Sudan University of Science & Technology
College of Graduate Studies

Calculating the Energy Gab of Photo Resistance Using Temperature Variation

حساب فجوة الطاقة للمقاومة الضوئية بإستخدام تغير درجة الحرارة

A thesis Submitted in Fulfillment of the Requirements for the Degree of M.Sc. in physics

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DEDICATION

I dedicate this work to my parents, and to my family.

Acknowledgements

This journey for the masters' degree could not have happened without the real help and support of my supervisor **Dr**. **Amel Abdallah AhmedElfaky** - Sudan University of Science and technology, who provided me with thoughtful comments and very useful suggestions. Because of the extraordinarily helpful and willing to be asked questions of people, **Dr**.**Ali Suliman Mohammed & A. Musa Alnour** , I was able to accomplish this dream of studying. I am really lucky to learn from them. I would like also to extend my thanks to my colleagues and friends for their efforts and supports to complete the research. The researcher would like to conclude with, glory and praise be to Allah, The Almighty and most high and may Peace and blessing be upon our Prophet Mohammed.

Abstract

In this thesis photo resistor (CdS) was used to calculate the energy gab using simple electrical method, it was found that to be $E_g = 0.12eV$ and $E_g = 0.22eV$ and electrical conductivity of photo resistor equal to$\sigma = 0.245\Omega^{-1}m^{-1}$ and (I.V) characteristic was studied under the influence of temperature variation and constant polarization angle of irradiation ($\theta = 0^0, 30^0, 60^0, 90^0$),also the of relation(I_{ph}) versus angle θ at constant voltage was considered with temperature variation. Different relation was plotted and the results were discussed for the resistance which obtained versus temperature.

المستخلص

في هذا الاطروحه استخدمت المقاومة الضوئية (Cds) لحساب فجوة الطاقة والموصلية الكهربائية باستخدام الطريقة الكهربائية البسيطة كالتالي $E_g = 0.12eV, 0.22eV$ و $\sigma = 0\cdot245\Omega^{-1}m^{-1}$ ودرست خصائص التيار والجهد تحت تأثير التغير في درجة الحرارة وثبوت زاوية الاستقطاب$(\theta = 0, 30, 60, 90)$ كما تم دراسة علاقة التيار الضوئي بزاوية الاستقطاب عند ثبوت الجهد (5V) مع التغيير في درجة الحرارة ونوقشت هذه النتائج والمنحنيات المختلفة المقاومة التي تم الحصول عليها مقابل التغير في درجة.

Table of contacts

Chapter one

Introduction

1.1Prelude

Semiconductors are a class of materials whose electrical properties are intermediate between good metallic conductors and good insulators. They are of enormous practical interest, forming the basis for a wide variety of
devices used in electronic circuitry, including diodes, transistors, photocells, particle detectors, and integrated circuits.

The simplest semiconductors are the elements silicon and germanium. The electrical conductivity of these materials is much less than that of metals, but it increases very rapidly with temperature, unlike the metals, in which the conductivity nearly always decreases with increasing temperature. Furthermore, the presence of certain kinds of impurities in silicon or germanium, even in extremely small concentrations, can increase the conductivity enormously.

The conductivity of any material depends on the existence of electrons which are more or less free to move within the material. In metals there are many mobile electrons, even at low temperatures. Germanium and silicon at low temperatures have no free electrons, because of their crystal structure. Each atom has four valence electrons and in the crystal lattice each atom has four nearest-neighbor atoms situated at the corners of a regular tetrahedron. Each valence electron participates in a covalent (shared-electron) bond with one of the nearest neighbors; thus all valence

Electrons are bound to individual atoms and none are free to move. But only a small amount of energy is needed to break one of these bonds, 1.1 eV for silicon, and only 0.7 eV for germanium. This energy can be supplied by thermal motion; hence as the temperature increases, more and more bonds are broken and electrons become free to participate in conduction. The positively charged vacancies or holes can also move by successive replacement of adjacent electrons, so these also contribute to conductivity. The conductivity increases rapidly with temperature. This type of conductivity is called intrinsic conductivity to distinguish it from impurity or extrinsic conductivity, to be discussed next.

If some atoms of an element having five valence electrons, such as arsenic, are added, four are involved in the covalent bonds, but the fifth is very loosely bound (binding energy of the order of 0.0l eV), and even at low temperatures can break away and move freely through the lattice. Such an impurity is called a donor impurity or an n-type impurity, since the atoms donate negatively charged current carriers. Conductivity of an n-type semiconductor at ordinary temperatures is chiefly due to the electrons from n-type impurities correspondingly, an impurity with only three valence electrons, such as gallium, can take an electron from an

Adjacent germanium atom to complete its four bonds, this leaves a hole at the adjacent atom and this hole can migrate through the lattice, contributing to the conductivity. Such an impurity is called an acceptor impurity and the resulting material is called a p-type semiconductor[1].

Photo resistor (CdS) cadmium sulfide is a resistor which made of semiconductor material and the conductance change with luminance variation, or its alight controlled variable resistor.

The resistance of a photo resistor decreases with increasing incident light intensity in other words the photo resistor can be applied in light sensitive detector circuit and light activated and dark activated; switching circuited.

The photo resistor is widely used in many industries such as toys, lampas, camera, control,[7].

The photo resistor can have a resistance a high as several mega ohms (MΩ) with in the light.

1.2 Problem of research

The thermal effect in semiconductor play an active role in their characteristic such as conductivity, resistivity, and band gab energy situation so it is very important to study how this characteristic varied with increasing or decreasing of temperature.

1.3 Objective of research

To study the thermal effect on the (CdS) in addition optical effect and to calculate the energy gab and conductivity of photo resistor (CdS) using temperature variation

1.4 Layout of research

This research contains four chapters, chapter one introduction, chapter two semiconductors, chapter three photo resistance and cadmium sulfide, chapter four material and methods.

1.5 literature reviews

CdS based novel photo impedance light sensor

A novel photo impedance (hybrid photo capacitive photo resistance) sensor for visible light employs gated cadmium sulfide photo resistance connecting two fixed capacitances the changes of the photo resistance and of the metal insulator (dielectric) semiconductor (MIS) under illumination a affect the overall device capacitance.

The MIS and photo resistor frequency dispersion allows for increasing the dynamic range by measuring the capacitance response at lower frequency by making this device apart of the tank circuit of a radio frequency oscillator the information on illumination intensity can be relayed as the signal frequency and detester remotely [11].

Chapter Two

Semiconductors

2.1 Prelude

Semiconductors are one of the technologically most important class of materials, According to the band theory of solids, which is an outcome of quantum mechanics, semiconductors possess a band gap, i.e., there is a range of forbidden energy values for the electrons and holes. In this experiment, we will calculate the energy band gap in the intrinsic region and the temperature dependence of the majority carrier mobility in the extrinsic region.

The available energies for electrons help us to differentiate between insulators, conductors and semiconductors. In free atoms, discrete energy levels are present, but in solid materials (such as insulators, semiconductors and conductors) the available energy states are so close to one another that they form bands.

A semiconductor material is one whose electrical properties between those of insulators and good conductors. examples are: germanium and silicon[10].

2.2 Classification of substances on the basis of conduction of electricity.

2.2.1Insulators

An insulator is a material that does not conduct electrical current under normal conditions; most good insulators are compounds rather than single-element materials and have very high resistivity's. Valence electrons are tightly bound to the atoms; therefore, there are very few free electrons in an insulator. Examples of insulators are rubber, plastics, glass, mica, and quartz.

2.2.2Conductors

A conductor is a material that easily conducts electrical current, most metals are good conductors. The best conductors are single-element materials, such as copper (Cu), silver (Ag), gold (Au), and aluminum (Al), which are characterized by atoms with only one valence electron very loosely bound to the atom. These loosely bound valences electrons can become free electrons with the addition of a small amount of energy to free them from the atom. Therefore, in a conductive material the free electrons are available to carry current[5].

2.2.3Semiconductors

A semiconductor is a material that is between conductors and insulators

in its ability to conduct electrical current. A semiconductor in its pure (intrinsic) state is neither a good conductor nor a good insulator. Single-element semiconductors are antimony (Sb), arsenic (As), astatine (At), boron (B), polonium (Po), tellurium (Te), and silicon (Si), and germanium (Ge).

Compound semiconductors such as gallium arsenide, indium phosphide, gallium nitride, silicon carbide, and silicon germanium are also commonly used.

The single-element semiconductors are characterized by atoms with four valence electrons[5].

2.3 Characteristics of Semiconducting Materials

Some more salient characteristics of semiconductors are given as follows.

2.3.1 They have negative temperature coefficient of resistance.

2.3.2 The resistivity of semiconductors at very low temperature matches with those of insulators.

2.3.3 The number of electrons free in semiconductors material decreased from the conductor material and big in insulators material.

2.3.4 The resistance R of semiconductors decreases nonlinearly on adding impurity into it

2.4 Comparisons between conductor material and semiconductor and insulator.

Table (2.1) shows the properties of and characteristics of conductors, semiconductors, insulators

Description	Conductors	Semiconductors	Insulators
Conductivity	High to very high	Low to medium	Nil to very low
Energy band Resistivity	Low to very low	Medium to low	Very high to High
Temperature coefficient of resistance	Always positive	Always negative	May be positive or negative

2.5 Energy Bands

The band gap is an energy range where no electronic states are present. In insulators, the valence band is separated from the conduction band by a large gap, in good conductors

Such as metals the valence band overlaps the conduction band, whereas in semiconductors there is a small gap between the valence and conduction Bands, small enough allowing thermal excitation of electrons from the valence to conduction band.

