



**Sudan University of Science and
Technology
College of Graduate Studies**



Identification of the Optical Properties of Low-Density Polyethylene

تحديد الخصائص البصرية لبولي ايثيلين منخفض الكثافة

**A dissertation Submitted as Partial Fulfillment of the Requirements for
the Degree of Master of Science in Physics.**

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الآية

((إِقْرَأْ بِإِسْمِ رَبِّكَ الَّذِي خَلَقَ * خَلَقَ الْإِنْسَانَ

مِنْ عَلَقٍ * إِقْرَأْ وَرَبُّكَ الْأَكْرَمُ * الَّذِي عَلَّمَ

بِالْقَلَمِ * عَلَّمَ الْإِنْسَانَ مَا لَمْ يَعْلَمْ))

صدق الله العظيم

Dedication

To my parents

To my husband, daughter and son

To my sisters and brothers

For every one who paved the knowledge way to me

Acknowledgments

I thank Almighty God for giving my grace and the Sudan University of Science and technology college of graduate Studies to endure until the end Dr, Faiz Mohammed Bader and Dr. Ali Abdel Rahman Saeed, my supervisors for their hard work and guidance throughout this entire thesis process and for believing in my abilities. I have learned so much. Thanks very much for a great experience.

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Abstract

In this work, low density polyethylene (LDPE) films were prepared with different thicknesses from (0.14, 0.15, 0.16, 0.18) $\times 10^{-2}$ mm. The optical properties such as absorbance, transmittance, and reflectance were studied in order to find out coefficient of absorption, extinction coefficient, and refractive index for all films.

The results showed that the absorption increased by increasing the thickness of the films. The absorption coefficients were found to be equal to (2.511, 2.548, 2.410, 2.142) $10^2 m^{-1}$ respectively and extinction coefficients were found to be equal to (126.5, 128.37, 121.42, 107.91) 10^{-8} respectively. Then films have transmittance about (T=70.3-67.5%) in visible region. The refractive index were found to be equal (3.3, 3.5, 3.6, 3.6) respectively and reflectance (R=29.7-32.5%) at wavelength (632.8nm). Also the energy gaps (E_g) were found to be equal to ($E_g=3.969, 4.0, 4.02, 4.03$)eV respectively all LDPE samples .

المستخلص

في هذا العمل حُضِرَتْ شرائح من مادة البولي ايثيلين منخفض الكثافة (LDPE) بسماكات مختلفة (0.14-0.15-0.16-0.18) 10^{-2} م ودرست من خلالها الخصائص البصرية كالإمتصاصية والنفاذية و الإنعكاسية وفجوة الطاقة لحساب معامل الإمتصاص ومعامل الخمود ومعامل الإنكسار للشرائح المستخدمة .

أظهرت النتائج العملية أن الإمتصاصية تزيد بزيادة السمك للشرائح . كما وجد أن قيم معاملات الإمتصاص تساوي (2.511- 2.548- 2.410- 2.142) $10^{-2} m^{-1}$ على الترتيب وقيم معاملات الخمود تساوي (126.5-128.37-121.42-107.91) 10^{-8} على الترتيب. تمتلك الألواح نفاذية تتراوح قيمتها % (67.5-70.3) في منطقة الطيف المرئي أما قيم معاملات الإنكسار تساوي (3.3-3.5-3.6-3.6) والانعكاسية (R=29.7-32.5%) عند الطول الموجي (632.8nm). وُجِدَتْ فجوة الطاقة E_g وتساوي (3.969- 4.04, -4.02, 4.03) eV على الترتيب لجميع شرائح (LDPE) المستخدمة .

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Chapter One

Introduction

CHAPTER ONE

Introduction

1.1. Background

Low-density polyethylene (LDPE) is a thermoplastic made from the monomer ethylene. It was the first grade of polyethylene, produced in 1933 by Imperial Chemical Industries (ICI) using a high pressure process via free radical polymerization. Its manufacture employs the same method today.

LDPE has more branching (on about 2% of the carbon atoms) than high density polyethylene (HDPE), so its intermolecular forces (instantaneous-dipole induced-dipole attraction) are weaker, its tensile strength is lower, and its resilience is higher. Also, since its molecules are less tightly packed and less crystalline because of the side branches, its density is lower. LDPE contains the chemical elements carbon and hydrogen.

In this thesis some of the optical properties of low density of polyethylene (LDPE) were studied when preparing films.

Helium neon (He-Ne) laser (632.8nm .1mw) was used to investigate the absorption coefficient and other optical properties.

Also uv radiation (USB2000-ocean optics- (400-150) nm) was used to find out the energy gap by studying the absorption spectrum.

1.2. Objectives

The main objective to study of some of the optical properties of (LDPE) and energy gap.

The specific objectives include:

- Investigate the absorption coefficient.
- Calculate the refractive index and determined the dielectric by using the relation between them.
- Found out the band gap of LPDE by its absorption spectrum.

1.3. Dissertation Outline

The dissertation described in five chapters:

Chapter one is an introduction of the dissertation with brief background, objectives and dissertation lay out.

Chapter two refers to an overview of the LDPE material which includes chemical properties, and some application of LDPE. Also this chapter includes the band gap and physical properties such as thermal, optical, electrical and magnetic properties.

Chapter three is about material and method of the work, also how the samples were prepared.

Chapter four shows the results and dissection of all sample prepared.

Chapter five provides general conclusions and recommendations.

Finally the list of references is given at the end of the dissertation

Chapter Tow

Theoretical Background

CHAPTER TWO

Theoretical Background

2.1 Introduction

This chapter discusses the low-density polyethylene (LDPE) and physical properties. Also, this chapter discusses the structure of band gap and absorption edge.

2.2 Low-Density Polyethylene (LDPE)

Low-density polyethylene (LDPE) is a synthetic resin using a high-pressure process via free radical polymerization of ethylene and is therefore also called "high-pressure polyethylene".

Since its molecular chain has many long and short branches, LDPE is less crystalline than high-density polyethylene (HDPE) and its density is low.

It features light, flexible, good freezing resistance and impact resistance. LDPE is chemically stable. It has good resistance to acids except strongly oxidizing acid), alkali, salt, excellent electrical insulation properties.

Its vapor penetration rate is low. LDPE has high fluidity and cv process sability. It is suitable for being used in all types of thermoplastic processing processes, such as injection molding, extrusion molding, blow molding, rot molding, coating, foaming, thermoforming, hot-jet welding and thermal .

LDPE is principally used for making films. It is widely used in the production of agricultural film (mulching film and shed film), packaging film (for use in packaging candies, vegetables and frozen food), blown film for packaging liquid (for use in packaging milk, soy sauce, juice, bean curds and soy milk), heavy-duty packaging bags, shrinkage packaging film, elastic film, lining film, building use film, general purpose industrial packaging film and food bags.

LDPE is also widely used in the production of wire and cable insulation on sheath. Cross-linked LDPE is the main material used in the insulation layer of high-voltage cables. LDPE is also used in the production of injection molded products (such as artificial flowers, medical instruments, medicine and food packaging material) and extrusion-molded tubes, plates, pipes, wire & cable coatings and profiled plastic products. LDPE is also used for making blow molded hollow products such as containers for holding food, medicine, cosmetics and chemical products (Birley, Arthur W, 2012).

