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EFFECT OF THE MAGNETIC FIELD ON ENERGY GAP IN IMPURITY (FE) LIGHT DEPENDENT RESISTANCE (LDR)

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ABSTRACT

In this work we studied how the magnetic field affects the value of the energy gap in impurity (Fe) Light Dependent resistance (LDR). This effect is studied at different visible light wave lengths . The variation of the energy gap with the Violet, Blue , Yellow ,Orange and Red light is also studied in this work.

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. The decrease in gap width has been calculated for (5 samples of Light Dependent Resistance of different concentration NFe From the results , it's clear that the impurity (Fe) light dependent resistance (LDR) is quite sensitive to the applied magnetic field . Also our 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 the visible light. The result of this work should provide useful guidance for the optical absorption in semiconductors.

***Keywords**: Light dependent resistance (LDR) , energy gap, concentration , The magnetic field ,impurity.*

I. INTRODUCTION

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 to a conduction band, 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 [3,4] . 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 texts [5,6].

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II. THEORETICAL SECTION [THEORETICAL ANALYSIS]

2.1 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[7,8].

$$I = I_0\left(e^{eV/kT} - 1\right) \approx I_0 e^{eV/kT} \qquad (2.1.1)$$

But

$$I_0 = Ae^{-eV_g/kT} \qquad (2.1.2)$$

Hence

$$I = Ae^{\frac{e(V-V_g)}{kT}} = Ae^{\frac{eV_L}{kT}} \qquad (2.1.3)$$

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

$$\ln I = \ln A + \frac{e}{k}(V - V_g)\left(\frac{1}{T}\right) \qquad (2.1.4)$$

Let:

$$\ln I = Y \ldots,\ldots x = \frac{1}{T} \ldots,\ldots b = \ln A \qquad (2.1.5)$$

$$a = \frac{e}{k}(V - V_g) \qquad (2.1.6)$$

Drawing the relation between $Y = \ln I \ldots and \ldots x = \frac{1}{T}$

Are finds from the graph that

$$b = \ln A \qquad (2.1.7)$$

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

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

$$V - V_g = \frac{kT}{e}\tan\theta \qquad (2.1.8)$$

Hence the energy gap is given by:

$$E_g = eV_g \qquad (2.1.9)$$

2.2 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 (2.1.4) one find[9,10]:

$$\ln I = \ln A - \frac{eV_g}{kT} + \frac{e}{kT}V \qquad (2.2.1)$$

$$\ln = \frac{e}{kT}V + \ln A - \frac{eV_g}{kT} \qquad (2.2.2)$$

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

$$a = \frac{e}{kT} .... b = \ln A - \frac{eV_g}{kT} \qquad (2.2.3)$$

$$Slope = \tan\theta = a = e/kT \qquad (2.2.4)$$

$$b = \ln A - \frac{eV_g}{kT} \qquad (2.2.5)$$

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

$$V_g = \frac{kT}{e}(\ln A - b) \qquad (2.2.6)$$

$$V_g = \frac{1}{a}(\ln A - b) \qquad (2.2.7)$$

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

$$E_g = eV_g \qquad (2.2.8)$$

III. CALCULATION METHODS AND EXPERIMENTAL TECHNIQUES

(3-1) 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 visible light wave lengths. The variation of the absorption coefficient with the wave number and temperature is also studied in this work.

(3-2) 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 expects to affect the magnetic properties of these samples. The concentration of (Fe) in these samples is 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.

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Table (3.2.1) 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

(3-3) 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 existence of P and Fe and gives their concentration in (ppm) (part per million of from gramme).

(3-4) Experimental Set up to Determine Current and Voltage Variation with to Violet, Blue, Yellow, Orange and Red light To find current and voltage with respect to Violet, Blue , Yellow , Orange , and Red light 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.)

