Chart (6) of Table (6) Voltage vs. Current

Table 7 Voltage and Current variation using $(x - ray)$ with high voltage $(100KV)$, $[\lambda_2]$, under the Effect of Magnetic field. [Using (LDR) with different concentration (N_{Fe})]. ($T = 300^{\circ}$K)

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.034	0.00257
Sn_{12}	1.041	0.00265
Sn_{13}	1.047	0.00276
Sn_{14}	1.054	0.00281
Sn_{15}	1.060	0.00292

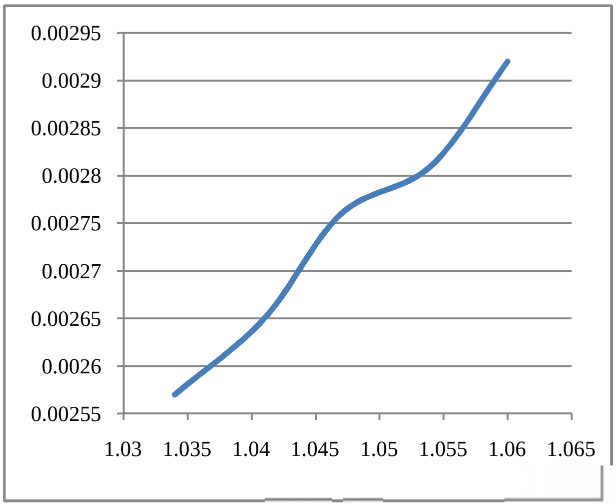

Chart (7) of Table (7) Voltage vs. Current

Table 8 Voltage and Current variation using $(x - ray)$ with high voltage$(150\ KV)$, $[\lambda_8]$, under the effect of Magnetic field. [Using (LDR) with different concentration (N_{Fe})]. ($T = 300^{\circ}$K).

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.031	0.00230
Sn_{12}	1.038	0.00241
Sn_{13}	1.042	0.00250
Sn_{14}	1.047	0.00257
Sn_{15}	1.053	0.00260

Table 9 Voltage and Current variation using $(x-ray)$ with high voltage$(200KV)$, $[\lambda_4]$, under the effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . ($T =$ 300˚K).

Sample code	Voltage (V)	Current (A)
Sn_{11}	1.009	0.00220
Sn_{12}	1.018	0.00229
Sn_{13}	1.027	0.00234
Sn_{14}	1.036	0.00240
Sn_{15}	1.040	0.00251

Table 10 Voltage and Current variation using $(x-ray)$ with high voltage $(250KV)$, $[\lambda_5]$, under the effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . ($T =$ 300˚K).

Sample code	Voltage(V)	Current(A)
Sn_{11}	0.910	0.00187
Sn_{12}	0.922	0.00193
Sn_{13}	0.930	0.00201
Sn_{14}	0.941	0.00209
Sn_{15}	0.954	0.00217