The first of the polyolefin, Low-Density Polyethylene (LDPE) was originally prepared some fifty years ago by the high-pressure polymerization of ethylene. Its comparatively low density arises from the presence of a small amount of branching in the chain (on about 2% of the carbon atoms). This gives a more open structure. Low-Density Polyethylene (LDPE) is the most useful and widely used plastic especially in dispensing bottles or wash bottles (Birley, Arthur W, 2012).

It is translucent to opaque, robust enough to be virtually unbreakable and at the same time quite flexible. Chemically LDPE is unreactive at room temperature although it is slowly attacked by strong oxidizing agents and some solvents will cause softening or swelling. It may be used at temperatures up to 95° Celsius for short periods and at 80° Celsius continuously. LDPE is ideally suited for a wide range of molded laboratory apparatus including wash bottles, pipette washing equipment, general purpose tubing, bags and small tanks. Dynalab Corp's plastic fabrication shop fabricates thousands of catalogue and custom LDPE products (Birley, Arthur W, 2012).

2.3 Physical Properties for (LDPE)

Tensile Strength 0.20 - 0.40 N/mm²

Notched Impact Strength no break kJ/m²

Thermal Coefficient of expansion 100 - 220 x 10⁻⁶

Max Cont Use Temp 65 °C

Density 0.917 - 0.930 g/cm³

Superior flexibility

Low melting point

High melt strength in combination with a relatively low melt viscosity

Excellent processability

Low gel levels

Good transparenc

2.4 Physical properties

2.4.1 Thermal properties

By “thermal property” is meant the response of a material to the application of heat. As a solid absorbs energy in the form of heat, its temperature will rise and its dimensions increase. The energy may be transported to cooler regions of the specimen if temperature gradients exist, and ultimately, the specimen may melt. Heat capacity, thermal expansion, and thermal conductivity are properties that are often critical in the practical utilization of solids (Somerton, wibur H,1992).

2.4.1.1 Heat capacity

A solid material, when heated, experiences an increase in temperature signifying that some energy has been absorbed. Heat capacity is a property that is indicative of a material’s ability to absorb heat from the external surroundings; it represents the amount of energy required to produce a unit

temperature rise. In mathematical terms, the heat capacity C is expressed as follows:

$$C = \frac{dQ}{dT} \dots\dots\dots (2.1)$$

Where dQ is the energy required to produce a dT temperature change. Ordinarily, heat capacity is specified per mole of material (e.g., J/mol-K, or cal/mol-K). Specific heat (often denoted by a lowercase c) is sometimes used; this represents the heat capacity per unit mass and has various units (J/kg-K, cal /g-K, Btu/lbm-F) (Somerton ,wibur H,1992).

There are really two ways in which this property may be measured, according to the environmental conditions accompanying the transfer of heat. One is the heat capacity while maintaining the specimen volume constant, the other is for constant external pressure, which is denoted C_p. The magnitude of C_p is always greater than however, this difference is very slight for most solid materials at room temperature and below (Somerton ,wibur H,1992).

2.4.1.2 Thermal Expansion

Most solid materials expand upon heating and contract when cooled. The change in length with temperature for a solid material may be expressed as follows:

$$\frac{l_f - l_0}{l_0} = \alpha_l (T_0 - T_f) \dots\dots\dots (2.2)$$

or

$$\frac{\Delta l}{l} = \alpha_l \Delta T \dots\dots\dots (2.3)$$

Where L_0 and L_f represent, respectively, initial and final lengths with the temperature change from T_0 to T_f . The parameter α_l is called the linear coefficient of thermal expansion; it is a material property that is indicative of the extent to which a material expands upon heating, and has units of reciprocal temperature [$(^{\circ}\text{C})^{-1}$ or $(^{\circ}\text{F})^{-1}$]. Of course, heating or cooling affects all the dimensions of a body, with a resultant change in volume. Volume changes with temperature may be computed from

$$\frac{\Delta V}{V} = \alpha_v \Delta T \dots\dots\dots (2.4)$$

Where V and V_0 are the volume change and the original volume, respectively, and α_v symbolizes the volume coefficient of thermal expansion. In many materials, the value of α_v is anisotropic; that is, it depends on the crystallographic direction along which it is measured. For materials in which the thermal expansion is isotropic, is approximately $3\alpha_l$ (Somerton ,wibur H,1992)) Ziman J,1967).

2.4.1.3 Thermal Conductivity

Thermal conduction is the phenomenon by which heat is transported from high to low-temperature regions of a substance. The property that characterizes the ability of a material to transfer heat is the thermal conductivity. It is best defined in terms of the expression

$$q = -k \frac{\Delta T}{\Delta X} \dots\dots\dots (2.5)$$

Where q denotes the heat flux, or heat flow, per unit time per unit area (area being taken as that perpendicular to the flow direction), k is the thermal conductivity, and dT/dx is the temperature gradient through the conducting

medium. The units of q and k are W/m^2 (Btu/ft²-h) and $W/m-K$ (Btu/ft-h-⁰F), respectively. Equation 1.5 is valid only for steady-state heat flow, that is, for situations in which the heats flux does not change with time. Also, the minus sign in the expression indicates that the direction of heat flow is from hot to cold, or down the temperature gradient (Somerton ,wibur H,1992).

2.4.2 Optical properties

2.4.2.1 Classification of Optical Processes

The wide-ranging optical properties are classified into a small number of general phenomena. The simplest group, namely reflection, propagation and transmission.

2.4.2.2 Optical Coefficients

The optical phenomena described in the previous section can be quantified by a number of parameters that determine the properties of the medium at the macroscopic level. The reflection at the surfaces is described by the coefficient of reflection or reflectivity. This is usually given the symbol R and is defined as the ratio of the reflected power to the power incident on the surface. The coefficient of transmission or transmissivity T is defined likewise as the ratio of the transmitted power to the incident power. If there is no absorption or scattering, then by conservation of energy we must have that:

$$R+T=1 \dots\dots\dots (2.6)$$

The propagation of the beam through a transparent medium is described by the refractive index n . This is defined as the ratio of the velocity of light in free space c to the velocity of light in the medium v according to:

$$n = \frac{c}{v} \dots\dots\dots (2.7)$$

The refractive index depends on the frequency of the light beam. This effect is called dispersion, and it, therefore, makes sense to speak of 'the' refractive index of the substance in question. The absorption of light by an optical medium is quantified by its absorption coefficient α . This is defined as the fraction of the power absorbed in a unit length of the medium. If the beam is propagating in the z-direction, and the intensity (optical power per unit area) at position z is $I(z)$, then the decrease of the intensity in an incremental slice of thickness dz is given by:

$$dI = -\alpha dz \cdot I(z) \dots\dots\dots (2.8)$$

This can be integrated to obtain Beer's law

$$I(z) = I_0 e^{-\alpha z} \dots\dots\dots (2.9)$$

Where I_0 is the optical intensity at $z = 0$. The absorption coefficient is a strong function of frequency, so that optical materials may absorb one colour but not another (Fox, Mark, 2002).