2.5.1Valence Band

This energy band contains valence electrons. This band may be partially or completely filled with electrons but never be empty. The electrons in this band are not capable of gaining energy

2.5.2Conduction Band

This band contains conduction electrons. This band is either empty or partially filled with Electrons. Electrons present in this band take part in the conduction of current.

2.5.3Forbidden Band

This band is completely empty. The minimum energy required to shift an electron from valence band to conduction band is called band gap (E_g).

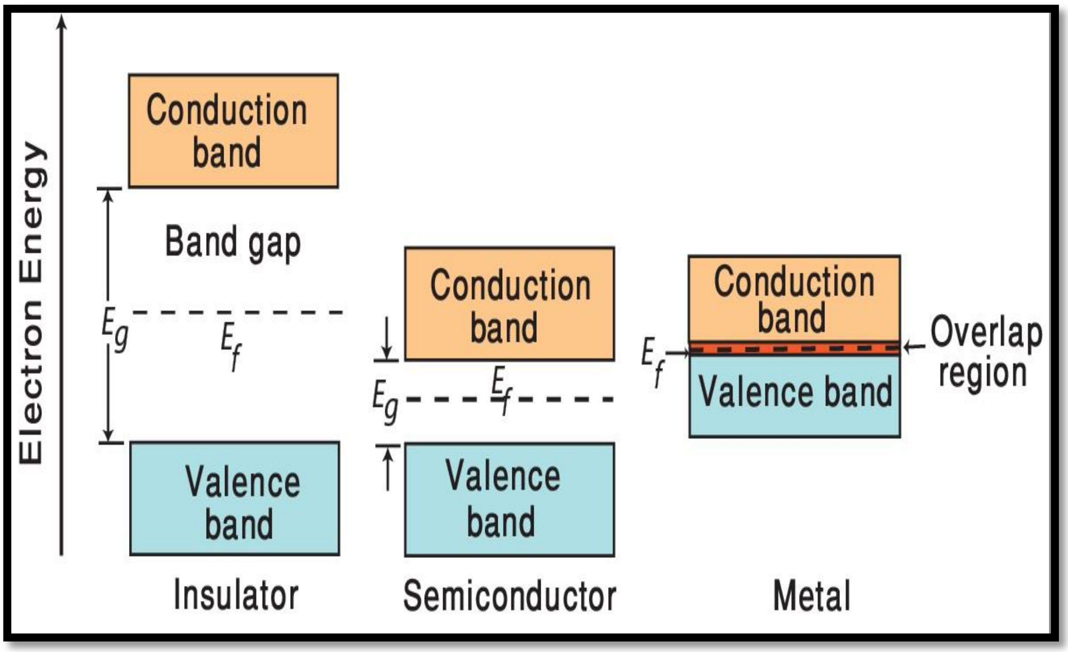


Figure (2.1): Implied diagram of the electronic band structure of insulators, semiconductors and metals. The position of the Fermi level is when the sample is at absolute zero temperature (0 K).

2.6 Types of Semiconductors

Semiconductor may be classified as shown

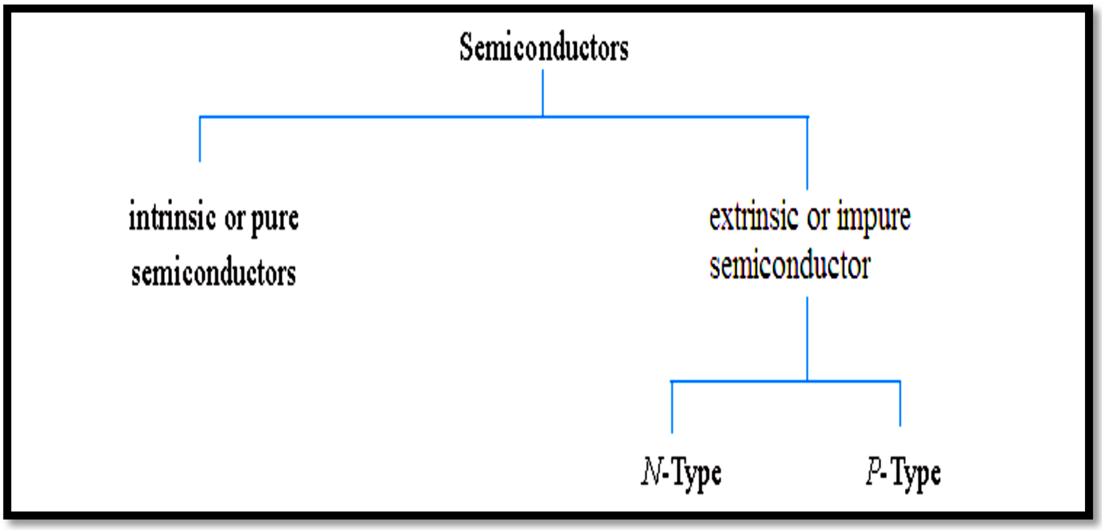


Figure (2.2) type of Semiconductors

2.6.1 Intrinsic Semiconductor

Semiconductor is a material whose conductivity lies in-between that of the conductors and the insulators. Semiconductors which are chemically pure, meaning free of impurities, are called Intrinsic Semiconductors or Undated Semiconductor or I-type Semiconductor. The most common intrinsic semiconductors are Silicon (Si) and Germanium (Ge), which belong to Group IV of the periodic table. The atomic numbers of Si and Ge are 14 and 32, which yields their electronic configuration as $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$ and $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^2$, respectively. This indicates that both Si and Ge have four electrons each in their outer-most i.e. valence shell (indicated by red color). These electrons are called valence electrons and are responsible for the conduction-properties of the semiconductors

Crystal lattice of Silicon (it is the same even for Germanium) in two-dimension is as shown in Figure (2.6). Here it is seen that each valence electron of a Si atom pairs with the valence electron of the adjacent Si atom to form covalent bond

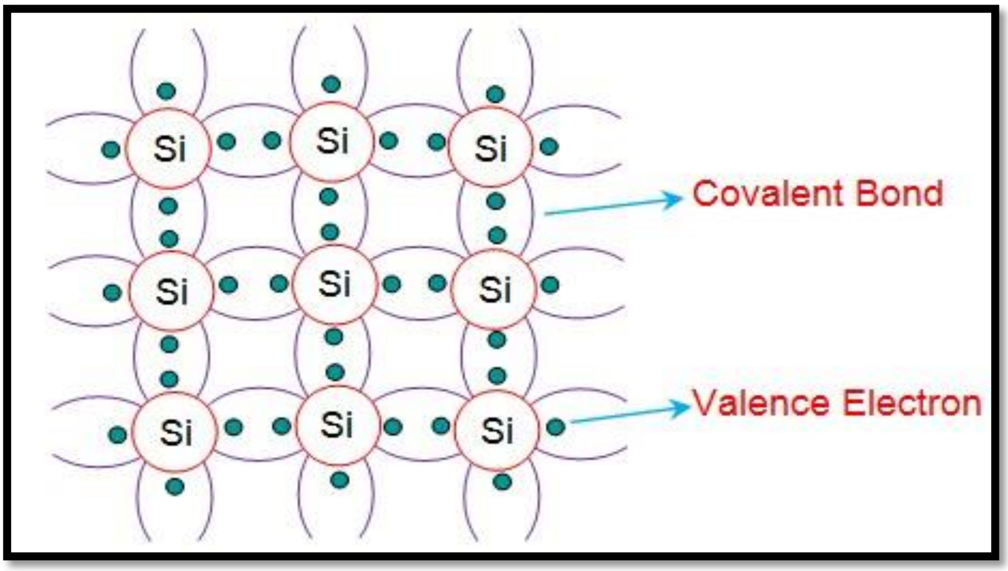


Figure 2.3 crystal lattice of silicon

2.6.2Extrinsic Semiconductors

Semiconductor materials can be classified into two types, intrinsic Semiconductors and Extrinsic Semiconductors; Semiconductors in their pure form are referred to as intrinsic semiconductors. On the other hand the semiconductors with intentionally added impurities are called extrinsic semiconductors. This process of adding impurities in minute quantities into the pure semiconductor material under controlled conditions is known as doping. The process is undertaken with an intention of increasing the conductivity of the material. Hence, the impurities are chosen in such a way that their addition into the pure semiconductor should increase the number of free carriers which can be either holes or electrons It is well known that the pure semiconductors like Silicon (Si) or Germanium (Ge) are tetravalent (have four electrons in their valence shell) as they belong to Group IV of the periodic table. Thus, if one needs to increase the number of electrons in them, they are to be doped with the Group V elements of the periodic table viz., Phosphorous (P), Arsenic (As), Antimony (Sb), Bismuth (Bi) or Lithium (Li). This is because Group V elements are pentavalent in nature, meaning which they have five electrons in their valence shell. This indicates that even after the formation of four covalent bonds due to the sharing of four electrons between the Group V and Group IV elements, one more electron (fifth electron of Group V element) would be left behind shown by figure (2.6).

