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# تأثير سمك الغشاء على الخواص البصرية لأغشية $Ta_2O_5$ النانوية

بحث مقدم

**إلى مجلس كلية التربية للعلوم الصرفة في جامعة بابل وهو جزء من متطلبات نيل درجة الدبلوم العالي تربية / فيزياء المواد وتطبيقاتها**

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بإشراف

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Republic of Iraq
Ministry of Higher Education & Scientific Research
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College of Education for Pure Sciences
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# *Effect of Film Thickness on Optical Properties of $Ta_2O_5$ Nanofilms*

**A research**

**Submitted to the Council of the College of Education for Pure Sciences of University of Babylon in Partial Fulfillment of the Requirements for the Degree of Higher Diploma Education/ Physics of Materials and its Applications.**

By

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**2021 م** **1443 هـ**

# Abstract

The result of the thin film of Tantalum oxide, $Ta_2O_5$, was prepared by thermal evaporation method were taken. The research dealt with the effect of thickness on the optical properties of the nanofilm in order to know the extent to which the optical properties and the energy gap change when the thickness of the film changes.

The nanofilm was prepared with a thickness of (20-100) and the results showed that the nano-thin film (Tantalum oxide) has good absorption in the infrared region in the range of wavelengths (210-230) nm for all thicknesses,[88].

While the transmittance decreases with increasing thickness of the Tantalum oxide thin film, and the highest value of the spectral transmittance through the nanofilm is obtained at the lengths (220-1000) nm, while the minimum transmittance is at the wavelengths region ranging between (210-220) nm.

The reflectivity decreases with the increase in the wavelength of the thickness of the nano-thin film, and the lowest value of the reflectivity is obtained at (210) nm, and the highest value of the reflectivity is 21% when the wavelengths range between (230-240) nm for thickness from (60-80-100) respectively. The absorption coefficient has values greater than $10^4$ $cm^{-1}$ indicating direct transmission.

The maximum value of the damping coefficient was at wavelength 200 nm, but it has the same value at wavelengths ranging from (600-100) nm.

The highest refractive index at thickness (20-40) nm, while increasing between (60-100) nm. The real differences of the dielectric constant are between 1.47 (at wavelength 224 nm) and about 6.9 (at wavelength 210 nm).

The energy loss referring to the imaginary dielectric constant has a maximum value of 1.98 when the wavelength is about 218 nm. The energy band gap can be controlled by controlling the thickness of the nano-thin film.

Thus, the results showed that increasing the thickness had a direct effect on all the studied optical properties.

# Contents

# Symbols

| Symbol | Physical Meanings |
|---|---|
| **A** | Absorbance |
| **α** | Absorption Coefficient |
| **h** | Blank Constant |
| **e** | Charge of Electron |
| **N** | Complex Refractive Index |
| **B** | Constant depended on type of material |
| **θ** | Diffraction Angle |
| $E_g$ | Energy Gap |
| **r** | Exponential constant |
| $K_o$ | Extinction Coefficient |
| **εi** | Imaginary Part of Dielectric Constant |
| **d** | Inter-planar distant |
| $E_P$ | Energy of an absorbed or emitted phonon |
| **hυ** | Photon Energy |
| **εr** | Real Part of Dielectric Constant |
| **R** | Reflectance |
| **n** | Refractive Index |
| **Ta** | Tantalum |
| $Ta_2O_5$ | Tantalum Oxide |
| **T** | Transmittance |
| **UV** | Ultra Violet Spectrum |
| **c** | Velocity of Light |
| **K** | Wave Vector |
| **λ** | Wavelength |
| $I_o$ | Incident Intensity of Light |
| **I** | Transmitted Intensity |

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# بسم الله الرحمن الرحيم

(إِنَّ فِي خَلْقِ السَّمَاوَاتِ وَالْأَرْضِ وَاخْتِلَافِ اللَّيْلِ وَالنَّهَارِ وَالْفُلْكِ الَّتِي تَجْرِي فِي الْبَحْرِ بِمَا يَنْفَعُ النَّاسَ وَمَا أَنْزَلَ اللَّهُ مِنَ السَّمَاءِ مِنْ مَاءٍ فَأَحْيَا بِهِ الْأَرْضَ بَعْدَ مَوْتِهَا وَبَثَّ فِيهَا مِنْ كُلِّ دَابَّةٍ وَتَصْرِيفِ الرِّيَاحِ وَالسَّحَابِ الْمُسَخَّرِ بَيْنَ السَّمَاءِ وَالْأَرْضِ لَآيَاتٍ لِقَوْمٍ يَعْقِلُونَ ﴿١٦٤﴾)

**صدق الله العلي العظيم**

**سورة البقرة - ١٦٤-**

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We members of Examining Committee, certify that after reading this research entitled ''***Effect of film Thickness on Optical Properties of $Ta_2O_5$***'' submitted by (***Reem Ahmed Habeeb***) , and examining the student in its contents, in our opinion it is adequate for the partial fulfillment of the requirement for the Degree of Higher Diploma Education/ Physics of Materials and its Applications.

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# Dedication

***To…***

***My dear parents ; Father And Mother,***

***My dear husband Haidar***

***And my children; Hussain,Ali &Mohamad***

***My best friend; Raghda***

***To my teachers...***

***Who provide me with the keys to success***

***The martyrs of Iraq…***

***with all my love and appreciation.***

Reem✍

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At the beginning, thanks Allah for what I have now…

I would like to express my special thanks to **Prof. Dr. Shurooq Sabah Abid Al-Abbas** for her supervision.

Without her endless support and help this work could not be achieved.

And all great thankfull for **Dr. Addnan H. Al-Aarajiy**.

I can not forget my beloved friends; their encouragement was my motivation. I also would like to thank my College. I apologize for whom I miss to mentioning. I wish success to all.

**Reem** ✍

# الخلاصة

تم اخذ نتائج الغشاء الرقيق لأوكسيد التنتالوم النانوي $Ta_2O_5$ المحضر بطريقة التبخير الحراري حيث تناول البحث تأثير السمك على الخواص البصرية للغشاء النانوي وذلك لمعرفة مدى تغير الخواص البصرية وفجوة الطاقة عند تغير سمك الغشاء.

