Available online at www.elixirpublishers.com (Elixir International Journal)

Nuclear and Radiation Physics

Elixir Nuclear & Radiation Phys. 91 (2016) 37952-37955

ISSN: 2229-712X

Effect of the Magnetic Field on Band Gap in Light Dependent Resistance (LDR) Doped with Different Concentration using Visible Light

Sawsan Ahmed Elhouri Ahmed[1] and Mohamed Toum Fadel[2]

[1]University of Bahri-College of Applied & Industrial Sciences-Department of Physics - Khartoum Sudan.

[2]University of Al-Baha (KSA) - College of Applied Arts & Science in Al-Mandag.

ARTICLE INFO

Article history:

Received: 11December 2015;

Received in revised form:

22 January 2016;

Accepted: 27 January 2016;

Keywords

Light dependent resistance (LDR),

Ban gap,

Concentration the magnetic field,

Doping process.

ABSTRACT

This work is devoted to see how the phosphors concentration (N_p) effect on the band gap value in Light Dependent resistance (LDR) doped with phosphors. This effect is studied using visible light. The variation of the band gap with the different concentration is also studied in this work. In this work the dependence of the band gap on the phosphors concentration (N_p) and 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 (7 samples) Light Dependent Resistance (LDR) with different concentration (N_p) . From our results we found that the band gap in the light dependent resistance (LDR) doped with phosphors (P) depends not only on the donor's concentration but also on the magnetic field, and the wave lengths of the visible light. The result of this work should provide useful guidance for the optical absorption in semiconductors.

Introduction

In solid state physics band gap, also called an energy 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. 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 [1]. 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 [2, 3]..

Tele:

E-mail addresses: sawsan.ahmed110@gmail.com

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[4,5]:

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

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 $Y = \ln I ... and ... x = \frac{1}{T}$

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:

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

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[6]:

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

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

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:

$E_g = eV_g$ (2.2.8)

Calculation Methods and Experimental Techniques

Introduction

This work is devoted to see how the concentration of phosphors (N_p) effects on the band gap in Light Dependent resistance (LDR) doping with phosphors (p). This effect is studied using visible light. The variation of the band gap with different concentration (N_p) under external magnetic flied and temperature is also studied.

Sample Preparation

The effect of phosphors concentration (N_p) on the band gap in light dependent resistance (LDR) is determined for (7samples) (LDR). These samples doping with different concentration (N_p) which one expect to affect the magnetic properties of these samples. The concentrations of phosphors (P) 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 (3.2.1). 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	Phosphors (P)	184
2	Sn_{12}	Ph S_2	Phosphors (P)	445
3	Sn_{13}	TR TFms	Phosphors (P)	480
4	Sn_{14}	Ph P_2	Phosphors (P)	691
5	Sn_{15}	037 A	Phosphors (P)	1782
6	Sn_{16}	136 AB	Phosphors (P)	6093
7	Sn_{17}	201 AC	Phosphors (P)	13051

Determination of Concentration :

The concentration of phosphors (P) for the (7samples) 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 know 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 phosphors (P) and gives it's concentration in (ppm) (part per million of from gramme).

Experimental Set up to Determine Current and Voltage Variation with the phosphors concentration (N_P)

6To find current and voltage with respect to the phosphors concentration (N_P) in different (LDR) samples. Each sample is connected as shown in Fig (3-4-1) using Digital millimeter (range 200 mV-1000 V and Digital ohmmeter (range: 200 □ - 200 M □.) .

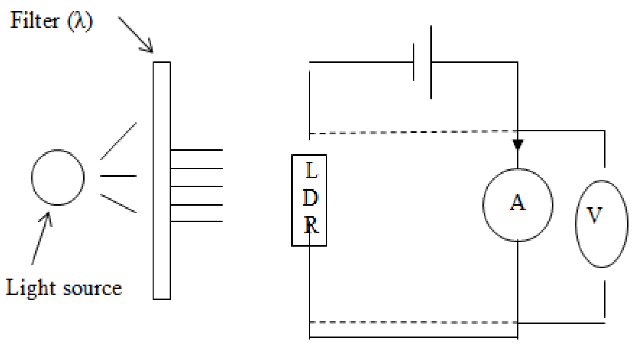

Fig (3.4.1). The circuit of LDR to measure photocurrent and voltage at different samples .

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

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

(3.4.1)

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

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

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 Δn 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.