In other words, pentavalent impurities are said to donate their electron to the tetravalent (pure) semiconductors and are hence called donors. The electron so donated will be very loosely bound to its parent atom and can thus be made 'free' by supplying very minimal amount of thermal energy Such an excitation causes the electron to transit from its current energy state, donor level E_D green line in figure (2.6) to the conduction band from then on it can actively contribute to the process of conduction in the semiconductor material along with the other free electrons generated due to the breaking of covalent bonds. From this, one can note that the total number of electrons in such a material is the sum of thermally generated electrons and the electrons

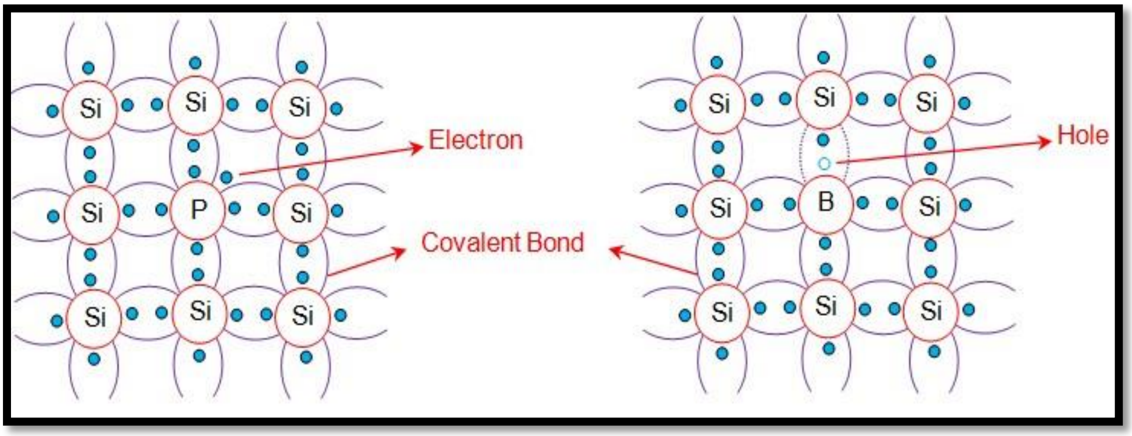


Figure (2.4) crystal lattice of silicon doped with (p) phosphorous and (B) boron.

The types of doped semiconductors formed after the addition of the Impurities are

2.6.1N-type semiconductor materials

Before understanding what n-type semiconductor is should focus on some basic theories of atomic science, all know that each atom of any substance requires eight electrons at its outermost orbit But it is also true that all atoms do not have eight electrons at their outermost orbit But all the atoms have an ultimate goal to have eight electrons at their outermost orbit. The electrons at an outermost orbit of an atom are called valence electrons. If the outermost orbit of an atom does not have eight electrons, then there will be as many vacancies as the lack of electrons in the orbit these vacancies are always ready to accept electrons to fulfill eight electrons in the outermost orbit of the atom. The most commonly used semiconductors are silicon and germanium. The Silicon has 14 electrons which have been configured as 2, 8, 4; Germanium has 32 electrons which have been configured as 2, 8, 18, 4. Both of the semiconductors have 4 electrons at their outer-most orbit.

Hence, there are vacancies for more 4 electrons, these vacancies are fulfilled by four valence electrons each from four individual neighboring semiconductor atom Actually, in this way all atoms of a semiconductor crystal make a covalent bond with their nearest most neighborhood atoms. Ideally, all valance electrons in a semiconductor crystal are involved in forming of covalent bond hence; there should not be any free electron in the crystal. But this is not the actual case. At absolute 0Kelvin there would not be any free electron in the crystal but when the temperature rises from absolute zero to room temperature, numbers of valence electrons in the bonds are thermally excited and come out from the bond and generate a numbers of free electrons in the crystal These free electrons cause the conductivity of the semiconductor materials at any temperature higher than absolute zero.

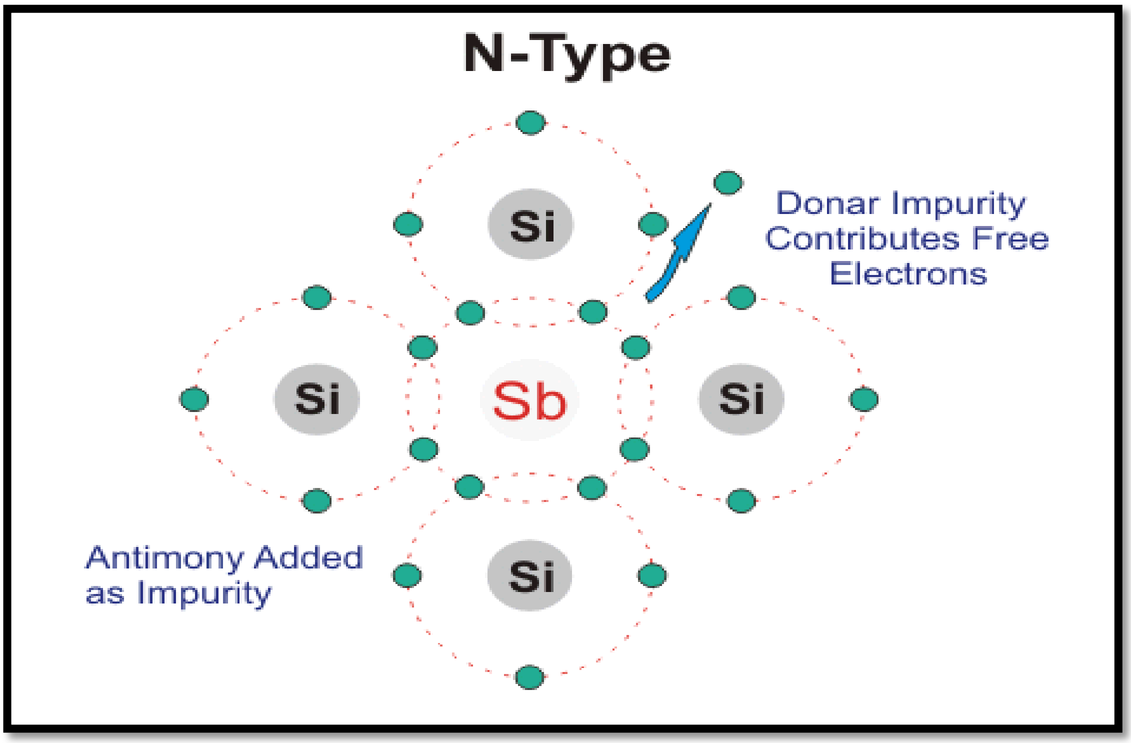


Figure (2.5) explains the n-type semiconductor for silicon doping with phosphide

2.6.2 P-type semiconductor materials

We all know that in semiconductor crystal each tetra valiant atom creates covalent bond with four neighboring atoms. In this way, each of the atoms in semiconductor crystal gets eight electrons in outermost orbit. Now if a small percentage of tri valiant impurity atoms are doped in the pure or intrinsic semiconductor crystal then electrical behavior of the crystal is drastically changed. Let us explain how the impurity atoms displace the same number of semiconductor atoms in the crystal and occupy their positions. Now three valence electrons of each trivalent impurity atom create covalent bond with three neighboring semiconductor atoms. In this way, each impurity atom gets 7 valence electrons at outermost orbit. But still there is lack of one electron in the outermost orbit of the impurity atom. In other words, there are three complete covalent bonds and one incomplete covalent bond with one electron. Hence, there is a vacancy for one electron and this vacancy is as each hole is created from one impurity atom. So far we explained, about creation of holes but did not focus how a hole can move in the crystal as it is associated with static impurity atom. But in a semiconductor crystal holes can also move like electrons but the mechanism of movement is different. When one hole that is one incomplete covalent bond created, it will not remain incomplete lifelong

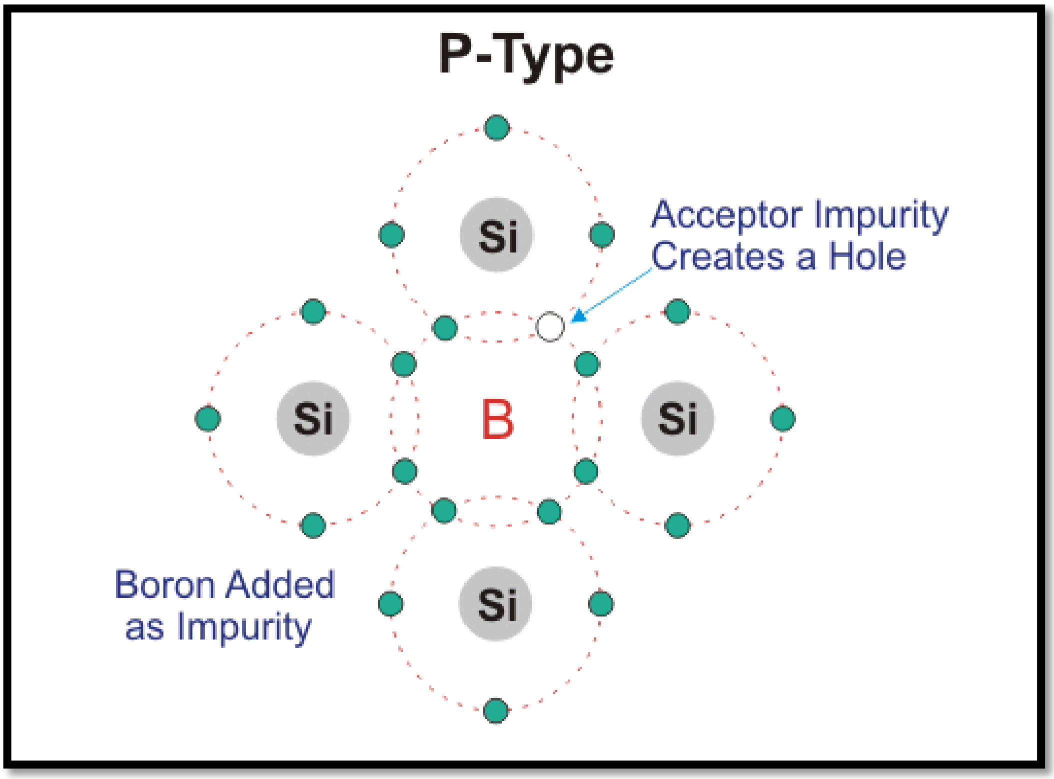


Figure (2.7) explains the p- type semiconductor for silicon doping with boron

Chapter Three

Photo resistor and Cadmium Sulfide

3.1 Cadmium Sulfide (CdS)

It is used to make photoconductors of high dissipation capability and excellent sensitivity in visible spectrum, and to prepare cadmium sulfide cell by depositing layer of CdS. This layer generally contains Ag, Sb, In etc. as impurity. Its energy gap is 2.4 eV.