تم تحضير الغشاء النانوي بسماكة (100-20) وقد أظهرت النتائج أن الفيلم النانوي الرقيق (اوكسيد التنتالوم ) يتمتع بامتصاص جيد في المنطقة التحت الحمراء في نطاق الأطوال الموجية (210-230) نانومتر لجميع الأسماك،[88].

بينما النفاذية تقل مع زيادة السمك للغشاء النانوي الرقيق لاوكسيد التنتالوم وان اعلى قيمة لنفاذية الطيف خلال الغشاء النانوي نحصل عليها عند الاطوال (1000-220) نانومتر، اما الحد الأدنى للنفاذية فهو عند منطقة الاطوال الموجية التي تتراوح مابين(220-210) نانومتر.

تقل الانعكاسيه مع زيادة الطول الموجي لسمك الغشاء النانوي الرقيق وان اقل قيمة للانعكاسية نحصل عليها عند (210)نانومتر وان اعلى قيمة للانعكاسيه هي 21% عندما تتراوح الاطوال الموجية مابين (240-230) نانومتر للاسماك من(100-80-60)نانومتر على التوالي.معامل الامتصاص له قيم تزيد عن $10^4$ سم$^{-1}$ مما يشير إلى انتقال مباشر.

كانت القيمة القصوى لمعامل الخمود عند الطول الموجي 200 نانومترولكن لها نفس القيمة عند الاطوال الموجية التي تتراوح مابين (1000-600) نانومتر.

كان أعلى معامل انكسار عند قيم الأسماك (20و40)نانومتر بينما يزداد مابين (100-60)نانومتر الاختلافات الحقيقية لثابت العازل بين1.47( عند الطول الموجي 224 نانومتر) وحوالي6.9 (عند الطول الموجي 210 نانومتر).

فقدان الطاقة الذي يشير إلى ثابت العزل الكهربائي التخيلي له القيمة القصوى 1.98 عندما يكن الطول الموجي حوالي 218 نانومتر يمكن التحكم في فجوة نطاق الطاقة عن طريق التحكم بسمك الغشاء النانوي الرقيق.

وبذلك فقد أظهرت النتائج أن زيادة السمك كان له تأثير مباشر على جميع الخواص البصرية المدروسة.

## 1.1 Introduction

A thin film material with a high transparency in the visible and soft UV range, low leakage current and high dielectric constant could widely benefit many applied science and technology branches. Tantalum oxide has been identified as such a candidate material based on these electric and optical properties. Consequently, the charge transport mechanisms [1], dielectric function, and optical constants [2] of $Ta_2O_5$ have been investigated. Due to its dielectric behaviour and good chemical and thermal stability, it has been used as a discrete capacitor insulator in electronic applications, as an oxygen sensor, and as a high-temperature resistor. A recent study of its ionic conductivity [3] has also demonstrated its performance as an ionic membrane or a solid electrolyte in multilayered electrochromic devices [4]. This structure is competitive with polymers [5] and other inorganic ionic conductors [6]. Further understanding of the relationship between $Ta_2O_5$'s ionic conductivity and its ability to maintain an acceptable optical transmittance are necessary to develop more efficient electrochromic devices. Improved $Ta_2O_5$ coatings properties require depth-dependent characterization of the coatings as a function of the preparation method employed. These include thermal evaporation [7], electron beam evaporation [2], UV-photo CVD [8], plasma-enhanced CVD [9], pulsed laser deposition [10] and RF magnetron sputtering [11]. Among these deposition techniques, the latter is often used because process variables can be independently controlled. This control on $Ta_2O_5$ film synthesis lets us vary its microstructure and composition, which affect its ionic conductivity and optical properties. Thus, reactive sputter deposition is a good choice to study these features in function of deposition parameters. This paper reports on deposition, and electric and optical characterization of RF sputtered $Ta_2O_5$ films. A kinetics model of film growth depending on deposition parameters is suggested by fitting the experimental data. Optical characterization provides the refractive index, absorption coefficient, thickness and optical gap of the films. Measurements of leakage electric current at high fields reveal steady state conductivity and Poole – Frenkel behaviour. $Ta_2O_5$ cationic conductivity is characterized by applying cyclic voltammetries to electrochromic semistructures in liquid electrolyte and calculating the transferred ionic charge. The results from electrochemical measurements appear correlated with optical features, and an explanation based on an Effective Medium Approximation (EMA) accounts for pores as void inclusions, as reported in other studies [12]. These results are of great interest in electrochromic applications. Experimental details Tantalum oxide films have been deposited at room temperature by means of reactive magnetron sputtering. $Ta_2O_5$ target in an atmosphere of oxygen and argon [13].

## 1.2 Literature review:

**S. Ezhilvalavan, *et al*. in (1999) [14]** Investigated the electrical properties of reactively sputtered $Ta_2O_5$ thin films with Ta as the bottom electrodes were investigated. Present study demonstrate the use of Ta as a potential bottom electrode material to replace the precious metal electrodes and to simplify the fabrication process of the $Ta_2O_5$ storage capacitor.

**C. Bartic ,*et al*. in(2002) [15]** Studied the use of $Ta_2O_5$ as gate dielectric material for organic thin-film transistors. $Ta_2O_5$ has already attracted a lot of attention as insulating material for VLSI applications. We have deposited $Ta_2O_5$ thin-films with different thickness by means of electron-beam evaporation. Being a relatively low-temperature process, this method is particularly suitable for organic thin-film transistor fabrication on plastic substrates. Deposition and patterning are achieved in one step by the use of shadow masks. The dielectric can be evaporated on top of the semiconducting layer. In this way a large variety of structures can be realized. The properties of the dielectric material as well as the operation of the organic transistors with a $Ta_2O_5$ gate dielectric are discussed.

**C. Corbella , *et al.* in (2003) [13]** Thin films of $Ta_2O_5$ were deposited at room temperature by RF-magnetron reactive sputtering from a tantalum oxide target. provides an approach for quantifying the ionic conductivity of the deposited material, and its probable correlation with porosity. Comparing these structural characteristics to the related optics, a relationship between ion conduction and porosity was found. Variation of process parameters to achieve optimal performance offers the industry new possibilities to use these films as solid electrolytes for electrochromic devices built on glass substrates or polymers.