Results and Discussion

In our numerical simulations, the thickness of (LDR) structure is (L=80nm) . All calculations were performed using the following parameters: m=0.067$m_\circ$ ($m_\circ$ is the free electron mass),μ=0.04$m_\circ$, $\epsilon_\circ$= 12.5 (static dielectric constant is assumed to be the same everywhere) , $V_{0=}$228meV , these parameters are suitable for the Light Dependent resistance (LDR) with the phosphors concentration **(N_p)** . The calculation were done for the temperature T=300 K. In this study we calculated the variation of the band gap in Light Dependent resistance (LDR) for several tilt angles and two different magnetic field values . Table (4.1) shows the (LDR) voltage and current variation with respect to different phosphors concentration**(N_p)** for B=50KG , while the table (4.2) shows the (LDR) voltage and current variation with respect to different phosphors concentration**(N_p)** under the effect of the magnetic field (B=50KG) for several tilt angles . As seen in these tables the voltage and current has a linear behavior with phosphors concentration **(N_p)**. Table (4.3) shows the (LDR) voltage and current variation with respect to different phosphors concentration**(N_p)** for B=100KG , while the table (4.4) shows the (LDR) voltage and current variation with respect to different phosphors concentration**(N_p)** under the effect of the magnetic field (B=100KG) for several tilt angles . As seen in this tables the voltage and current also has a linear behavior with phosphors concentration **(N_p)** . Table (4.5) shows the Band Gap variation with respect to different phosphors concentration **(N_p)** in different (LDR) samples , under the effect of magnetic field , at T=300^0K , B=50KG , while table (4.6) shows Band Gap variation with respect to different phosphors concentration **(N_p)** in different (LDR) samples , under the effect of magnetic field , at B=100KG . The experimental values of tables (4.5) and (4.6) present the effect of the phosphors concentration **(N_p)** on the band gap in (LDR) . As seen in this tables the values of the band gap in table (4.5) less than the values of the band gap in table (4.6) . This is due to the predominant spatial confinement of the electron . In table (4.5) , by changing the direction of the magnetic field we present the variation of the band gap with respect to different phosphors concentration **(N_p)** in different (LDR) for several tilt angles and the effect of external magnetic field values (when B=50KG . As seen in this table the band gap decreases as the tilt angle increases . In view of the empirical relation in tables (4.5) and (4.6) , it is clear that the band gap in (LDR) is affected by the magnetic field .

We have also study the effect of the phosphors concentration **(N_p)** on the band gap of (LDR) [tables (4.5) and (4.6)] . As seen from this tables the band gap decreases with increasing the value of the phosphors concentration **(N_p)** , however for high concentration. The band gap has minimum value, when the concentration **(N_p)** is high . In this case the variation of the band gap in (LDR), in terms of concentration under magnetic field is not symmetric , it has only minimum value for high concentration . In table (4.2) for B=50KG , present the variation of the band gap for several tilt angles. As seen in this table the band gap decreases as the tilt angles increases. In table (4.4) for B=100KG , present the variation of the band gap for several tilt angles. We find that in this case the values of band gap are not enhanced in magnitude compared with the B=50KG , this is due to the predominant spatial confinement of the electron. Finally, when one comparing the experimental values of the band 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 different phosphors concentration (N_p) , under the effect of magnetic field (B=50KG). (T=300^0K) *5*

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn_{11}	184	0.8123	0.0012	1.20
Sn_{12}	445	o.9012	0.0023	2.30
Sn_{13}	480	0.9706	0.00290	2.90
Sn_{14}	691	1.0010	0.00312	3.12
Sn_{15}	1782	1.0082	0.00361	3.61
Sn_{16}	6093	1.0167	0.00394	3.94
Sn_{17}	13051	1.0230	0.00451	4.51

Table (4.2) : Voltage and Current variation with respect to different phosphor concentration (N_p) **, under the effect of magnetic field [for several tilt angles .By changing the direction of (B)] (B=50KG). (T=300^0K) .**

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn_{11}	184	0.8133	0.00121	1.21
Sn_{12}	445	o.9021	0.00236	2.36
Sn_{13}	480	0.9715	0.00294	2.94
Sn_{14}	691	1.0018	0.00323	3.23
Sn_{15}	1782	1.0093	0.00374	3.74
Sn_{16}	6093	1.0177	0.00407	4.07
Sn_{17}	13051	1.0239	0.00465	4.65