Cadmium Sulfide (CdS) is one of the highly photo sensitive and good semiconductor material of II-VI group elements. Cadmium Sulfide (CdS) have different applications in optoelectronic devices like solar cells, photo detectors etc.

Cadmium sulfide (CdS) is an II-VI semiconductor which is insoluble in water, but soluble in dilute mineral acids.

Cadmium sulfide (CdS) is a semiconductor material and belongs to group second of table cyclic, and is a yellow colored material, decay of water and density evenness (4.84gm/cm^3).

CdS is have hexadecane structure crystal and cubic sometimes correlates cadmium with sulfur in this composite by conduction subscribe and deemed the material (CdS) of widely material application when introduces this composite by photo basics in industry photo solar and may be deposition with other material ,to forming layer for resultant on solar cell good characteristic. The cadmium sulfide is alchemical compound that has formula (CdS) it is yellow in color and a semiconductor of electricity; it exists as two different polymorphs hexagons [10].

(3.2) Application cadmium sulfide (CdS)

Light dependent photo resistor for light sensors, chemical bath deposition, electrochemical deposition, sputtering, spraying with precursor

(3.3) Properties of cadmium sulfide (CdS)

Some basic properties of cadmium sulfide are listed below

Table (3.1) shows the properties of cadmium sulfide

Property	**Value**
Physical state and appearance	Solid powder
Molecular weight	1440g/mole
Color	Yellow or brown
Melting point	Sublimes
Specific gravity	$4.82 g/cm^3$
Solubility	Insoluble in hot and cold water

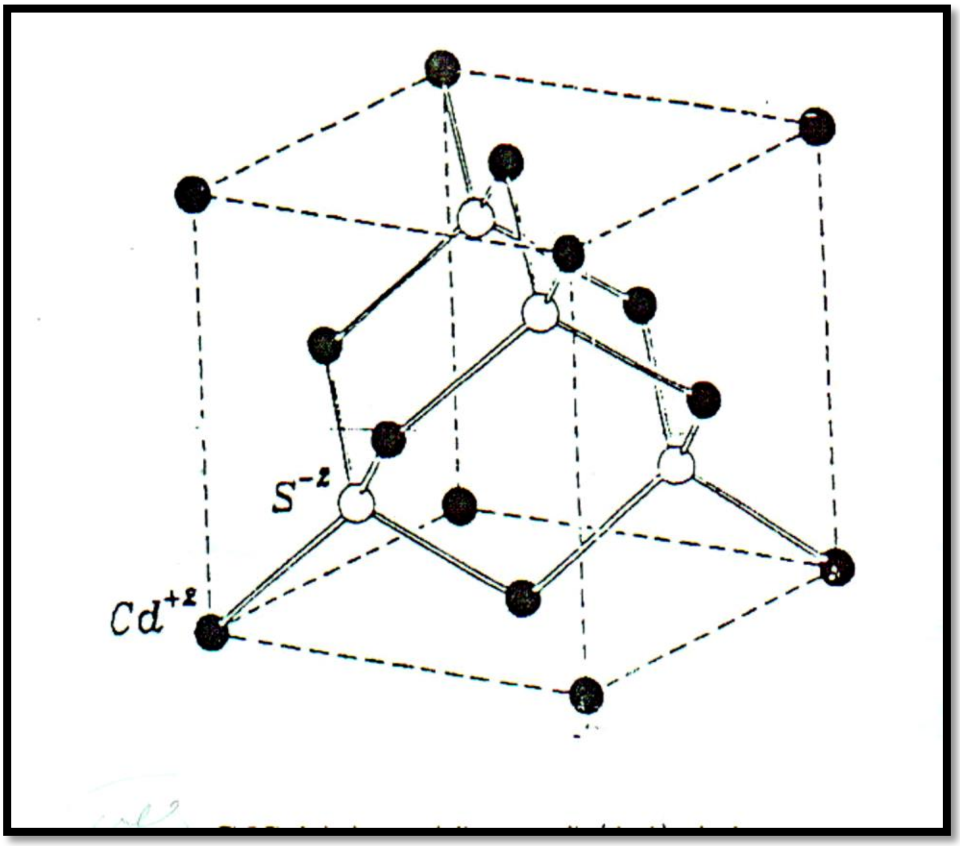


Figure (3.1) illustrates cadmium sulfide (CdS) structure crystal

3.4 The Photo resistor

is simply a resistor whose resistance depends on the amount of light incident upon it, Photo resistors are used to make light-sensitive devices, and are often made from cadmium sulfide (CdS), The resistance of a CdS photo resistor varies inversely to the amount of light incident upon it, In other words, its resistance will be higher at low light levels (in the dark) and lower at high light levels (in the light) [4].

Photo resistor is a resistor which made of semi-conductor material, and the conductance changes with luminance variation, the photo resistor can be manufactured with different figures and illuminated area based on this characteristic, Photo resistor is widely used in many industries, such as toys, lamps, camera, etc.

A photo resistor also called a photocell or light-dependent resistor (LDR) is a semiconductor that changes its electrical resistance when exposed to light.

A photo resistor is a resistive element that is sensitive to light. It is usually made from cadmium sulfide (CdS). Its resistance is extremely large under dark conditions, in the range of mega-ohms, and very low, only a few hundred ohms, when exposed to light. We can therefore use a photo resistor to detect lighting conditions because the voltage across, or the current through, the photo resistor will vary with respect to the intensity of light incident upon it, Photo resistor or light dependent resistor or cadmium sulfide (CdS) is a resistor whose resistance decreases with increasing incident light intensity It can be also referenced as a photoconductor. If light falling on the device is of high enough frequency, photos absorbed by the semiconductor give band electron enough energy to jump into the conduction band, the resulting free electron and its whole partner conduct electricity, there by lowing resistance [4].

3.5 Applications of photo resistor

Photoelectric control, photo switch, auto flash for camera, electronic toys industrial control

3.6 Features of photo resistor

Quick Response, Reliable Performance, hermetical package, Good Characteristic [4]

3.7 Type of optoelectronic devices

3.7.1 Photodiodes

A photodiodes a two terminal device, which responds to photon absorption

3.7.2 Photoconductors (or photo detectors)

Are used to detect and measure the quanta of light such as in automatic door opener, in switching the street lights, and as burglar alarm. CdS, CdSe and CdTe are commonly used photo conducting semiconductors.

3.7.3 Photocells

Convert the light energy into electrical energy. They are fabricated from CdS, Se and PbSO4. Photocells are used in cinematography, fire-alarms and television cameras etc.

3.7.4 Solar cells

Made from semiconducting materials are of immense utility in satellites

and space-going vehicles, they are also used in calculators, solar power Generation and solar auto vehicles

3.7.5 Light-emitting diode

Is an incoherent light source, which is used as a light source in fiber optic systems and other devices.

3.7.6 Laser

Is the source of a highly directional, monochromatic coherent light which is used as a light source for various optical and electronic devices.

3.7.7 Optical fibber

Is a means of transmitting optical signals from a source to detector.

3.7.8 Integrated circuits

Are manufactured on single chip that contains diodes, transistors, resistors and capacitors They are generally monolithically constructed using either unipolar or bipolar techniques [7].