**W. Chang, *et al*. in (2004) [16]**Investigated the amorphous oxide thin films consisting of $SiO_2/Ta_2O_5$ multilayers with high-reflectance as well as low-loss quality were grown on a glass substrate by ion beam sputtering. Using both the rotating anode and synchrotron radiation x-rays, we have characterized the thickness and density of the thin layers and the interface roughness from the x-ray reflectivity profiles. Concerning possible impurities contained in the coating layers, the total reflection x-ray fluorescence spectra showed that the major 3d-element contamination of the films within the minimum detection limit of this work, $6\times10^{10}$ atoms/cm$^2$, was Fe.

**D.R.M. Crooks, *et al*. in (2006) [17]** Previous studies have quantified the mechanical dissipation associated with dielectric thin films formed from alternating layers of ion-beam-sputtered $SiO_2$ and $Ta_2O_5$ and concluded that such dissipation could lead to potentially significant levels of thermally induced displacement noise in proposed advanced gravitational wave detectors.

In addition, we report our measurements of the elastic properties of $Al_2O_3/Ta_2O_5$ and $SiO_2/Ta_2O_5$ coatings, as the film elastic properties can significantly influence expected levels of coating thermal noise. In summary, our analysis suggests that $SiO_2/Ta_2O_5$ coatings currently present the best option for future detectors from a thermal noise standpoint.

**T.J. Bright,** ***et al*****. in (2013) [18]** Studied the dielectric functions are obtained for amorphous and nanocrystalline thin film samples of $Ta_2O_5$ deposited by magnetron sputtering. These sputtered films are smooth and of good structural quality and uniform thickness. Samples are amorphous as deposited at the substrate temperature used during deposition. Upon annealing at 800 C, the samples become nanocrystalline with an orthorhombic phase being dominant. This induces a drastic change in the far-IR optical properties of the film. The low-frequency phonon modes become much sharper in the nanocrystalline samples. The frequencies of the effective phonon modes are determined by a line-shape analysis to quantitatively show the optical phonons in sputtered $Ta_2O_5$ films.

**I. Martin,** ***et al*****. in (2015) [19]** This studied explain thermal noise arising from mechanical dissipation in oxide coatings is a major limitation to many precision measurement systems, including optical frequency standards, high resolution optical spectroscopy and interferometric gravity wave detectors. leading to possibilities for the reduction of thermal noise effects

**T. Sertel,** ***et al*****. in [2019] [20]** Influences of thermal annealing on structural, optical and morphological properties of the tantalum pentoxide ($Ta_2O_5$) thin films were investigated and anti-reflective performances were discussed in detail. In addition, thermal annealing process has decreased the optical reflectivity of the film. The obtained experimental results showed that single-layer $Ta_2O_5$ thin films can be used as anti-reflective layer in optical and optoelectronic applications. The best optical transmittance and anti-reflective performance were obtained at the annealing temperature of 500 °C.

**M.G.Abd_Al kazim, in [2020] [21]** This study deals with $Al_2O_3$ nanocomposite thin films of thickness 200 nm prepared by thermal evaporating method deposited on a glass substrate. Absorbance, transmittance and reflectance spectra were registered, optical constants were calculated. Energy band gap were determined as directed transition. The results show nanocomposite $Al_2O_3$ /Ge thin film has a good absorbance in the visible region at the range of wavelengths (300-600) nm for all contributed rates, while transmittance increased the range of wavelengths (600- 1000) nm. The reflectance has an alternative at changes according to the oxide / semiconductor contributing rate. Absorption coefficient has values more than 104 cm-1 which indicates a direct transition.

## 1.3 Aims of this Work

1- The mean aims of this work first is finding the effect of tantalum thin which most suitable for optoelectronic applications using optical energy band gap as indicator.

2- to determine the best region of wavelengths in the UV-Visible range (200-1100) nm which show high sense in absorbance and most suitable for optoelectronic and solar cells application and in Medicine.

## 2.1 Introduction

In this chapter, we deal with everything related to theoretical topics and their details.

## 2.2 Semiconductor

Semiconductor is commonly described between the conductors and the insulators as a solid chemical component or a compound with electronic properties. Semiconductor electrical conductivity is typically in the range ($10^3$ -$10^{-8}$ ) ($\Omega$ cm)$^{-1}$ . It is determined by the current or voltage supplied to the semiconductor, as well as the intensity of incident irradiation or temperature [22]. The distance in semiconductors between the valance band and the conduction band is lower than that of insulators. When the temperature rises, the conductivity increases and as the temperature rises, more electrons are thermally excited and the band difference between the valance band and the conduction band is transmitted. The insulators are very low electrical conductivity materials and the band gap between valance and conduction is high. Table (1.1) demonstrates the classification of solids according to their energy difference, eg, and charge carrier density (n) at Room temperature (RT) [23].

Table (2.1): Classification of solids according to their energy gap $E_g$ and charge carrier density (d) at (RT) [23].

| Type of solid | $E_g$ (eV) | n ($cm^{-3}$ ) |
|---|---|---|
| Metal | No energy gap | $10^{22}$ |
| Semimetal | $E_g \leq 0$ | $10^{17}$ -$10^{21}$ |
| Semiconductor | $0 > E_g > 4$ | $> 10^{17}$ |
| Insulator | $E_g \geq 4$ | >> 1 |

There are two kinds of semiconductors, the semiconductor n-type and the semiconductor p-type. In the form of negative charge (electrons), the n-type semiconductor bears a current equivalent to the current conduction in the wire. The current is borne by the p-type semiconductor as electron deficiencies (holes). A hole has an electrical charge that is similarly positive and negative of an electron's charge. Hole flows arise in the opposite direction to the electron flow in a semiconductor material [22].