Table (4.3) . Voltage and Current variation with respect to different phosphors concentration (N_p) **, under the effect of magnetic field (B=100KG). (T=300^0K) .**

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn_{11}	184	0.8103	0.00118	1.18
Sn_{12}	445	o.8108	0.00175	1.75
Sn_{13}	480	0.8115	0.00183	1.83
Sn_{14}	691	0.8122	0.00198	1.98
Sn_{15}	1782	0.8135	0.00202	2.02
Sn_{16}	6093	0.8143	0.00209	2.09
Sn_{17}	13051	0.8151	0.00264	2.64

Table (4.4) : Voltage and Current variation with respect to different phosphors concentration (N_p) , under the effect of magnetic field [for several tilt angles .By changing the direction of (B)] (B=100KG). (T=300^{0}K) .

Sample code	Concentration	Voltage (V)	Current (A)	Current (mA)
Sn_{11}	184	0.8105	0.00119	1.19
Sn_{12}	445	o.8109	0.00178	1.78
Sn_{13}	480	0.8110	0.00185	1.85
Sn_{14}	691	0.8114	0.00201	2.01
Sn_{15}	1782	0.8119	0.00206	2.06
Sn_{16}	6093	0.8123	0.00208	2.08
Sn_{17}	13051	0.8129	0.00210	2.10

Table (4.5). Band Gap variation with respect to different phosphors concentration (N_p) in different (LDR) samples , under the effect of magnetic field , at (T=300^{0}K), (B=50KG).

Sample code	Phosphors concentration (N_p)	Band gap [E_{GeV}]
Sn_{11}	184	1.139
Sn_{12}	445	1.133
Sn_{13}	480	1.129
Sn_{14}	691	1.116
Sn_{15}	1782	1.083
Sn_{16}	6093	1.050
Sn_{17}	13051	1.011

Table (4.6). Band Gap variation with respect to different phosphors concentration (N_p) in different (LDR) samples , under the effect of magnetic field , at (T=300^{0}K), (B=00KG).

Sample code	Phosphors concentration (N_p)	Band gap [E_{GeV}]
Sn_{11}	184	1.142
Sn_{12}	445	1.138
Sn_{13}	480	1.132
Sn_{14}	691	1.124
Sn_{15}	1782	1.113
Sn_{16}	6093	1.100
Sn_{17}	13051	1.046

Conclusion

In conclusion band gap in light dependent resistance (LDR) has been studied for different phosphors concentration(N_p) under an external magnetic field. The table (4.5) shows the effect of the phosphors concentration(N_p) on the band gap under external magnetic field (when B=50KG). It is clear from the experiments result that the gap width of the band gap in (LDR) decreases as the phosphors concentration(N_p) increases.

In The table (4.6) for (B=100KG), we find that in this case the values of band gap are not enhanced in magnitude compared with the B=50KG . Also our results indicate that the band gap depends not only on the phosphors concentration (N_p) , but also on the tilt angles and the magnetic field values. At last our experimental results shows that the light dependent resistance (LDR) doped with phosphors concentration(N_p) is quite sensitive to the applied external magnetic field, and the visible light.

References

1. S.E. Aw, H.S. Tan, and C.K. Ong , Optical Absorption Measurements of Band-Gap Shrinkage in Moderately and Heavily Doped Silicon , J.Phs.Condensed Matter 3 , 8213-23 (2009) .
2. J.Tauc, Amorphous and Liquid Semiconductors, Plenum , London , New York , (2011).
3. J.C .Slater , Quantum Theory of Molecules and Solids , Mc Graw. Hill New York , (2012).
4. Malan O.Scully and M.Suhail Zubairy, Quantum Optics, Cambridge University Press, London(2013).
5. R. Kaplan, Optical Spectra of Donor Impurities In Semiconductor in High Magnetic Fields, Volume [181]. American physical society (2014).
6. V.N Fleurov and K.A. Kikoin, Perturbation theory for Light absorption in semiconductors, Volume [31], Moscow. USSR (2007).
7. H.J. Stocker and H. Kaplan, Theory of Oscillatory Photoconductivity in Semi conductors, Volume [150], Syracuse University (New York 2010).
8. G.A. Thomas and T.M. Rice, Optical Study of Interacting Donors in Semiconductor, Volume [23], American Physical Society (1981).
9. J.I. Pankove, Optical Process in Semiconductors, Dover, New York. (2013).