In the next section, we will explain how both the absorption and the refraction can be incorporated into a single quantity called the complex refractive index. Knowledge of this quantity enables us to calculate the reflectivity R , and hence the transmissivity T . This last point follows because the transmissivity of an absorbing medium of thickness L is given by:

$$T = (1-R_1) e^{-\alpha L} (1-R_2) \dots\dots\dots (2.10)$$

Where R_1 and R_2 are the reflectivity of the front and back surfaces respectively (Fox, Mark, 2002).

This formula applies to the transmission of light through an optical medium. The first and third terms on the right-hand side of eq. 2.10 account for the transmission of the front and back surfaces respectively, while the middle term gives the exponential decrease in intensity due to the absorption according to Beer's law. If the front and back surfaces have equal reflectivity R , as will usually be the case, then eq.2.10 simplifies to:

Given by:

$$T = (1-R)^2 e^{-\alpha l} \dots\dots\dots (2.11)$$

The absorption of an optical medium can also be sometimes quantified in terms of the optical density (O.D.). This is sometimes called the absorbance and is defined as:

$$O.D = -\log_{10} \frac{I(l)}{I_0} \dots\dots\dots (2.12)$$

Where l is the length of the absorbing medium. It is apparent from eq. 2.9 that the optical density is directly related to the absorption coefficient α through:

$$O.D = \frac{\alpha l}{\log_e(10)} = 0.434\alpha l \dots\dots\dots (2.13)$$

We will quantify the absorption by α instead of the optical density because it is independent of the sample (Fox, Mark, 2002).

2.4.2.3 The complex refractive index and dielectric constant

In the previous section, we mentioned that the absorption and refraction of a medium can be described by a single quantity called the complex refractive index. This is usually given the symbol \tilde{n} and is defined through the equation:

$$\tilde{n} = n + iK \dots \dots \dots (2.14)$$

The real part of \tilde{n} , namely n , is the same as the nonnal refractive index defined in eq. 2.7. The imaginary part of \tilde{n} , namely K , is called the extinction coefficient. As we will see below, K is directly related to the absorption coefficient α of the medium. The relationship between α and K can be derived by considering the propagation of plane electromagnetic waves through a medium with a complex refractive index. If the wave is propagating in the z -direction, the spatial and time dependence of the electric field is given by:

$$\varepsilon(z, t) = \varepsilon_0 e^{i(kz - \omega t)} \dots \dots \dots (2.15)$$

Where k is the wave vector of the light and ω is the angular frequency. ε_0 is the amplitude at $z = 0$. In a non-absorbing medium of refractive index n , the wavelength of the light is reduced by a factor n compared to the free space wavelength λ . k and ω are therefore related to each other through:

$$k = \frac{2\pi}{\lambda/n} = \frac{n \omega}{c} \dots \dots \dots (2.16)$$

This can be generalized to the case of an absorbing medium by allowing the refractive index to be complex:

$$\kappa = \tilde{n} \frac{\omega}{c} = (n + ik) \frac{\omega}{c} \dots\dots\dots (2.17)$$

On substituting eq. 2.17 into eq. 2.15, we obtain:

$$\varepsilon(z, t) = \varepsilon_0 e^{i(\tilde{n}\omega z/c - \omega t)} = \varepsilon_0 e^{-\kappa\omega z/c} e^{i(n\omega z/c - \omega t)} \dots\dots\dots (2.18)$$

This shows that a non-zero extinction coefficient leads to an exponential decay of the wave in the medium. At the same time, the real part of \hat{n} still determines the phase velocity of the wave front, as in the standard definition of the refractive index given in eq. 2.7.

The optical intensity of a light wave is proportional to the square of the electric field, namely $I \propto \varepsilon \dot{\varepsilon}$. We can, therefore, deduce from eq. 2.18 that the intensity falls off exponentially in the medium with a decay constant equal to $2(\kappa\omega/c)$. On comparing this to Beer's law given in eq. 2.9 we conclude that:

$$\alpha = \frac{2\kappa\omega}{c} = \frac{4\pi k}{\lambda} \dots\dots\dots (2.19)$$

Where λ is the free space wavelength of the light. This shows us that K is directly proportional to the absorption coefficient. We can relate the refractive index of a medium to its relative dielectric constant ε_r by using the standard result derived from Maxwell's equations:

$$n = \sqrt{\varepsilon_r} \dots\dots\dots (2.20)$$

This shows us that if n is complex, then ε_r must also be complex. We, therefore, define the complex relative dielectric constant $\tilde{\varepsilon}_r$ according to:

$$\tilde{\epsilon}_r = \epsilon_1 + \epsilon_2 \dots \dots \dots (2.21)$$

By analogy with eq. 2.20, we see that \tilde{n} and $\tilde{\epsilon}_r$ are related to each other through:

$$\tilde{n}^2 = \tilde{\epsilon}_r \dots \dots \dots (2.22)$$

We can now work out explicit relationships between the real and imaginary parts of \tilde{n} and $\tilde{\epsilon}_r$ by combining eqs 2.14, 2.21 and 2.22. These are:

$$\epsilon_1 = n^2 - k^2 \dots \dots \dots (2.23)$$

$$\epsilon_2 = 2nk \dots \dots \dots (2.24)$$

And

$$n = \frac{1}{\sqrt{2}} (\epsilon_1 + (\epsilon_1^2 + \epsilon_2^2)^{\frac{1}{2}})^{\frac{1}{2}} \dots \dots \dots (2.25)$$

$$k = \frac{1}{\sqrt{2}} (-\epsilon_1 + (\epsilon_1^2 + \epsilon_2^2)^{\frac{1}{2}})^{\frac{1}{2}} \dots \dots \dots (2.26)$$

This analysis shows us that n and k are not independent variables: if we know ϵ_1 and ϵ_2 we can calculate n and k , and *vice versa*. Note that if the medium is only weakly absorbing, then we can assume that k is very small so that eqs 2.25 and 2.26 simplify to:

$$n = \sqrt{\epsilon_r} \dots \dots \dots (2.27)$$

$$k = \frac{\epsilon_2}{2n} \dots \dots \dots (2.28)$$

These equations show us that the refractive index is basically determined by the real part of the dielectric constant, while the absorption is mainly determined by the imaginary part. This generalization is obviously not valid if the medium has a very large absorption coefficient (Fox, Mark, 2002).

The microscopic models that we will be developing throughout the book usually enable us to calculate ϵ_r , rather than n . The measurable optical properties can then be obtained by converting ϵ_1 and ϵ_2 to n and K through eqs 2.25 and 2.26. The refractive index is given directly by n , while the absorption coefficient can be worked out from K using eq. 2.18. The reflectivity depends on both n and K and is given by

$$R = \left| \frac{\tilde{n}-1}{\tilde{n}+1} \right|^2 = \frac{(n-1)^2+k^2}{(n+1)^2+k^2} \dots\dots\dots (2.29)$$

This formula gives the coefficient of reflection between the medium and the air (or vacuum) at normal incidence (Fox, Mark, 2002).

In a transparent material such as glass in the visible region of the spectrum, the absorption coefficient is very small. Equations 2.18 and 2.24 then tell us that K and ϵ_2 are negligible, and hence that both \tilde{n} and $\tilde{\epsilon}_r$ may be taken as real numbers. This is why tables of the properties of transparent optical materials generally list only the real parts of the refractive index and dielectric constant. On the other hand, if there is significant absorption, then we will need to know both the real and imaginary parts of \tilde{n} and $\tilde{\epsilon}_r$. (Fox, Mark, 2002) (Dresselhaus M,S,2001).