Figure (2.1) shows two diagrams of the p-type and n-type semiconductor according to the energy level [23]

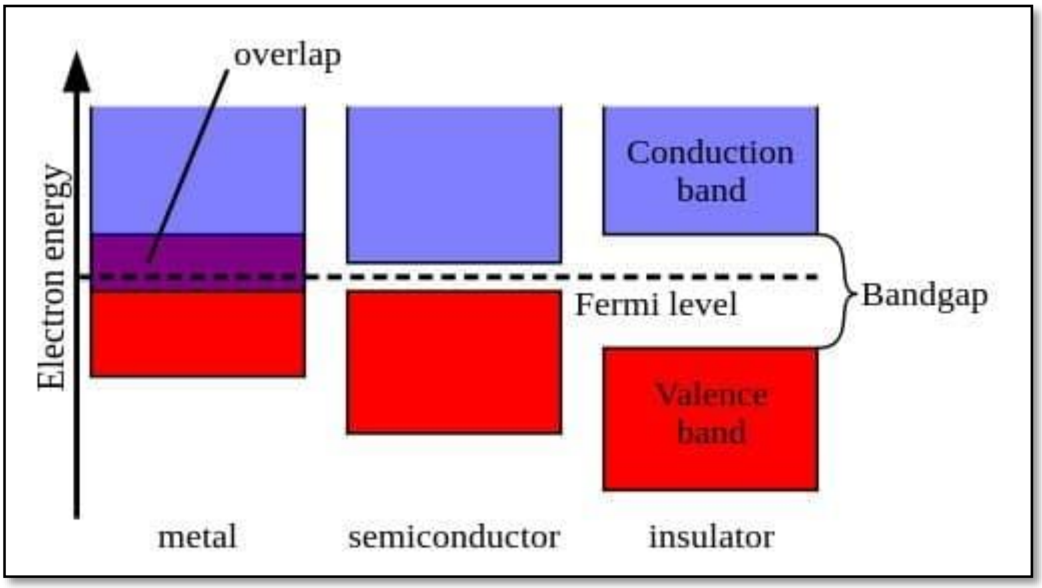


Figure (2.1): p-type and n-type semiconductor according to the energy level

The Fermi level is precisely the energy at which the chance of an electron occupying an energy level is exactly 1/2. The Fermi frequency is situated roughly between the valance band energy Valence Band (V.B) and conduction band energy Conductive Band (C.B) in the case of an intrinsic semiconductor.

The Fermi level shifts toward the conduction band edge for n-type doping, while p-type doping shifts toward the edge of the valance band [24].

## 2.3 Inorganic Semiconductors:

light-emitting diodes (LEDs) are environmentally benign and have found widespread use as indicator lights, mobile displays, large-area displays, signage applications, and lighting applications. The entire visible spectrum can be covered by light-emitting semiconductors: AlGaInP and AlGaInN compound semiconductors are capable of emission in the red-to-yellow wavelength range and violet-to-green wavelength range, respectively. For white light sources based on LEDs, the most common approach is the combination of a blue LED chip with a yellow phosphor. Alternatively, a group of red, green, and blue (RGB) LEDs can be used; such source allows for color tenability [25]. White LEDs are currently used to replace incandescent and fluorescent sources. The properties of inorganic LEDs will be presented, including emission spectra, electrical characteristics, and current-flow patterns. Structures providing high internal quantum efficiency, namely heterostructures and multiple quantum well structures, will be discussed. Advanced techniques enhancing the external quantum efficiency will be reviewed, including die shaping (chip shaping) and surface roughening. Different approaches to white LEDs will be presented and figures-of-merit such as the color rendering index and luminous efficacy will be explained. Besides visible LEDs, the technical challenges of newly evolving deep ultraviolet (UV) LEDs will be introduced.

## 2.4 Tantalum

Tantalum is a chemical element with the symbol Ta and atomic number 73. Previously known as Tantalum, it is named after Tantalus, a villain from Greek mythology. Tantalum is a rare, hard, blue-gray, lustrous transition metal that is highly corrosion-resistant. It is part of the refractory metals group, which are widely used as minor components in alloys.

The chemical inertness of tantalum makes it a valuable substance for laboratory equipment, and as a substitute for platinum. Its main use today is in tantalum capacitors in electronic equipment such as mobile phones, DVD players, video game systems and computers.

Tantalum, always together with the chemically Similar niobium occurs in the mineral groups tantalite, columbite and coltan (the latter is a mix of columbite and tantalite, though not recognized as a separate mineral species)[26].

## 2.5 The mechanical and physical properties of Tantalum

The mechanical and physical properties of tantalum depend to a great extent on the metal purity. Purity is mainly related to the presence of metalloids (e.g., carbon, oxygen, nitrogen and hydrogen) of which even low concentrations cause considerable changes in the properties. The structural state, which depends on the manufacturing process of the compact metal (e.g., sintered or melted by electron beam), and the rate of deformation are also of great significance [27,28,29]. The specifically characteristic physical and mechanical properties of 99.9% pure tantalum are its high melting point, high density, excellent formability, good heat conductivity, very good toughness (even at low temperature) and its weldability [27,28,29,30,31]. Tantalum has the ability of taking up, interstitially, the elements hydrogen, oxygen, nitrogen and carbon. This real solubility can amount to considerable value. If the solubility is exceeded, hydrides as well as very hard oxides, nitrides, carbides and mixed phases are formed. In order to remove the adsorbed metalloids, a high temperature and a good vacuum or very pure inert gas are required. The hardness is a very sensitive indicator for the content of metalloids and is, therefore, also used as a criterion of metal purity. Hardness differences of 100 to 200% exist between technically pure tantalum, which contains approximately 99.5 wt.% Ta (limit of hot deformability, and cold-ductile tantalum, which is purer than 99.95 wt.% . The different processes of producing tantalum from raw tantalum-by means of electron beam melting, vacuum electric arc melting or sintering supply metal grades of different purity and structure. Electron-beam-melted tantalum has the highest purity and the coarsest structure [28,32].