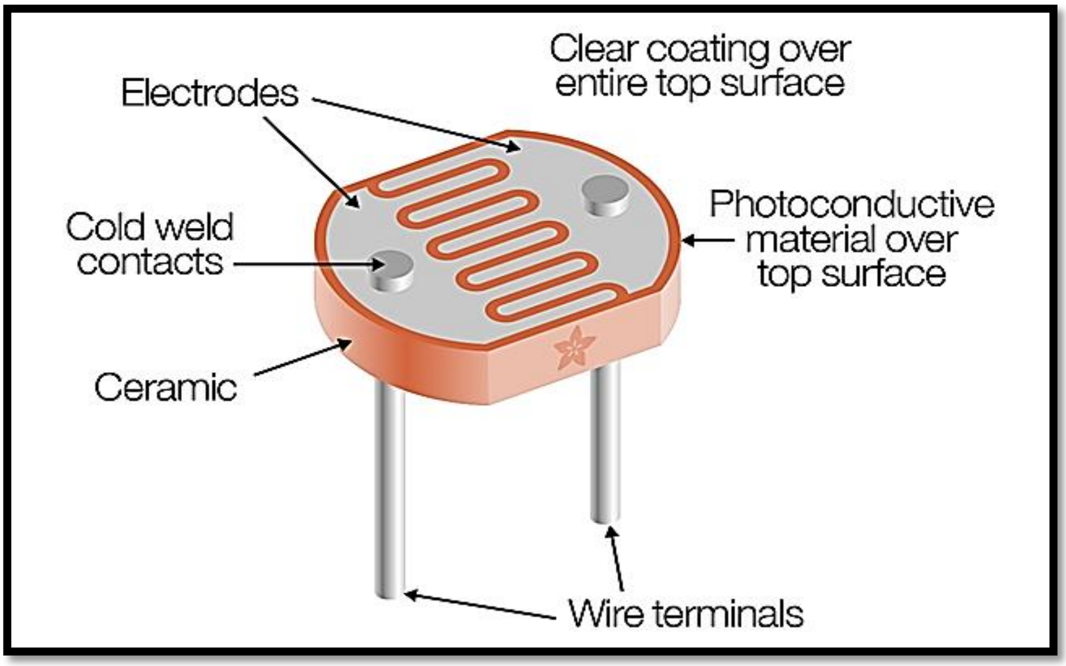


Figure (3.2) illustrates form of photo resistor (CdS) used

Chapter Four

Material and Methods

4.1 Introduction

In this chapter material and method that was followed to determine energy gap by means of temperature effect on resistance of semiconductor, this experiment was carried out in physics lab in Omdurman Islamic university.

4.2 Apparatuses or materials

The experiment involves the following major components.

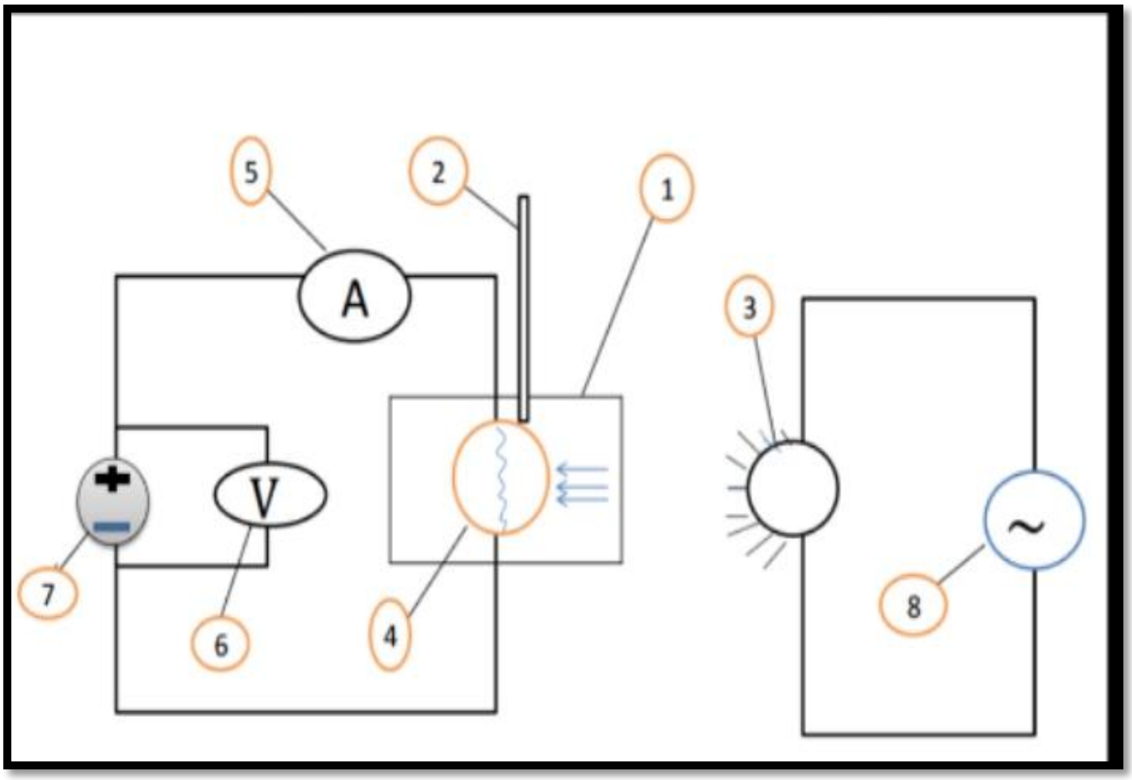
Power supply (DC/AC)(2-16V), voltmeter(0-15V), millimeter(0-100mA), thermometer(0-100C^0), connection wires, photo resistor (CdS), heater, light source, photo sensor polarization.

4.3 The method

Photo resistor made of cadmium sulfide was prepared and subject to fixed intensity irradiation through optical polarized and analyzer and variable temperature of (27, 30, 35, 40) C^0 in two different steps.

First step I-V characteristic was studied for different angle of irrigation at room temperature

In second step I-V was done by raising temperature of the sample, also current and angle of irradiation was introduced with fixed potential difference.



1. Heater **2.**Thermometer **3.**Light source **4.**CdS **5.**millimeter**6.**voltmeter 7.power supply DC **8.**power supply AC

The figure (4.1) shows the apparatus used in the experiment (CdS)

4.4 The results

Table (4.1) shows potential difference (V) versus photo current (I_{ph}) for different angle of irradiant at temperature (T=$27C^0$)

	$\theta = 0$	$\theta = 30$	$\theta = 60$	$\theta = 90$
V/v	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA
1	3	2	1	0
2	6	5	3	0
3	9	8	4	0
4	13	11	6	0
5	16	14	7	0
6	19	16	9	0
7	23	19	10	0
8	26	22	12	0
9	30	25	12	0

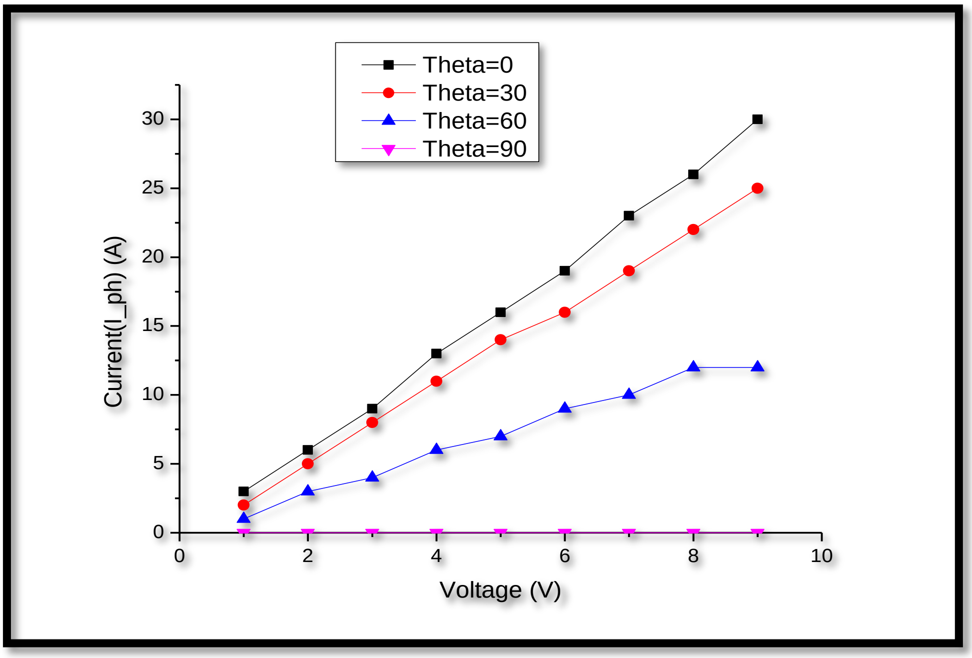


Figure (4.2) relationship between voltage and the photocurrent (I_{ph}) of photo resistor (CdS) at room temperature (T=$27C^0$)

Table (4.2) shows potential difference (V) versus photo current (I_{ph}) for different angle of irradiant at temperature (T=$30C^0$)

	$\theta = 0$	$\theta = 30$	$\theta = 60$	$\theta = 90$
V/v	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA
1	3	2	1	0
2	5	5	2	0
3	8	7	3	0
4	11	10	4	0
5	13	12	6	0
6	14	14	7	0
7	19	18	8	0
8	22	19	10	0
9	25	21	11	0
10	28	24	12	0