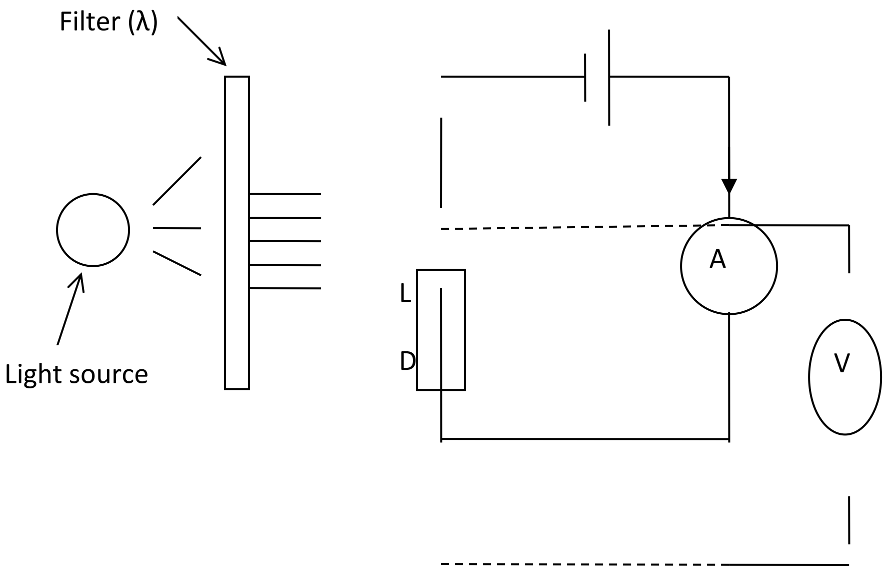

Fig (3.4.1): The circuit of LDR to measure photocurrent and voltage at different illuminations

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 [11,12]

$$\sigma_o = \frac{L}{R_o\, A} \qquad \sigma = \frac{L}{R\, A} \qquad (3.4.1)$$

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

$$n_o = \frac{m\ \sigma_o}{\tau\ e^2} \qquad n = \frac{m\ \sigma}{\tau\ e^2} \qquad (3.4.2)$$

Where :-

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 $\Delta\ n$ is calculated from the relation

$$\Delta\ n = n - n_0 \qquad (3.4.3)$$

Thus the energy gap is found from relation (2.2.8) for different (LDR) samples as shown in tables.

IV. RESULTS & DISCUSSION

In our numerical simulations, the thickness of (L D R) structure is . The calculation was done for the temperature . Tables (4.1) , (4.2) , (4.3) , (4.4) and (4.5) shows the (LDR) voltage and current as functions of the wave lengths of visible light (Violet , Blue , Yellow , Orange and Red light) , while the tables (4.6) , (4.7) , (4.8) , (4.9) and (4.9) shows the (LDR) voltage and current as functions of the wave lengths of visible light under the effect of the magnetic field . As seen in this tables the voltage and current has a linear behavior with concentration and the wave length of visible light . Table (4.11) shows the energy gap as function of the wave lengths of visible light (Violet , Blue , Yellow , Orange and Red) and concentration in the (LDR) ,while table (4.12) shows energy gap as function of the wave lengths of visible light and concentration in the (LDR) , under the effect of the magnetic field , at K) . The experimental values of tables (4.11) and (4.12) 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 (4.12) less than the values of the energy gap in table (4.11) . This means that the gap width decreases when one applied the magnetic field. In table (4.12) , 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 visible light (using violet ,blue , yellow , orange and red light) 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 (4.11) and (4.12) , it is clear that the energy gap in (LDR) is affected by the magnetic field .

We have also study the effect of the concentration on the energy gap of (LDR) [tables (4.11) and (4.12)] . As seen from this tables the energy gap decreases with increasing the value of concentration, however for high concentration. The energy gap has minimum value, when the impurity is high . 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.

Table (4.1) : Voltage and Current variation with respect to Violet light .

[Using (LDR) with different concentration (N_{Fe})] . K)

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn_{11}	138	1.039	0.00277	2.77
Sn_{12}	480	1.046	0.00286	2.86
Sn_{13}	648	1.051	0.00290	2.90
Sn_{14}	1824	1.058	0.00301	3.01
Sn_{15}	6091	1.066	0.00309	3.08

Table (4.2) : Voltage and Current variation with respect to Blue light

[Using (LDR) with different concentration (N_{Fe})] . K)

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	1.030	0.00258	2.58
Sn12	480	1.037	0.00265	2.65
Sn13	648	1.045	0.00273	2.73
Sn14	1824	1.051	0.00281	2.81
Sn15	6091	1.056	0.00290	2.90

Table (4.3): Voltage and Current variation with respect to Yellow light [Using (LDR) with different concentration (N_{Fe})] .K)

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn_{11}	138	1.028	0.00237	2.37
Sn_{12}	480	1.033	0.00244	2.44
Sn_{13}	648	1.037	0.00249	2.49

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Sn_{14}	1824	1.042	0.00254	2.54
Sn_{15}	6091	1.048	0.00260	2.260

Table (4.4) : Voltage and Current variation with respect to Orange light .