The influence of cold deformation also depends on the content of metalloids. The influence is small in the case of pure, electron-beam melted grades, but is more pronounced for electric-arc melted tantalum. Cold deformation rates of 99% can be achieved [28]. The corrosion resistance decreases with increasing temperature. The oxide layer is slightly acid, so it is mainly attacked by alkali hydroxide solutions. The oxide layer is semiconductive, allowing the use of tantalum for capacitors. At 100°C tantalum is resistant to most organic compounds, and stable to all mineral acids except for hydrofluoric from 300°C upwards, the reaction with oxygen, hydrogen and nitrogen becomes stronger, leading to embrittlement due to the solution of the elements and to the formation of nitride, hydride and scale layers. Under the influence of atomic hydrogen, tantalum can become brittle at room temperature. From a temperature of 50°C and a partial pressure of 10-9 bar on,

$O_2$ is adsorbed by tantalum. This gettering effect is utilized in vacuum technology to reduce the concentration of molecules [33].

## 2.6 Applications

The largest part of the production and consumption of tantalum and its compounds is concentrated in Japan, Western Europe and, to a small extent, the Soviet Union. Commercial raw materials for tantalum are ore concentrates and synthetic concentrates as well as tantalum-containing tin slags. The most important commodities for the processing industry are tantalum carbide, tantalum oxide and tantalum metal or tantalum alloys [33,34]. Tantalum is offered in the unprocessed state, as powder, reduced by sodium or electron-beam melted, then hydrated and dehydrated, in special grades, and in the processed state, as foils, plates, wires, etc. There are four main areas of application: capacitors [35,36,34,37], alloys [28,29,38], hard metals [34,39] and equipment for the chemical industry and apparatus engineering [29] The demand has fluctuated greatly during the last 25 years. Consumption will probably balance out at around 950-1,150 tones within the next ten years, the main emphasis shifting towards high-technology metal products.

### 2.6.1 Capacitors

The future of the capacitor market essentially determines the future development of the tantalum industry, because capacitors account for such a large percentage of total tantalum consumption (45% in 1986) [34]. Tantalum capacitors currently account for approximately 4% of the total capacitor market. Tantalum oxide has a high dielectric coefficient and good stability. For capacitors, tantalum is used as powder, wire, foil and coatings. The characteristics of capacitors are high reliability, low leakage currents, temperature stability (working temperatures between -60°C and +200°C) and high capacitance with little space required. Tantalum capacitors compete with aluminum electrolyte capacitors and ceramic multilayer capacitors. The metal consumption will still increase, responding to an increased demand for capacitors.

### 2.6.2 Chemical Industry and Apparatus Engineering

The good corrosion resistance of the oxide layer makes tantalum suitable for wide application in chemical engineering, and, in 1986, this market consumed 15% of the tantalum supply. Components are manufactured for installations under corrosion attack, such as heat exchangers, heating spark plugs, coolers, pipes and coatings for vessels. Because of its excellent durability and reliability, and despite its high price, tantalum competes seriously with special steel, lead, glass, ceramic, enamel and plastic coatings. The initial costs of installations are high; on the other hand, there are low repair and maintenance costs as well as a very long equipment lifetime [29]. Emitting electrodes for gas cleaning plants, tantalum anodes for transmitting valves and tantalum spinning jets are also used. The electronics industry applies the metal for building emitter valves and heavy-duty components. Because of the high melting point and low tendency to recrystallize, the metal is applied as heat conductor material and for coatings in high-temperature vacuum technology. Tantalum is tolerated by tissue and can therefore be applied as a replacement for bones and for surgical joints [29].

### 2.6.3 Alloys

The engineering application of un alloyed tantalum is limited because of its relatively low hot strength and its low resistance to oxidation in air at high temperatures. In 1986, only 10% of the Tantalum consumption was accounted for by alloying. Tungsten improves the corrosion resistance against hydrofluoric acid solutions. There has been a considerable increase in tantalum consumption for super alloys. In alloys based on nickel, cobalt and iron-nickel, tantalum improves the corrosion resistance, makes the grain structure finer, stabilizes carbon, and increases the hardness and tensile strength. Super alloys containing tantalum are more expensive than those without; however, they have a longer life and better corrosion resistance. They are used mainly in aviation, propulsion and jet engine tech-nology and in spacecraft engineering. Another area of application is nuclear energy technology. In the steel industry, ferrotantalum has been replaced to a large extent by ferroniobium, which is cheaper and more effective [40].

### 2.6.4 Tantalum in Medicine

Surgeons have long been interested in taking advantage of the properties of various metals for the reconstruction of body defects [41]. However, the use of metals quickly gained a poor reputation since they were associated with inflammatory or foreign body reactions and often resulted in pain and discomfort for patients. It was discovered that these unfavorable effects occurred due to an electrochemical process known as corrosion. With this discovery, the obvious step has been to utilize metals that are extremely resistant to corrosion, such as tantalum. The favorable feature of tantalum is the formation of a thin, impenetrable oxide film on the metal surface that prohibits access of damaging substances, including acids and alkalies. In other words, oxidation of tantalum renders the metal biocompatible. Since tantalum is very strong and ductile, it was initially employed for the production of surgical sutures [42]. The long-term, favorable outcome, devoid of any inflammatory/foreign body reaction, encouraged surgeons to use it for more complex applications. Tantalum began to be widely used for cranioplasty of skull defects following battlefield injuries [43]. It was highly valued because, unlike any other implantable materials, it had all the advantages of a traditional bone graft. Subsequently there was an expansion of tantalum usage including mesh for hernia surgery [44], foil for peripheral nerve reconstruction [45], and tubes for frontal sinus reconstruction [46], as well as for blood vessel anastomoses [47].

## 2.7 Tantalum Oxide

Tantalum pentoxide ($Ta_2O_5$) is a high refractive index dielectric with chemical stability at high temperatures and a melting point of 1785 C, and is thus suitable for high temperature applications. $Ta_2O_5$ films have been used or have potential applications in thin-film capacitors [48], microelectronics [49], anti-reflection coatings [50], multilayer optical coatings [51,52], corrosion resistant protective coatings [52], and infrared (IR) emissivity modulating devices [53]. Knowledge of the optical properties of $Ta_2O_5$ is needed for the design of devices that tailor radiative properties such as anti-reflection and multilayer coatings.