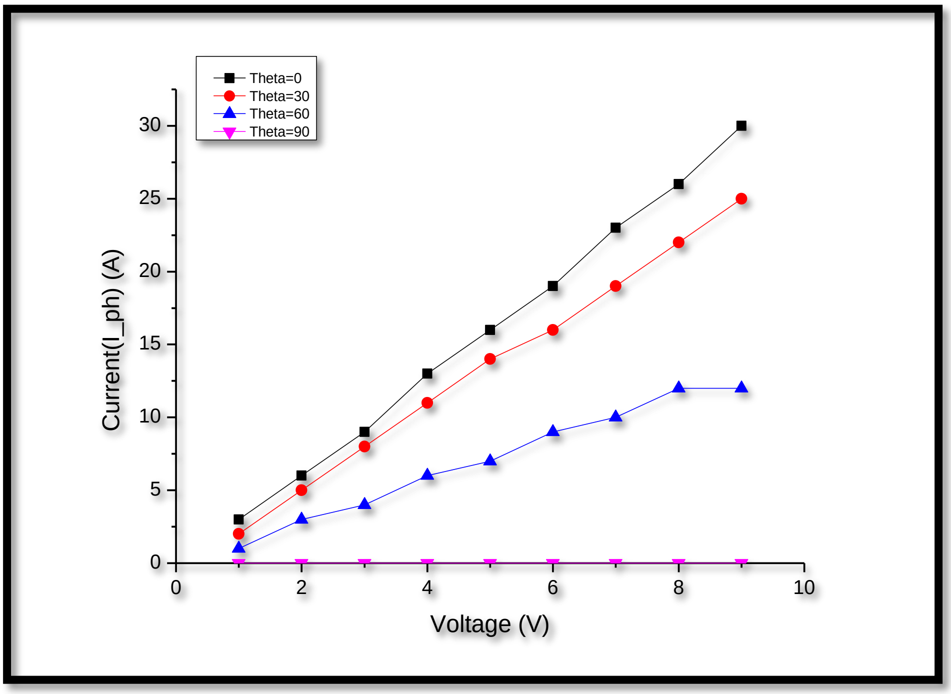


Figure (4.3) relationship between voltage and current of semiconductor (CdS) at temperature (T=$30C^0$)

Table (4.3) shows potential difference (V) versus photo current (I_{ph}) for different angle of irradiant at temperature (T=35C^0)

	$\theta = 0$	$\theta = 30$	$\theta = 60$	$\theta = 90$
v/V	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA
1	2	2	1	0
2	5	5	2	0
3	9	7	3	0
4	11	10	4	0
5	14	13	6	0
6	16	16	7	0
7	19	18	8	0
8	19	21	10	0
9	21	25	11	0
10	24	27	12	0

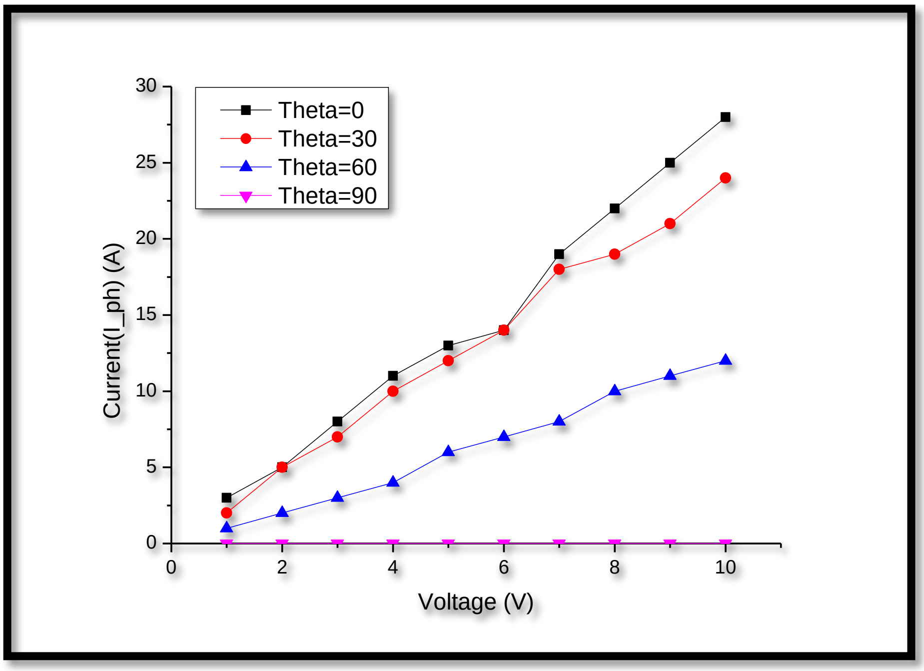


Figure (4.4) relationship between voltage and the photocurrent (I_{ph}) of photo resistor (CdS) at temperature (T=35C^0)

Table (4.4) shows potential difference (V) versus photo current (I_{ph}) for different angle of irradiant at temperature ($T=40C^0$)

	θ=0	θ=30	θ=60	θ=90
v/V	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA	I_{ph}/mA
1	2	2	1	0
2	5	4	2	0
3	8	7	3	0
4	10	9	4	0
5	13	11	6	0
6	16	13	7	0
7	18	16	8	0
8	21	18	9	0
9	24	21	11	0
10	28	23	12	0

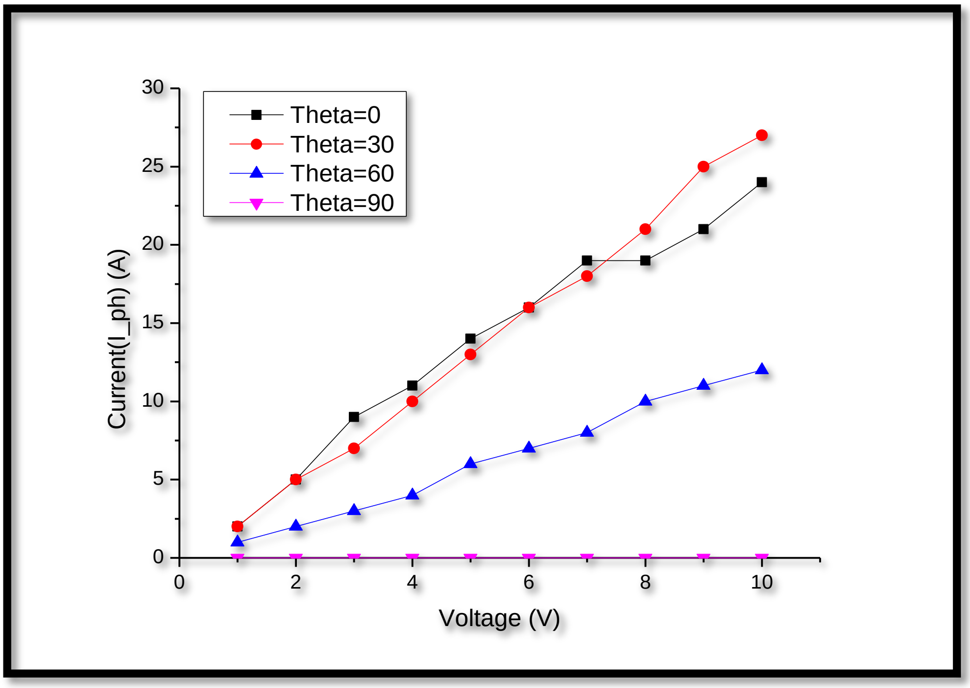


Figure (4.5) relationship between voltage and the photocurrent (I_{ph}) of photo resistor (CdS) at temperature ($T=40C^0$)

Table (4.5) shows potential difference photo current (I_{ph}) for different angle of irradiant at temperature (T=$27C^0$), constant voltage

V/v	I_{ph}/mA	θ	$\cos^2 \theta$
5	16	0	1
5	14	30	0.8
5	6	60	0.3
5	0	90	0

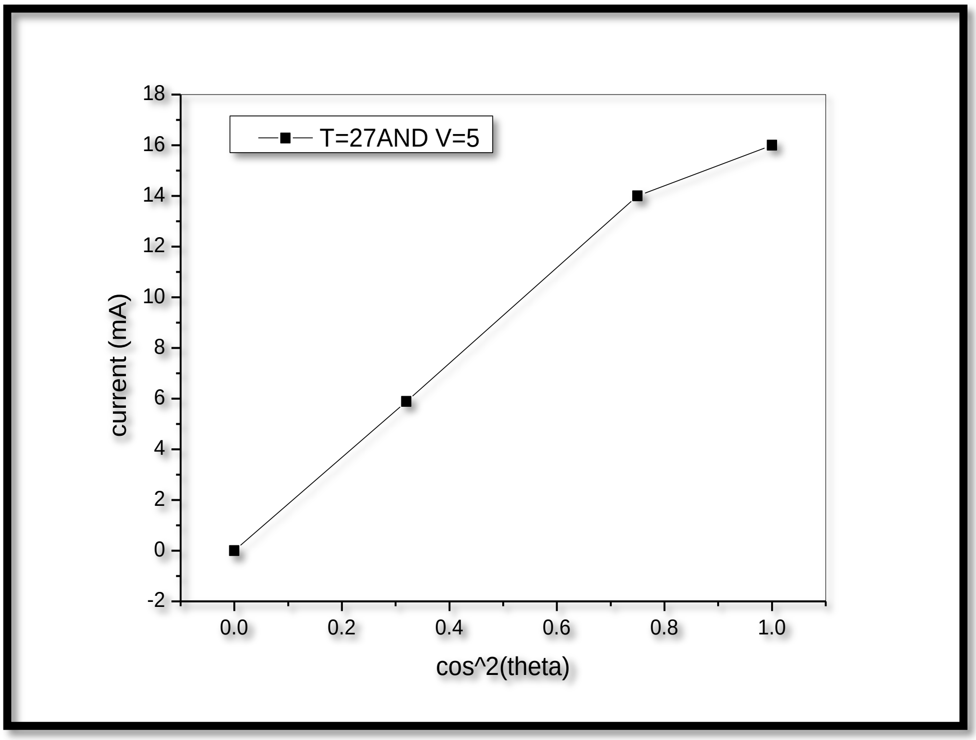


Figure (4.6) relationship between photocurrent (I_{ph}) and different angles polarization of photo resistor (CdS) at temperature (T=$27C^0$)