[Using (LDR) with different concentration (N_{Fe})] . K)

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	1.009	0.00224	2.24
Sn12	480	1.016	0.00232	2.32
Sn13	648	1.021	0.00240	2.40
Sn14	1824	1.029	0.00249	2.49
Sn15	6091	1.035	0.00253	2.53

Table (4.5) : Voltage and Current variation with respect to Red light . [Using (LDR) with different concentration (N_{Fe})] . K)

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	0.912	0.00195	1.95
Sn12	480	0.921	0.00204	2.04
Sn13	648	0.930	0.00208	2.08
Sn14	1824	0.938	0.00212	2.13
Sn15	6091	0.945	0.00216	2.16

Table (4.6) : Voltage and Current variation with respect to Violet light , under the effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . K) .

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	1.053	0.00282	2.82
Sn12	480	1.059	0.00294	2.94
Sn13	648	1.061	0.00299	3.00

Sn14	1824	1.066	0.00305	3.10
Sn15	6091	1.072	0.00317	3.20

Table (4.7): Voltage and Current variation with respect to Blue light , under the Effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . K) .

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	1.043	0.00263	2.63
Sn12	480	1.046	0.00271	2.71
Sn13	648	1.049	0.00282	2.82
Sn14	1824	1.056	0.00287	2.87
Sn15	6091	1.061	0.00299	2.99

Table (4.8): Voltage and Current variation with respect to Yellow light , under the effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . K) .

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	1.041	0.00239	2.39
Sn12	480	1.047	0.00248	2.48
Sn13	648	1.051	0.00251	2.51
Sn14	1824	1.054	0.00258	2.58
Sn15	6091	1.058	0.00264	2.64

Table (4.9): Voltage and Current variation with respect to Orange light, under the effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . K) .

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	1.017	0.00227	2.27
Sn12	480	1.020	0.00235	2.35
Sn13	648	1.035	0.00246	2.46
Sn14	1824	1.042	0.00252	2.52

Sn15	6091	1.044	0.00256	2.56

Table (10): Voltage and Current variation with respect to Red light , under the effect of Magnetic field . [Using (LDR) with different concentration (N_{Fe})] . K) .

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn11	138	0.920	0.00197	1.97
Sn12	480	0.931	0.00206	2.06
Sn13	648	0.944	0.00211	2.11
Sn14	1824	0.956	0.00216	2.16
Sn15	6091	0.969	0.00222	2.22

Table (4.11) : Energy Gap variation with respect to Violet , Blue , Yellow , Orange and Red Light in different (LDR) samples , at K) .

Sample code	Concentration	Violet	Blue	Yellow	Orange	Red
Sn11	138	1.135	1.270	1.292	1.297	1.314
Sn12	480	1.123	1.263	1.286	1.288	1.305
Sn13	648	1.120	1.254	1.281	1.278	1.298
Sn14	1824	1.089	1.232	1.275	1.273	1.291
Sn15	6091	1.072	1.227	1.264	1.268	1.283

Table (4.12): Energy Gap variation with respect to Violet , Blue , Yellow Orange and Red Light in different (LDR) samples , under the effect of magnetic field ,at K) .

Sample code	Concentration	Violet	Blue	Yellow	Orange	Red
Sn11	138	1.112	1.256	1.277	1.289	1.308
Sn12	480	1.096	1.243	1.267	1.281	1.296
Sn13	648	1.088	1.233	1.259	1.272	1.285
Sn14	1824	1.073	1.226	1.250	1.259	1.276
Sn15	6091	1.059	1.214	1.244	1.251	1.264

V. CONCLUSION

In conclusion energy gap in light dependent resistance (LDR) has been studied under an external magnetic field . The table (4.12) shows the effect of the magnetic field on the energy gap . It is clear from the experiments result that the gap width of the energy gap in (LDR) , 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 , in the samples of (LDR) , and the wave lengths of visible light (Voltage , Blue , Yellow , Orange And Red) .

At last our experimental results shows that the impurity light dependent resistance (LDR) is quite sensitive to the applied magnetic field , and the visible light .

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