## 2.8 Thin Films

The thin-film technology is one of the most important technologies that contributed to the development of the semiconductor study and gave a clear idea of many physical properties [54]. The term thin films are usually called a layer or several layers of specific atoms whose thickness may not exceed one micron resulting from the condensation of atoms or molecules that possess unique properties, that differ from whether they are a thick particle such as physical and engineering properties and the balance of their microstructure, and because of the thickness of these membranes and ease Its cracking is therefore deposited on as sedimentation bases [55]. The type of base depends on the nature of use and study such as glass, quartz, silicon and aluminum. Thin films have multiple industrial uses, as they are “used in the installation of electronic devices in the form of resistors, capacitors and transistors”, etc. They are considered a basis for manufacturing solar and photovoltaic cells, and they are also used “in the manufacture of electro-optical” detectors within specific spectral ranges and have many applications [56].

The Deposition thin film is made or deposited in two types:

1- CD Chemical deposition: Here, as a prelude to fluids, is subject to a chemical change on the surface of the steel until it leaves a solid thin layer. For this procedure, there are also several methods and devices.
2- Physical deposition: Physical deposition uses mechanical, electrical or thermal methods to produce a thin steel film [57].

## 2.9 Spectrophotometer

A spectroscope that is used to measure the properties of light in a specific field of the electromagnetic spectrum for the study and identification of materials in spectroscopy. [58] Through the device, it is possible to determine the emission and absorption spectrum, know the wavelength and the optical intensity of the spectral lines [59]. The scientist Joseph von Fraunhofer was the first to develop an optical spectrometer; [60] then Gustav Robert Kirchhof and Robert Bunsen benefited from the optical spectrometer, which contributed to the discovery of the elements cesium and rubidium; [61] [62] in addition to being able to add a chemical explanation to the phenomenon of lines Astronomical spectroscopy including Fraunhofer lines. [63] A compact, double-beam UV-Visible spectrophotometer wrapped in a sleek form [64].

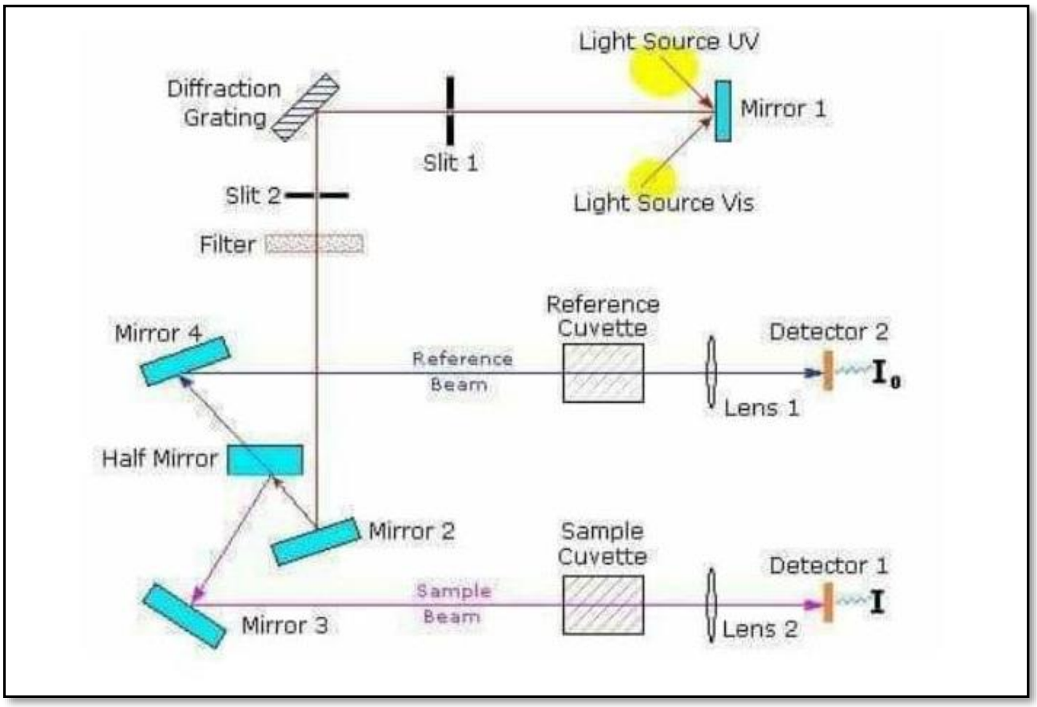


Figure (2.2) Diagram showing the components of the optical spectrometer double beam.

## 2.10 Optical properties

The optical properties of a semiconductor are related to intrinsic effect. Based on the intrinsic location of the top of the valence band (V.B.) and bottom of the conduction band (C.B.). Theory The fundamental absorption is the most important absorption process which involves the transition of electrons from the valence to the conduction band [64]. the “absorption coefficient is of the order of $10^5$ to $10^6$ $cm^{-1}$. Rapid drop in the absorption coefficient on the high energy side of the absorption band leads to the band edge in semiconductors. Because of its relation to the dynamics of the electrons and ions of the medium under the influence of electromagnetic radiation, absorption is a phenomenon of fundamental interest. One can determine the energy gap of the material from the frequency dependence of the absorption [65]. If the photon energy (hν) is equal or more than energy gap ($E_g$) then, the photon can interact with a valence electron, elevates the electron into the C.B. and creates an electron–hole pair. The maximum wavelength (nm) of the incident photon which creates the electron–hole pair is defined as [66]:

$$\lambda\,(nm) = hc/E_g = 1240\,/\,E_g(ev) \quad \ldots\ldots(2.1)$$

Where λ is the wavelength of the incident radiation, h blank constant, c light velocity. The intensity of the photon flux decreases exponentially with distance through the semiconductor according to the following equation [67].

$$I = I_\circ \exp(-\alpha\, t) \quad \ldots\ldots(2.2)$$

Where is the absorption coefficient I and I are the incident and the transmitted photon intensity respectively which is defined as the relative number of the photons absorbed per unit distance of semiconductor, and t is the thickness of the material [68].