2.4.3 Electrical Properties

Solids show an amazing range of electrical conductivities. Electrical conductivity is the reciprocal of resistivity. Whereas resistivity is the property of solids to resist flow of electricity, conductivity is the property to conduct electricity.

The SI unit of resistivity is ohm meter. Since conductivity is the reciprocal of resistivity, thus its unit is reciprocal of ohm meter, i.e. $\text{ohm}^{-1} \text{m}^{-1}$. Conductivity is generally represented by Greek letter σ (sigma). The SI unit of conductivity is Siemens per meter, i.e. S/m (Bube R, 2012).

On the basis of magnitude of range of conductivities, i.e. from 10^{-20} to $10^7 \text{ohm}^{-1} \text{m}^{-1}$, solids can be classified into three types:

(a) Conductor: - Solids having magnitude of range of conductivities from 10^4 to $10^7 \text{ohm}^{-1} \text{m}^{-1}$ are classified as conductors. Metals are a good conductor of electricity. Silver has conductivity in the order of $10^7 \text{ohm}^{-1} \text{m}^{-1}$ is considered as a very good conductor.

(b) Insulator: - Solids having range of conductivity from 10^{-20} to $10^{-10} \text{ohm}^{-1} \text{m}^{-1}$ are considered as insulators.

(c) Semiconductor: - Solids having intermediate range of conductivity, i.e. from 10^{-6} to $10^4 \text{ohm}^{-1} \text{m}^{-1}$ are called semiconductors.

2.4.3.1 Conduction of Electricity in Metals:

Metals show electrical conductivity because of movement of electrons. Electrolytes show electrical conductivity because of movement of ions. Metals show electrical conductivity in solid and molten states both while electrolytes show electrical conductivity in molten state and aqueous solution (Bube R, 2012).

Conductivity in metals depends upon presence of unpaired electrons in their valence shell per atom. Electrons present in valence shell of metals are free to move and allow conducting electricity in metals (Bube R, 2012).

Energy level (atomic orbital) with electrons and vacant energy levels present in metals have if minute difference in energy they together are called energy band or simply band. The empty energy levels or unoccupied energy levels are known as conduction band also since they help in conduction of electricity.

When partially filled energy levels (atomic orbital) are too close or overlapped with unoccupied energy level or conduction band; electrons can easily flow between them under the electrical field. Because of flows of unpaired electrons from occupied energy level to conduction band metals conduct electricity (Bube R, 2012).

2.4.3.2 Conduction of electricity in Insulators:

In insulators, the difference in energy between occupied energy level and unoccupied energy level (conduction band) is higher because of which electrons do not flow from occupied energy band to the next higher unoccupied energy band resulting insulators do not conduct electricity as electrons do not flow

2.4.3.3 Conduction of electrical in Semiconductor:

In semiconductors like silicon and germanium, the energy gap between valence shell and conduction band is so smaller than electrons may jump from filled orbital to conduction band when putting under an electrical field. Because of this behavior, i.e. lower gap between valence band and conduction band semiconductor show the conduction of electricity (Bube R, 2012).

The conduction of electricity in semiconductors increases with increase in temperature. Elements such as silicon and germanium show such behavior and are called intrinsic semiconductors.

2.4.4 Magnetic Properties

Substance shows magnetic properties because of presence of electrons in them. Each electron in an atom behaves like a magnet because of its two types of motions - one is around their axis and other around the nucleus. Electrons in an atom because of charge over them and in motion continuously; possess small loop of current which shows the magnetic moment (Spaldin NA, 2010).

Substances are classified into five types on the basis of magnetic properties:

- Paramagnetic
- Diamagnetic
- Ferromagnetic
- Antiferromagnetic
- Ferrimagnetic

(a) Paramagnetism: Substances which are attracted slightly by magnetic field and do not retain the magnetic property after removal of magnetic field are called paramagnetic substances. For example O_2 , Cu^{2+} , Fe^{3+} , Cr^{3+} , Magnesium, molybdenum, lithium, etc.

Substances show paramagnetism because of presence of unpaired electrons. These unpaired electrons are attracted by magnetic field (Spaldin NA, 2010).

(b) Diamagnetism: Diamagnetic substances are just opposite to that of paramagnetic. Substances which are repelled slightly by magnetic field are called diamagnetic substances. For example; H_2O , $NaCl$, C_6H_6 , etc.

Diamagnetic substances are magnetized slightly when put under magnetic field but in the opposite direction.

Substances show diamagnetic property because of presence of paired electrons and no unpaired electron. Thus, pairing of electrons cancels the magnetic property (Spaldin NA, 2010).

(c) Ferromagnetism: Substances that are attracted strongly with a magnetic field are called ferromagnetic substances, such as cobalt, nickel, iron, gadolinium, chromium oxide, etc. Ferromagnetic substances can be permanently magnetized also.

Metal ions of ferromagnetic substances are randomly oriented in normal condition and substances do not act as a magnet. But when metal ions are grouped together in small regions, called domains, each domain acts like a tiny magnet and produce a strong magnetic field, in such condition ferromagnetic substance act like a magnet. When the ordering of domains in group persists even after removal of magnetic field a ferromagnetic substance becomes a permanent magnet (Spaldin NA, 2010).

(d) Antiferromagnetism: Substances in which domain structure are similar to ferromagnetic substances but are oriented oppositely, which cancel the magnetic property are called antiferromagnetic substances and this property is called antiferromagnetism. For example; MnO.

(e) Ferrimagnetism: Substances which are slightly attracted in magnetic field and in which domains are grouped in parallel and anti-parallel direction but in unequal number, are called ferromagnetic substances and this property is called ferrimagnetism. For example, magnetite (Fe_3O_4), ferrite (MgFe_2O_4), ZnFe_2O_4 , etc (Spaldin NA, 2010).

Table (2.1): Physical Properties of (LDPE).

Physical properties	Value
Density	0.92g cm ⁻³
Refractive index	1.51
Coefficient of thermal expansion	100-200 ×10 ⁻⁶ K ⁻¹
Specific heat	1900-2300 JK ⁻¹ kg ⁻¹
Thermal conductivity	0.33Wm ⁻¹ K ⁻¹
Dielectric constant	2.2-2.35
Tensile strength	5-25MPa

2.5 Band gap

The term “band gap” refers to the energy difference between the top of the valence band to the bottom of the conduction band (See Figure 1.1); electrons are able to jump from one band to another. 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 band gap energy.^{1,2} A diagram illustrating the band gap is shown in Figure 1.1.

Measuring the band gap is important in the semiconductor and nanomaterial industries. The band gap energy of insulators is large (> 4eV), but lower for semiconductors (< 3eV). The band gap properties of a semiconductor can be controlled by using different semiconductor alloys (Dharama J, Pasl A, & Shelton C, T, 2009).