Table (4.6) shows potential difference photo current (I_{ph}) for different angle of irradiant at temperature (T=$30C^0$), constant voltage

V/v	I_{ph}/mA	θ	$\cos^2\theta$
5	13	0	1
5	11	30	0.8
5	5	60	0.3
5	0	90	0

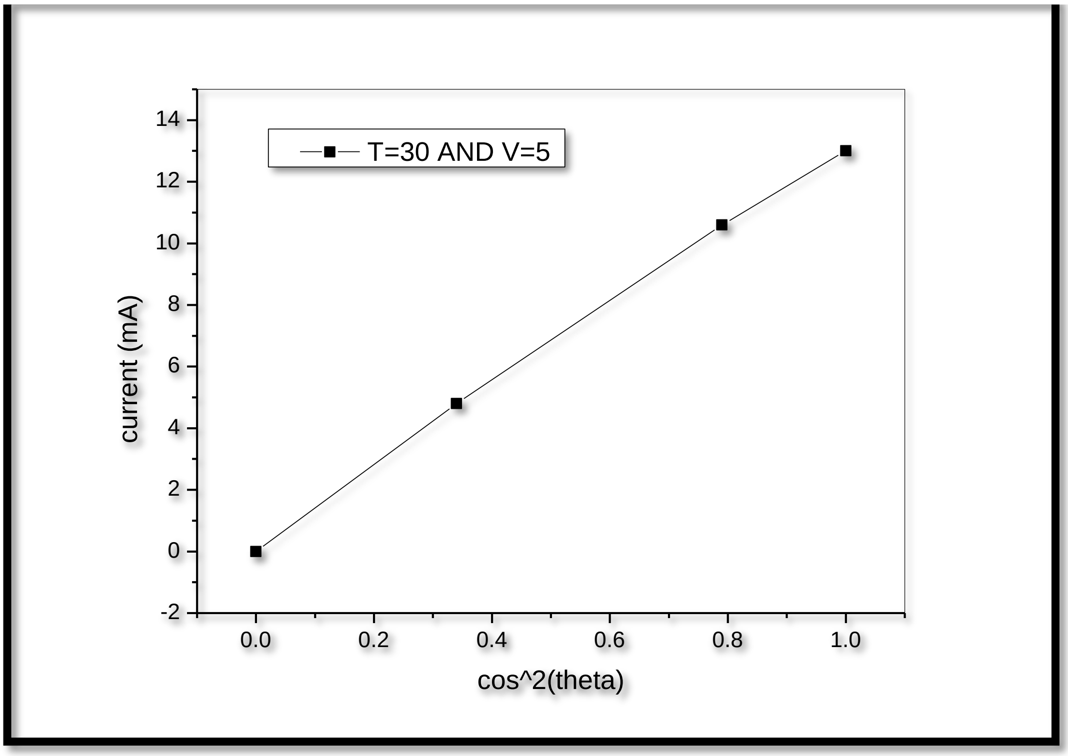


Figure (4.7) relationship between photocurrent (I_{ph}) and different angles polarization of photo resistor (CdS) at temperature (T=30^0C)

Table (4.7) shows potential difference photo current (I_{ph}) versus for different angle of irradiant at temperature (T=$35C^0$) constant voltage

V/v	I_{ph}/mA	θ	$\cos^2 \theta$
5	13	0	1
5	11	30	0. 8
5	5	60	0.3
5	0	90	0

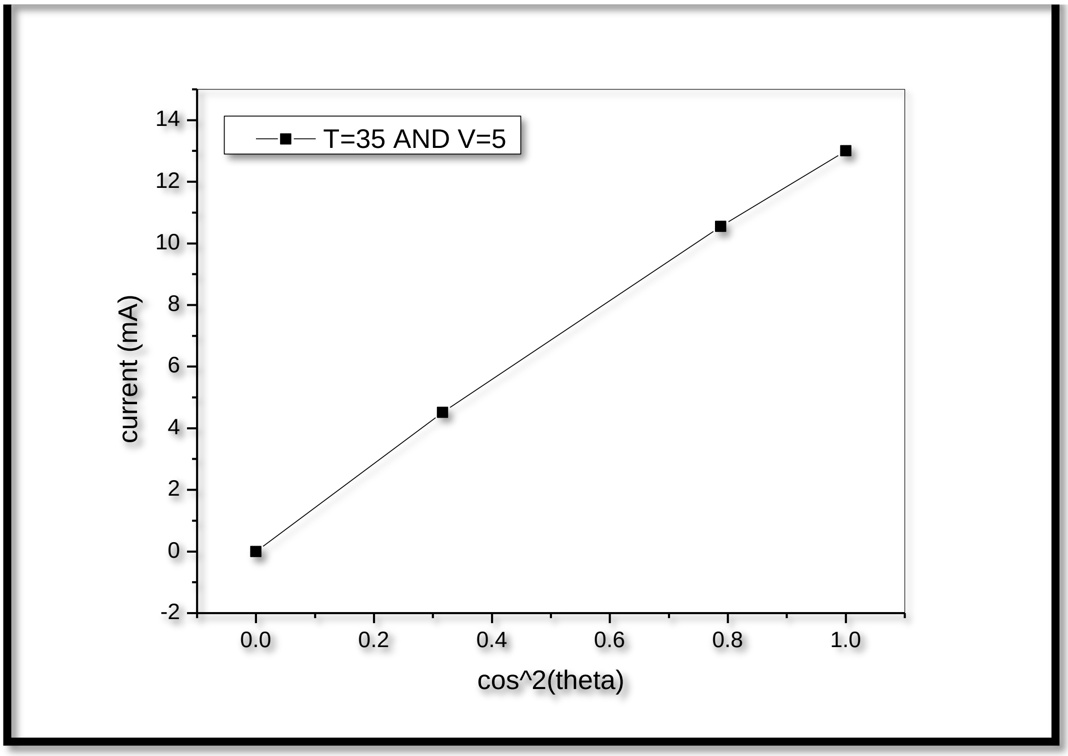


Figure (4.8) illustrates relationship between photocurrent (I_{ph}) and different angles polarization of photo resistor (CdS) at temperature (T=$35C^0$)

Table (4.8) shows potential difference photo current (I_{ph}) versus for different angle of irradiant at temperature (T=$40C^0$) constant voltage

V/v	I_{ph}/mA	θ	$\cos^2\theta$
5	14	0	1
5	12	30	0.8
5	5	60	0.3
5	0	90	0

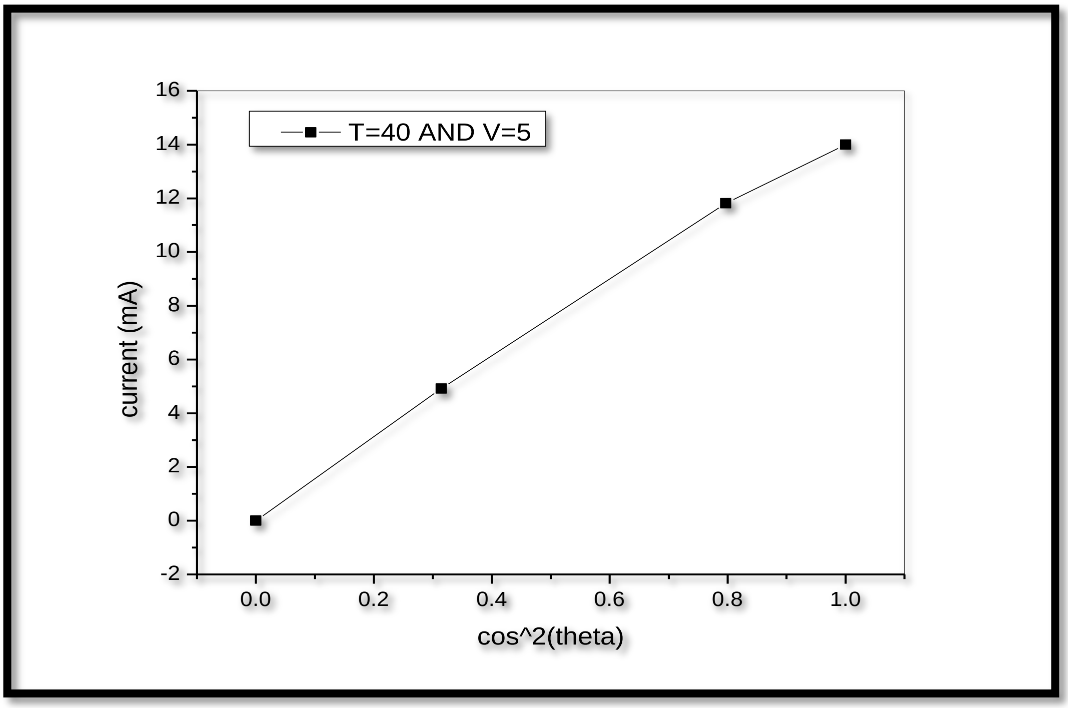


Figure (4.9) relationship between photocurrent (I_{ph}) and different angles polarization of photo resistor (CdS) at temperature (T=$40C^0$)

Table (4.9) shows potential difference logarithm $Ln(R_T)$ versus temperature (1/T) for different angle of irradiant constant