### 2.10.1 Absorbance (A)

Absorption is the sample absorption of a portion of the incident light beam at a specified wavelength. The term visible permeability and visible absorption are also expressed that express specific parts of the spectrum [69]. So-called visible spectrum.

$$A = -\log_{10}(I/I_\circ) \quad \ldots\ldots(2.3)$$

The term absorption refers to the physical process of absorbing light, whereas the term absorption refers to the mathematical quantity. In addition to that absorption does not always affect absorption. In a case, a portion, in a case, a portion of the light that is scattered by the tagged particles, and the attribute (the distribution will not complete) Its absorption in the pigeon. In this case it is preferred to use the term attenuation (called extinction), which explains the losses due to scattering and pearling. In spite of the fact that the absorbency does not have units, it Absorbance Units or AU [70].

### 2.10.2 Transmittance (T)

In optics and spectroscopy, a portion of the incident light beam passes at a specified wavelength across the sample. As for the habit, it depletes part of it in the sample because it is absorbed in the sample and is gradually placed, and the part that is not absorbed is removed from the sample [71]. This is why the concept of permeability combines you with the concept of absorption.

$$T=10^{-A} \qquad (2.4)$$

### 2.10.3 Optical Constants:

The optical parameters are very important parameters because they describe the optical behavior of the materials. optical constants of thin films are available from the absorption and reflectivity data [72]. The absorption coefficient of the material is a very strong function of the photon energy and band gap energy. Absorption coefficient represents the attenuation that occurs incident photon energy on the material for unit thickness, and the main reason for this attenuation is attributed to the absorption processes [73]. Optical constants included refractive index (n), extinction coefficient ($k_o$), and real ($\varepsilon_r$) and imaginary parts ($\varepsilon_i$) of dielectric constant. The complex refractive index (N) is defined as [72]:

$N = n - iK_o$ ………………………………………………... (2.5)

And it is related to the velocity of propagation (v), and light velocity (c) by:

$v = c/N$ ……………………………………......................... (2.6)

The refractive index value can be calculated from the formula [74]:

$$n = \left(\frac{4R}{R-1} - K^2\right)^{\frac{1}{2}} - \frac{R-1}{R+1}$$ ……………………… (2.7)

Where R is the reflectance, and can be expressed by the relation [74]:

$R = 1 - A - T$ ……………………... (2.8)

The extinction coefficient, which is related to the exponential decay of the wave as it passes through the medium, is defined as [75]:

$K_o = \alpha\lambda/4\pi$ ……………….……… (2.9)

Where is the wavelength of the incident radiation and is given by [76]:

$\alpha = 2.303A/t$ ……………….……... (2.10)

Where **A** is the absorbance and **t** is the sample thickness. The real and imaginary part of dielectric constant can be calculated by using the following equations [70]:

$(n + ik)^2 = \varepsilon_r + i\varepsilon_i$ ……............................ (2.11)

Where

$\varepsilon_r = n^2 - k^2$ …………………..…………..(2.12)

And

$\varepsilon_i = 2nk$ ……………………………….…..(2.13)

**2.10.4 Reflectance**

It is a diamond that is used in the field of light and heat expansion to know the ratio of the bounced rays from the total salad rays. The reflection of the electromagnetic ray is not fixed at each frequency, but rather is governed by the reflection coefficient and the radiation frequency. Its reflection is greater than what is fully blamed for its duty, if the beam sent a ray at a frequency with little reflection, it would not bounce back to the spot except for a night of rays that might not suffice to give information [77].

**2.10.5 Absorbance coefficient or attenuation coefficient ($\alpha$)**

It is a word that determines the permeability of light in a substance, or the permeability of sound in a substance, or the permeability of a particle in a substance. Coefficient of absorption, by the length of the column 1/ cm [77]. Sometimes the absorption coefficient is called the linear attenuation coefficient

When a beam of electromagnetic waves crosses the surface of a body, part of it is reflected, and another part is executed in the material of the body, silence is part of the body. The absorbed length is the internal length of the body. The absorption factor (and hence the spectral absorption factor) is given the orbit of the first part of the absorption The coefficient of absorption is zero from zero, so the material I and $I_o$ are inside. The orbit of the part with the meaning of the internal beam is almost I transparent to the beam and vice versa if the coefficient of absorption and soils is completely absorbed. The absorption coefficient is dependent on the frequency of the incident beam.

$\alpha = (1/t) \ln 1/T$ ……..........................................(2-14)

### 2.10.6 Extinction Coefficient ($K_o$)

The damping factor is defined as the dormant obtained by the electromagnetic wave inside the material, which is the amount of the electrons of the material absorbed by the length of the photons' power. On this basis, its parameter is determined by the interaction of the electromagnetic wave with the medium [78].

$K_o = \alpha\lambda / 4\pi$ …...........................................................................(2-15)

### 2 .10.7 Refractive index (n)

Is the ratio of the speed of light to the refractive index of a medium (such as; air, water, etc., and is symbolized by the symbol in the vacuum to its velocity in this medium. It is a coefficient that shows how the material is affected by the electromagnetic waves. Two parts are bathed and imagined the diffusion of light in an absorbing material for it can describe the refractive index as a complex number The portion of this complex number expresses the attenuation of the light beam, while its intimate part reflects the refraction of light in the material [70].

The refractive index depends on the wavelength and density. The higher density leads to a higher refractive index in the material.

### 2.10.8 Dielectric Constant

Dielectric constant workability of the material for polarization. The material can respond to different frequencies in a complex manner, at optical frequencies represented by light waves. The electronic polarity is dominating above other remaining types of polarization. The real ($\varepsilon_r$) and imaginary ($\varepsilon_i$) parts of dielectric constant were determined from the complex dielectric ε [79]:

$$\varepsilon = \varepsilon_r - i\varepsilon_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.16)$$

where $\varepsilon_r$ represents the normal dielectric constant and $\varepsilon_i$ is the absorption associated with radiation by free carrier [80]. The relation between (ε) and (N) is expressed in the following equation:

$$\varepsilon = N^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.17)$$

From the equation (2.26), the real and imaginary complex dielectric constant can be expressed by the following equation [81,82]:

$$\varepsilon_r = n^2 - k_o^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.18)$$

$$\varepsilon_i = 2nk_o \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2.19)$$

### 2.10.9 The electronic transitions:

The electronic transitions can be classified into two types:

#### 2.10.9.1 Direct Transitions:

When the energy of the incident photon exceeds the band gap energy ($E_g$) of the material, an electron is excited from the valence band to the conduction band. Transition involving photons only is direct type and transition involving photon and phonon is termed as indirect. A direct optical transition near the fundamental absorption edge in a semiconductor is shown schematically in figure (2-5 a).