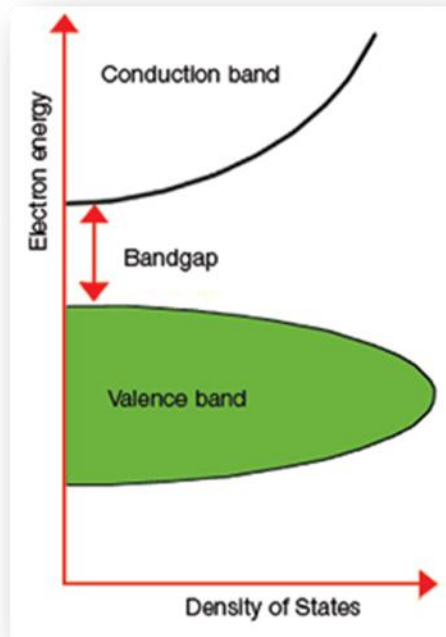


Figure 2.1. Explanation of band gap energy.

2.5.1. Insulator Energy Bands

Most solid substances are insulators, and in terms of the band theory of solids, this implies that there is a large forbidden gap between the energies of the valence electrons and the energy at which the electrons can move freely through the material (the conduction band) (nave rod ,2000).

Glass is an insulating material which may be transparent to visible light for reasons closely correlated with its nature as an electrical insulator. The visible light photons do not have enough quantum energy to bridge the band gap and get the electrons up to an available energy level in the conduction band. The visible properties of glass can also give some insight into the effects of "doping" on the properties of solids. A very small percentage of impurity atoms in the glass can give it color by providing specific available energy levels which absorb certain colors of visible light. The ruby mineral (corundum) is aluminium oxide with a small amount (about 0.05%) of

chromium which gives it its characteristic pink or red color by absorbing green and blue light (nave rod ,2000).

While the doping of insulators can dramatically change their optical properties, it is not enough to overcome the large band gap to make them good conductors of electricity. However, the doping of semiconductors has a much more dramatic effect on their electrical conductivity and is the basis for solid-state electronics (nave rod, 2000).

2.5.2. Semiconductors band gap

For intrinsic semiconductors like silicon and germanium, the Fermi level is essentially halfway between the valence and conduction bands. Although no conduction occurs at 0 K, at higher temperatures a finite number of electrons can reach the conduction band and provide some current. In doped semiconductors, extra energy levels are added.

The increase in conductivity with temperature can be modeled in terms of the Fermi function, which allows one to calculate the population of the conduction band.

2.5.3. Conductor energy bands

In terms of the band theory of solids metals are unique as good conductors of electricity. This can be seen to be a result of their valence electrons being essentially free. In the band theory , this is depicted as an overlap of the valance band and the conduction band so that at least a fraction of the valence electrons can move through the material nave rod, 2000).

Chapter Three

Experimental Part

CHAPTER THREE

Experimental Part

3.1. Introduction

This chapter discusses the general idea, experimental steps, samples preparations, materials and method.

3.2. Samples preparation

Low-density polyethylene (LDPE) in the form of grain was used to produce films from it. Films were prepared as follows:

A layer of tin on the hot plate was put after switch on the hot plate until to molting point. The 15g of the material in the form granules was added to them, and then another layer of tin was put in that metal and was compressed by a hot soft plate. After 1 minute the two layers of tin were separated from each other.

This experiment was repeated many times to gain for different thickness of the sample. Then these samples were cated by different sizes.

3.3. Instruments

Prepared layers of (LDPE)

He-Ne laser (632.8nm)

USB 2000 (ocean optics (400-150nm))

Multimeter

Computer

Optical Detector



Fig (3,1) LDPE in the form of grain



Fig (3.2) multimeter



Fig (3.3) USB 2000 (ocean optics (400-150nm))

3.4 Setup

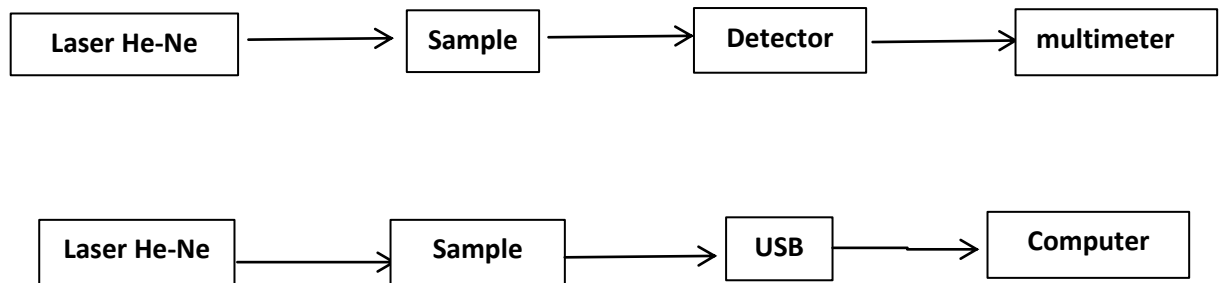


Fig (3.4) schematic diagram of the experimental setup

3.5 Method

The method of the experimental part included two parts:

Part 1: to get the absorbed coefficient (α)

Part 2: to get the energy gap (E_g)

Part 1 Absorption Coefficient (α)

To determine the absorption coefficient, the sample was placed on the holder and highlighted the laser light ($\lambda= 632.8\text{nm}$) on the sample. And then the optical detector which was put behind the sample was connected to malt meter to calculate the intensity of light falling on the sample

Part 2 Energy gap (E_g)

The laser light was highlighted on the sample, which was connected with a detector. The wire from the fiber was connected with it and arrived from the other side with a computer.