		$\theta = 0$		$\theta = 30$		$\theta = 60$	
T/K	$(1/T)K^{-1}$	R_t	$Ln(R_t)$	R_t	$Ln(R_t)$	R_t	$L(nR_t)$
300	$33.3X10^{-3}$	3.36	1.2	2.83	1.04	1.43	0.36
303	$33X10^{-3}$	2.73	1	2.4	0.87	1.28	0.25
308	$32.4X10^{-3}$	2.38	0.86	2.8	1.02	1.28	0.25
313	$31X10^{-3}$	2.33	0.84	2.7	0.99	1.23	0.21

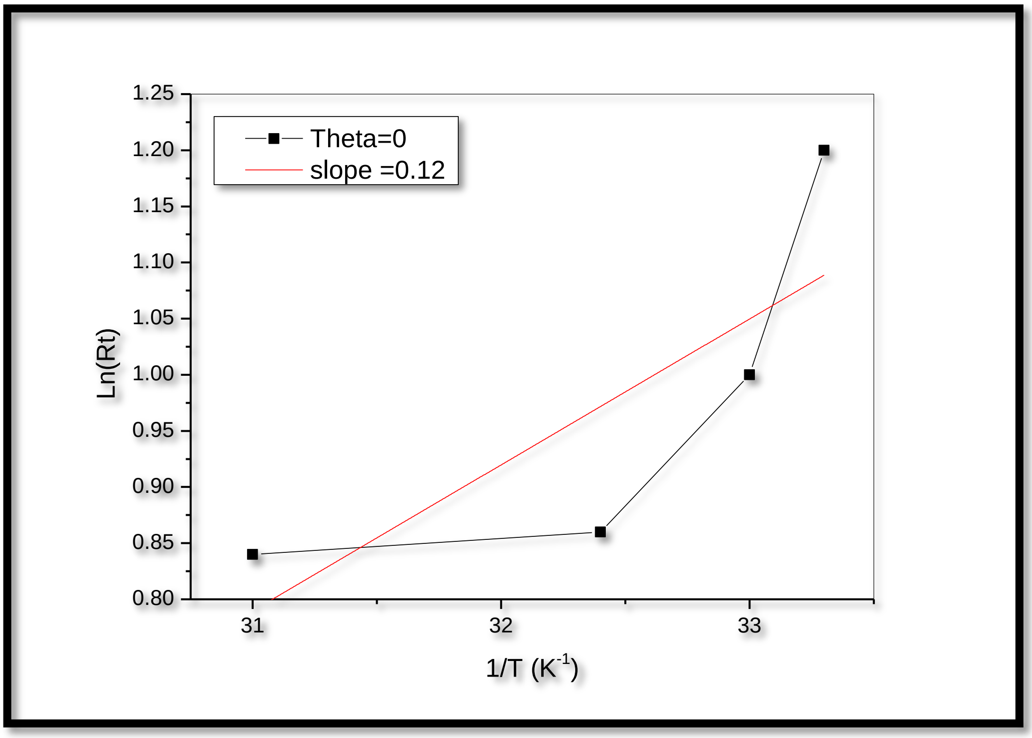


Figure (4.10) relationship between $Ln(Rt)$ and reciprocal temperature $(1/T)$ at angle polarization $\theta = 0$

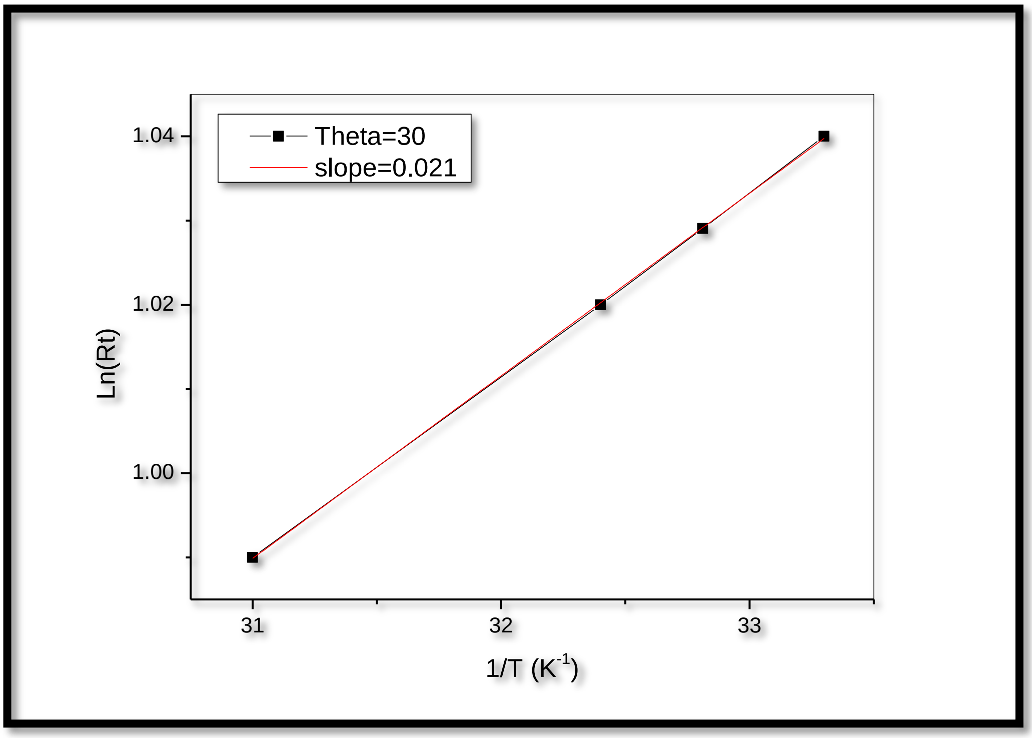


Figure (4.11) relationship between $Ln(Rt)$ and reciprocal temperature $(1/T)$ at angle polarization $\theta = 30$

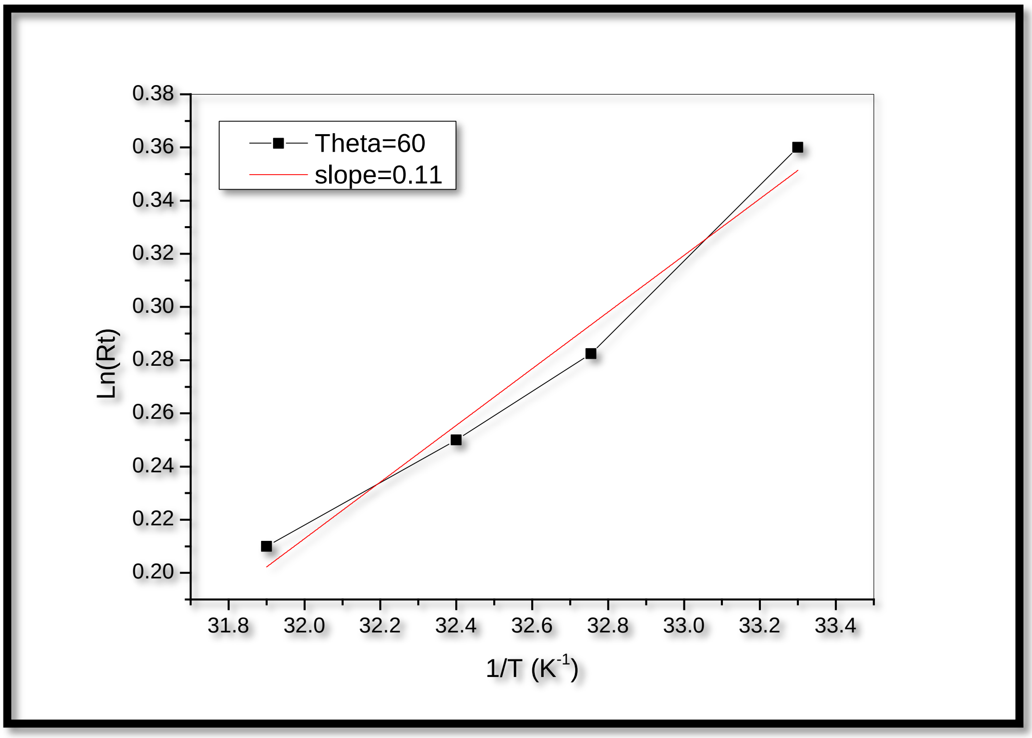


Figure (4.12) relationship between $Ln(Rt)$ and reciprocal temperature $(1/T)$ at angle polarization $\theta = 60$

4.5 Discussion

The current and voltage characteristic at variable temperature and constant irradiance angle was shown in the figures (4.5), The a data points lie on straight line through the origin for each characteristic in accordance with$I_{ph} = \frac{A}{d}\Delta\sigma v$, Where A is cross section of the current path and d is the distance between the electrical and σ is the conductivity from which the conductivity has been calculated, The slope of each characteristic depends on the irradiance, the relation between the photo current and irradiance of a constant voltage with varying temperature also has been considered.

The current – irradiance characteristic is shown in the figure (4.6), According to $\emptyset = \emptyset_0 D \cos^2(\text{theta})$ where $\emptyset_0$is irradiance without polarization and D is transparency when the polarization planes are parallel.

As expected the photocurrent increases with increasing irradiance however the characteristic are not perfectly linear the slope are rather decrease with increasing irradiance.

4.6 Conclusion

From the results obtained in section (4.4) it is clear that the energy gab and conductivity is equal to $E_g = 0.12eV, 0.22eV$ and $\sigma = 0.245\Omega^{-1}m^{-1}$

4.7 Recommendation

The electric oven devices sufficient not enough to study the calculating of energy gabE_g in semiconductors material, I hope if another one do that with good oven without lose in temperature.

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