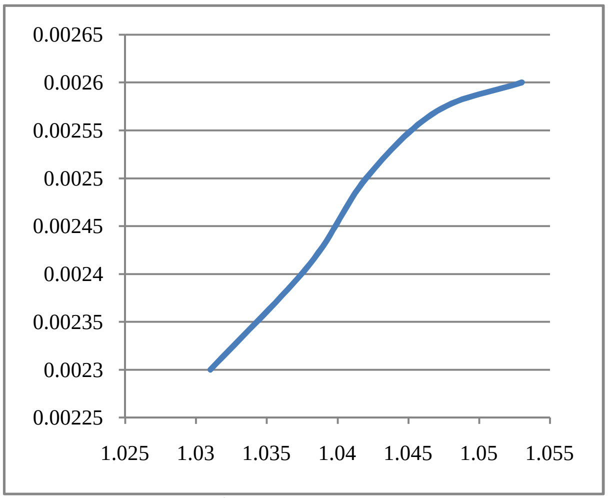

Chart (8) of Table (8) Voltage vs. Current

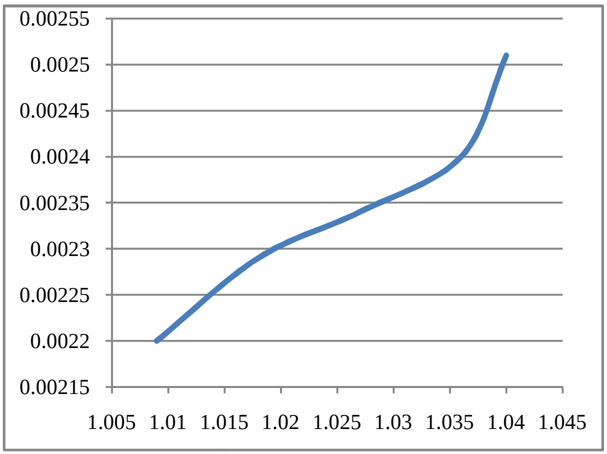

Chart (9) of Table (9) Voltage vs. Current

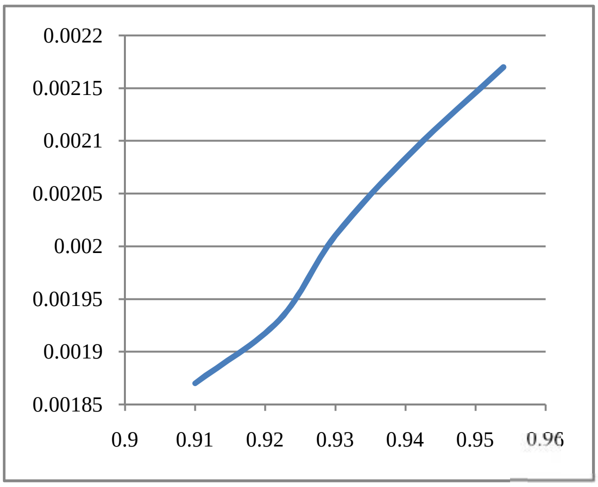

Chart (10) of Table (10) Voltage vs. Current

We have also study the effect of the concentration (N_{Fe}) on the energy gap of (LDR) [tables (11) and (12)]. As seen from this tables the energy gap decreases with increasing the value of (N_{Fe}) concentration, however for high concentration. The energy gap has minimum value, when the impurity is high.

Table 11 Energy Gap variation with respect to ($x-ray$) with different high voltage, in different (LDR) samples , at ($T =$ 300˚K) .

Sample code	Concentration	Voltage $(50KV)$, $[\lambda_5][E_g(eV)]$	Voltage $(100KV)$, $[\lambda_5][E_g(eV)]$	Voltage $(150KV)$, $[\lambda_5][E_g(eV)]$	Voltage $(200KV)$, $[\lambda_5][E_g(eV)]$	Voltage $(250KV)$, $[\lambda_5][E_g(eV)]$
Sn_{11}	138	1.145	1.281	1.300	1.305	1.320
Sn_{12}	480	1.133	1.270	1.296	1.292	1.317
Sn_{13}	648	1.117	1.261	1.290	1.284	1.3o9
Sn_{14}	1824	1.091	1.240	1.282	1.279	1.300
Sn_{15}	6091	1.083	1.234	1.271	1.270	1.292

Table 12 Energy Gap variation with respect to ($x-ray$) with different high voltage in different (LDR) samples , under the effect of magnetic field ,at ($T =$ 300˚K).

Sample code	Concentration	Voltage $(50KV)$ $[E_g(eV)]$	Voltage $(100KV)$ $[E_g(eV)]$	Voltage $(150KV)$ $[E_g(eV)]$	Voltage $(200KV)$ $[E_g(eV)]$	Voltage $(250KV)$ $[E_g(eV)]$
Sn_{11}	138	1.115	1.260	1.281	1.294	1.317
Sn_{12}	480	1.110	1.252	1.274	1.287	1.309
Sn_{13}	648	1.094	1.244	1.267	1.280	1.301
Sn_{14}	1824	1.081	1.231	1.264	1.272	1.296
Sn_{15}	6091	1.076	1.223	1.251	1.269	1.284

In this case the variation of the energy gap in (LDR), in terms of impurity under magnetic field is not symmetric; it has only minimum value for high impurity.

Finally, when one comparing the experimental values of the energy gap of (LDR) in the tables with theoretical values, it is clear that the empirical values and theoretical values are in conformity with each other.

CONCLUSION

In conclusion energy gap in light dependent resistance (LDR) has been studied under an external magnetic field. The table (12) shows the effect of the magnetic field on the energy gap value. It is clear from the experiments result that the gap width of the energy gap in (LDR) decreases with the magnetic field approaching the critical value. Also our results indicate that the energy gap depends not only on the magnetic field, but also on the concentration of(N_{Fe}), in the samples of (LDR), and the wave lengths of X-ray.

At last our experimental results shows that the impurity (N_{Fe}) light dependent resistance (LDR) is quite sensitive to the applied magnetic field, and the lengths of X-ray.

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