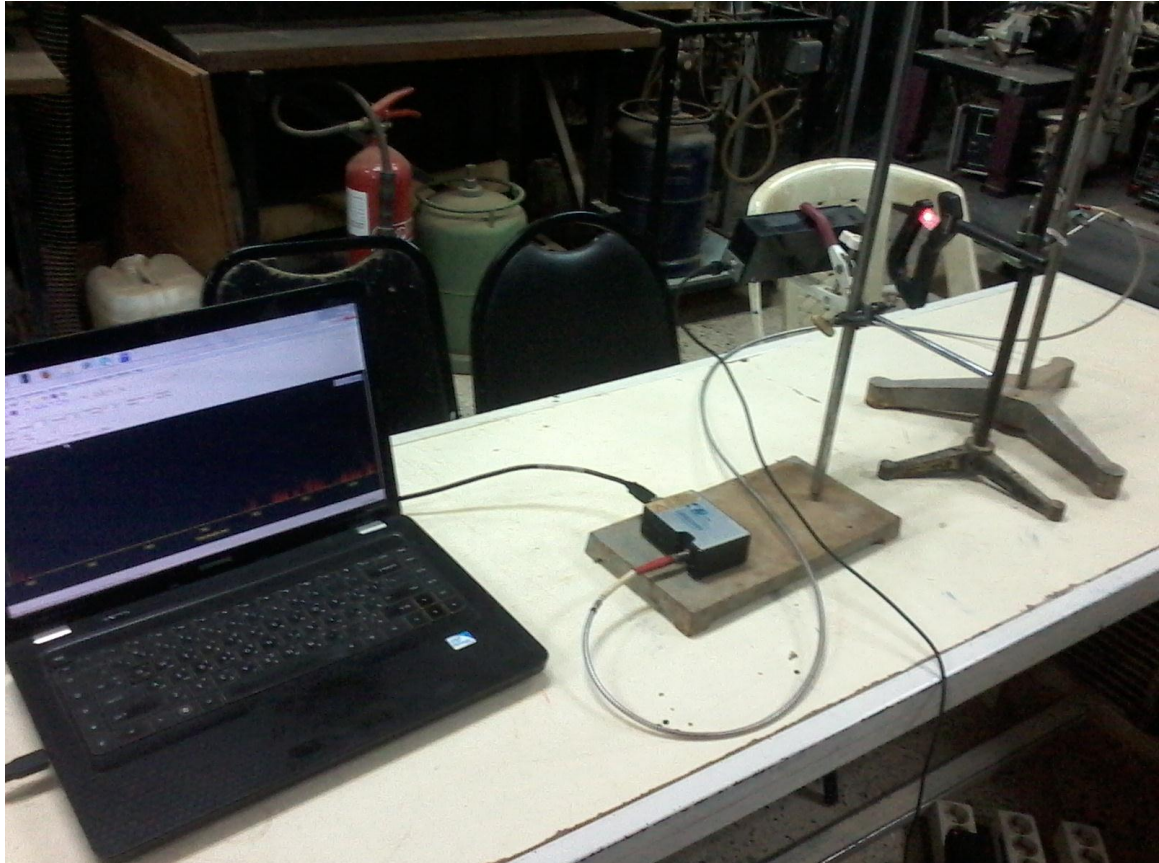


Fig (3.5) the experimental setup.

Chapter Four

Results and Discussion

CHAPTER FOUR

Results and Discussion

4.1 Introduction

This chapter shows and discusses all the elements set in the experimental part and how the results are to be gained with the general comments.

4.2 Results and Discussion

4.2.1 Results

Table (4.1): below shows the results of transmittance intensity of the four samples with iridium by the layer

$$I_0 = 0.425A$$

Samples	Thickness (mm)	Intensity (A)	Ln I/I ₀
Sample1	0.14	0.299	-0.352
Sample2	0.15	0.290	-0.382
Sample3	0.16	0.289	-0.385
Sample4	0.18	0.287	-0.393

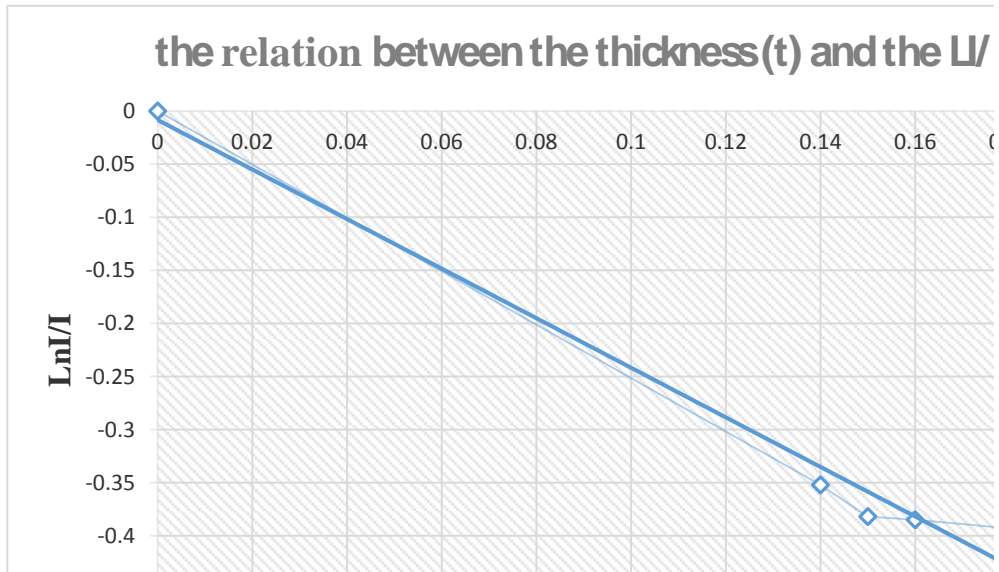


Fig (4.1)` The relation between the thickness (t) and the $\ln I/I_0$.

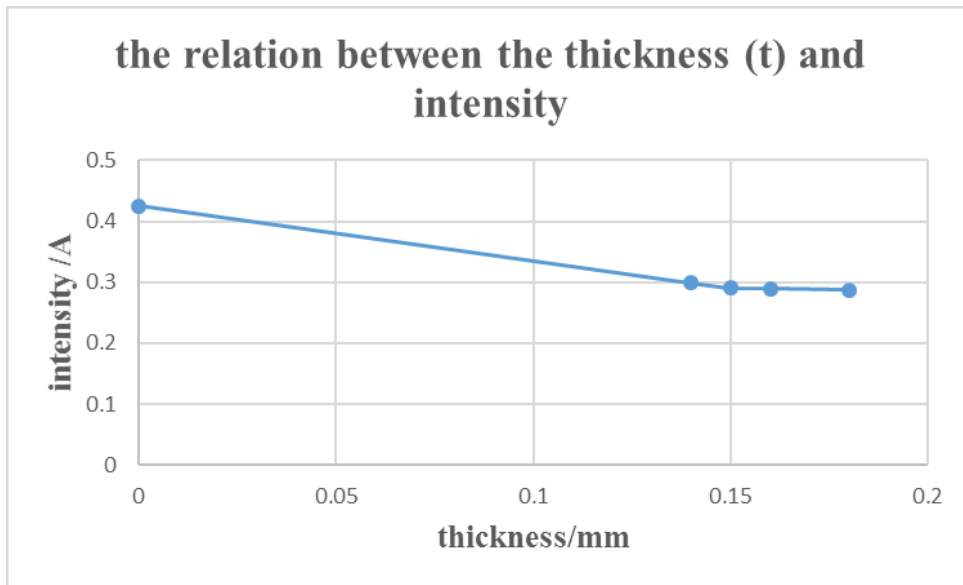


Fig (4.2): Intensity curve was achieved bear Lambert's law.

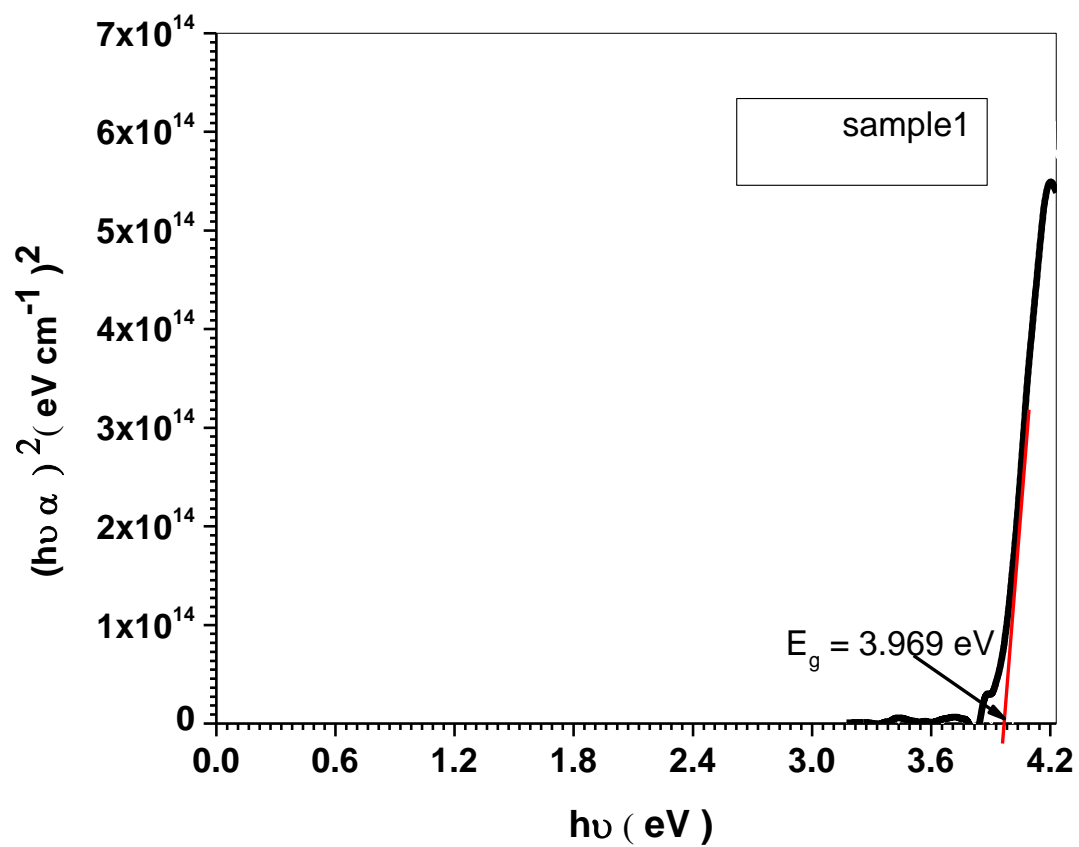


Fig (4.3): energy gap was founded that for sample 1

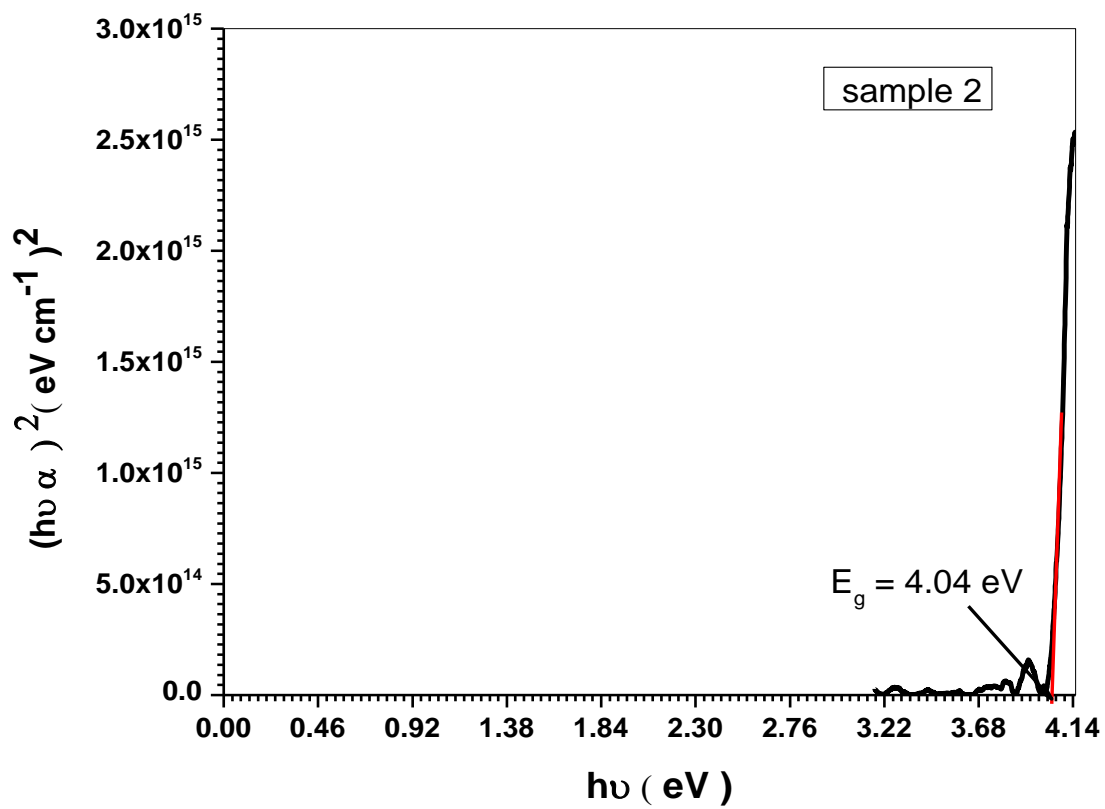


Fig (4.4): energy gap was founded that for sample 2

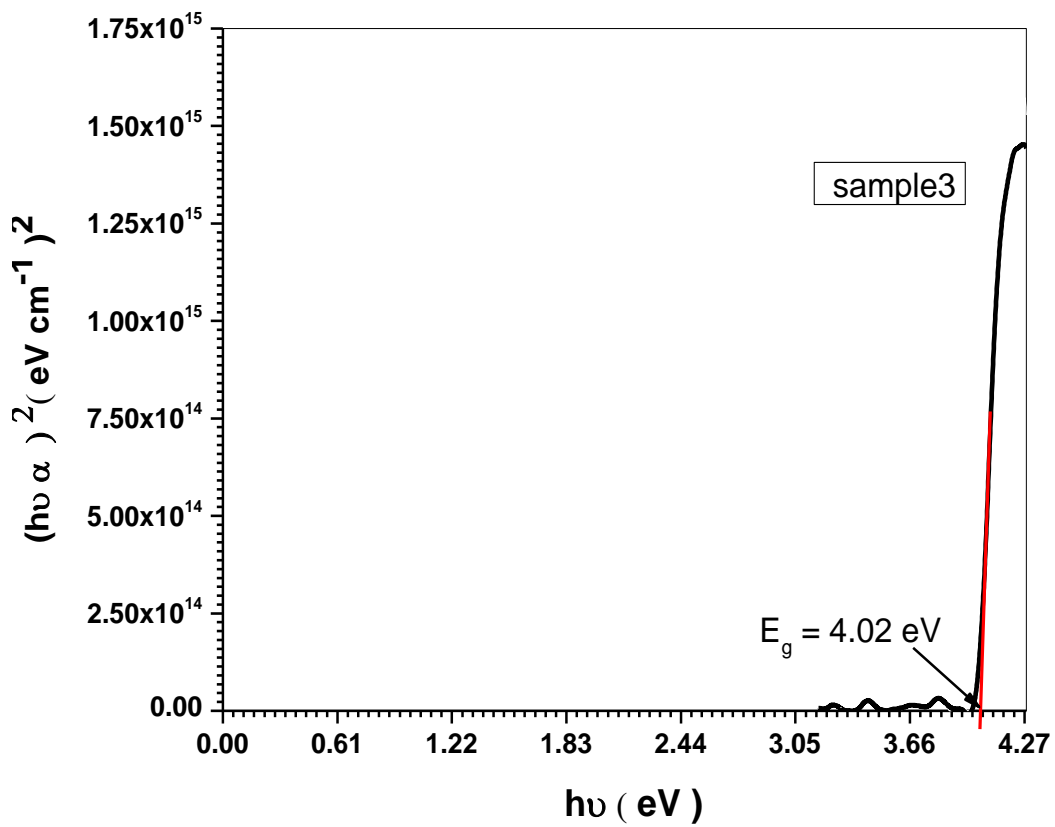


Fig (4.5): energy gap was founded that for sample 3

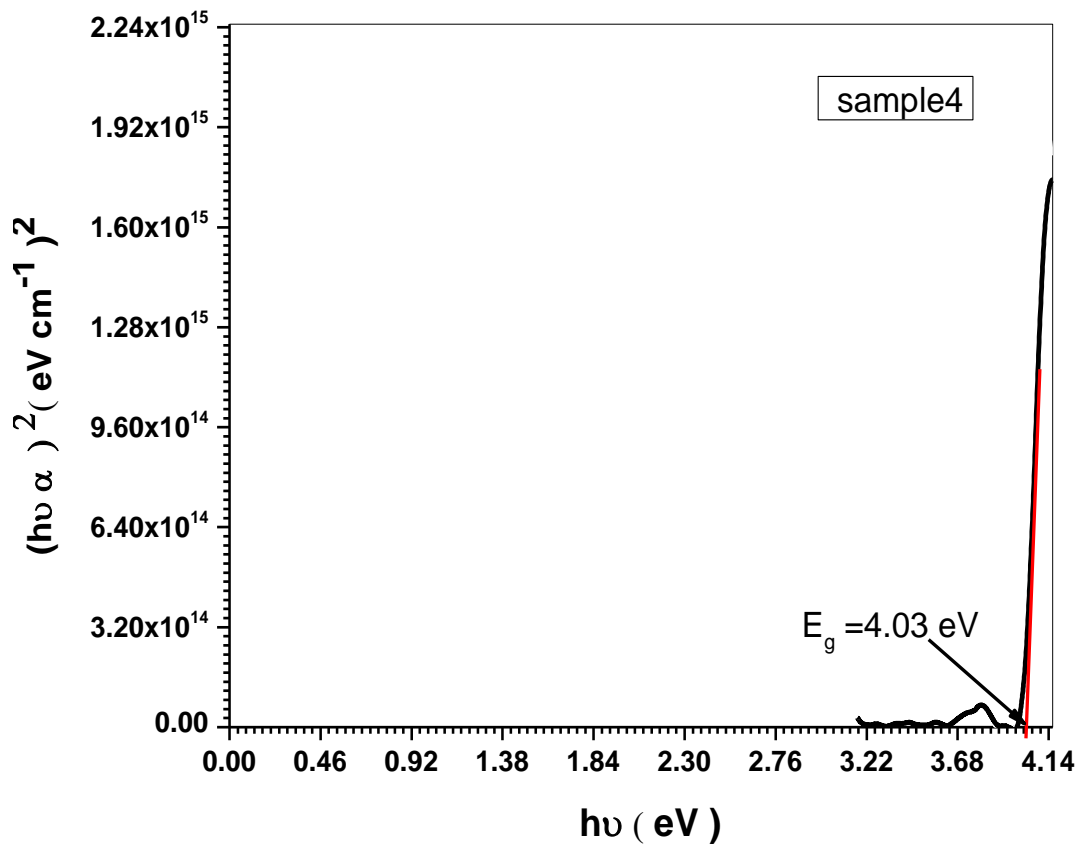


Fig (4.6): energy gap was founded that for sample 4

Table (4.2): The table below illustrates the calculation of the coefficients κ , n , (ϵ), and energy gap (E_g)

Samples	Absorption coefficient(α) 10^2 m^{-1}	Coefficient (K) 10^{-8}	Refraction index (n)	Dielectric (ϵ)	Energy gap (E_g) ev
Sample1	2.511	126.5	3.3	10.8	3.969
Sample2	2.558	128.37	3.5	12.25	4.04
Sample3	2.410	121.42	3.6	12.96	4.02
Sample4	2.142	107.91	3.6	12.96	4.03

4.2.2 Discussion

Part 1

- Four films of polyethylene .in different thickness (0.14-0.18) m were prepared.
- Optical properties as reflection, refraction and absorption were studied, in order to calculated the optical constants
- The absorption coefficient (α) was calculated which increased with an increase in thickness according to the account relationship (2.9)

$$I(z) = I_0 e^{-\alpha z} \dots\dots\dots (4.1)$$

- The Extinction coefficient (K) was calculated, which increases with an increase in the absorption coefficient and wavelength according to the account relationship (2.19)

$$\alpha = \frac{2\kappa\omega}{c} = \frac{4\pi k}{\lambda} \dots\dots\dots (4.2)$$

- Refractive index (n) was calculated by application of this equation (2.29)

$$R = \left| \frac{\tilde{n}-1}{\tilde{n}+1} \right|^2 = \frac{(n-1)^2+k^2}{(n+1)^2+k^2} \dots\dots\dots (4,3)$$

- Dielectric (ϵ) was calculated according to the account relationship (2.26)

$$n = \sqrt{\epsilon_r} \dots\dots\dots (4.4)$$

Part 2

- Energy gap was founded that approximately equal to ($E_g=4.01\text{ev}$)
- As in fig (4,1) and so draw tangent curve when the basic region of the absorption, which increased with increase in absorption coefficient and liner tangent cuts the x-axis representing the incident photon energy at the point which represents energy gap .The relation between absorption coefficient and optic band gap for direct transition ($K=0$) is given by equation (Hershberger,S 2000)

$$\sqrt{\alpha h\nu} = B(h\nu - E_g^{opt}) \dots\dots\dots (4.5)$$

And for indirect transition ($K \neq 0$) the relation becomes

$$\alpha (h\omega) = \frac{(\hbar\omega - E_g)^2}{\hbar\omega} \dots\dots\dots (4.6)$$

Chapter Five

Conclusion and Recommendation

CHAPTER FIVE

Conclusion and Recommendation

5.1 Conclusion:

Low-density polyethylene films were prepared with different thicknesses ranging from (0.14-0.15-0.16-0.18) 10^{-2} mm. The optical properties were studied, such as absorptive, transmittance, and reflective in order to find out the optical properties, were the results showed the following Absorption coefficient $\alpha = (2.511-2.548-2.410-2.142)\times 10^{-2} \text{ m}^{-1}$ respectively, Extinction coefficient $k = (126.5-128.37-121.42-107.91)\times 10^{-8}$ respectively, then have transmittance about (T=70.3-67.5)% and Reflective (R=29.7-32.5)% at wavelength (632.8nm). The refractive index were found to be equal $n = (3.3-3.5-3.6-3.6)$ respectively, also Dielectric $\epsilon = (10.8-12.25-12.25-12.9)$ respectively, and Energy gap $E_g (3.9-4.04-4.02-4.03)\text{eV}$ respectively.

5.2 Recommendation:

LPDE can be painted and used in applied visual studies and in architectural processes such as decoration for its shape

Also can be made thin which contribute to the protection of the system of pressure, humidity, chemicals and corrosion as an insulating material.

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