The valence band maximum and the conduction band minimum appear at the same point in the Brillouin zone at k = 0. A vertical transition (also called direct transition) from the state located at the top of the valence band to the state of k = 0 in the conduction band involves the minimum energy difference and consequently, corresponds to absorption edge, This transition is described by the following relation [83]:

$$\alpha h\nu = B\,(h\nu - E_g)^{1/2} \quad \text{.......................................(2.20)}$$

Where B is inversely proportional to amorphusity. If the transition occurs also between states of the same wave vector, but the wave vector does not equal to zero, the transition is called forbidden direct transition as shown in Figure (2-5b).

**2.10.9.2 Indirect Transitions**

In indirect transition there is a large momentum difference between the points to which the transition takes place in valence and conduction bands.

This means that the conduction band minima are not at the same value of K as the valence band maxima, then, assistance of a phonon is necessary to conserve the momentum, therefore:

$$h\nu = E_g - E_p \quad \text{.......................................(2.21)}$$

Where $E_p$ is the energy of an absorbed or emitted phonon [84]. For an allowed indirect transition, the transition occurs from the top of the valence band to the bottom of the conduction band as shown in figure (2-5 c) so that [85]:

$$\alpha h\nu = B\,(h\nu - Eg)^{1/3} \quad \text{....................................... (2.22)}$$

While, the forbidden indirect transitions occur from any point near the top of V.B. to any point other than the bottom of the C.B., as shown in figure (2-5d).

Experimentally it is possible to differentiate between direct and indirect processes by the level of the absorption coefficient, takes values from $10^4$ to $10^5$ $cm^{-1}$ for direct transitions [86].

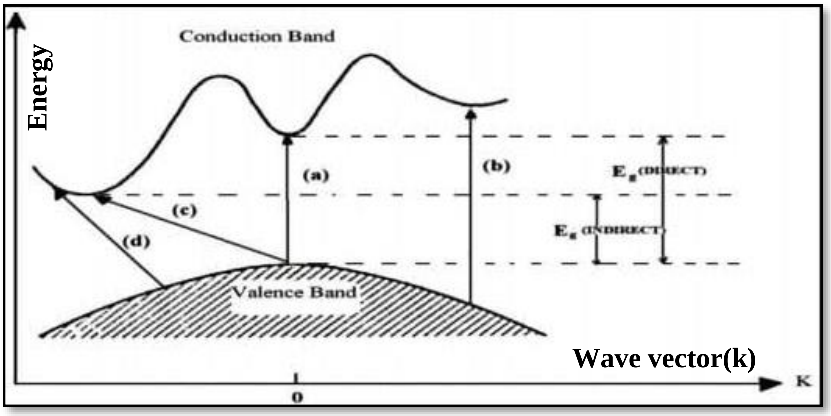


Figure (2.3): The optical transitions (a) Allowed direct, (b) Forbidden direct; (c) Allowed indirect, (d) Forbidden indirect [87].

## 2.11 Energy Band Gap

The gap is a field in the solid body in which the electrons cannot be found. Looking at the electron-band composition structures of solid bodies, we find that the band gap represents the long difference, which, between the highest valence band and below the conduction range.

Especially the band gap in insulators and semiconductors, where the blade gap determines many visual and electrical properties of the solid body.

As for the electrical conductor, the valence and conduction bonds are overlapping, so they do not have a band gap [78].

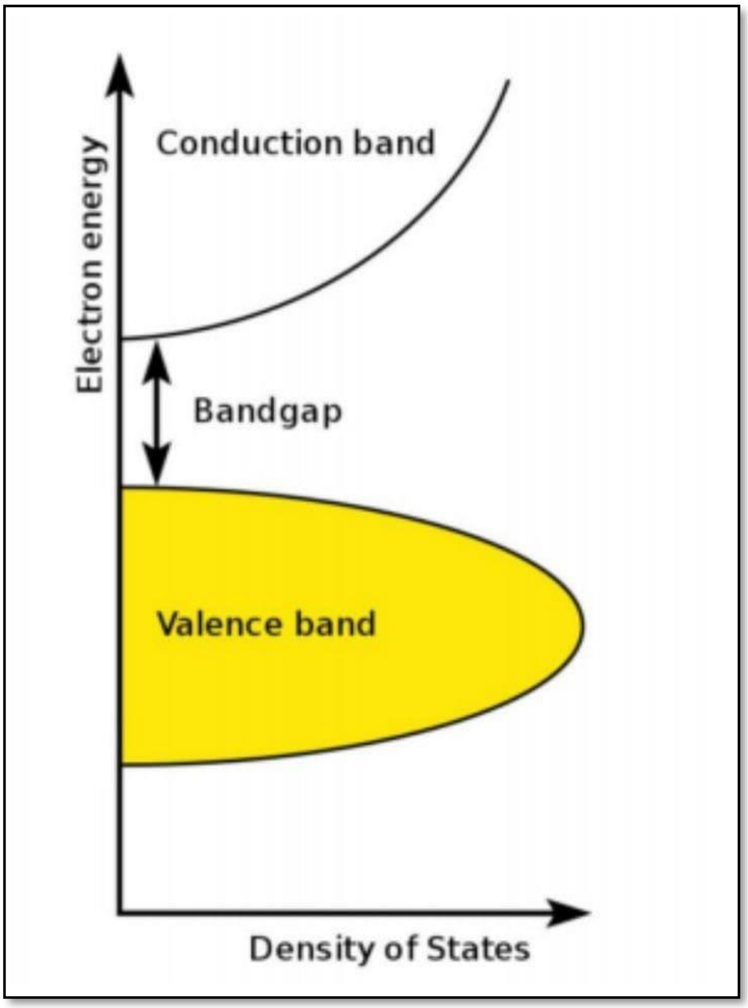


Figure (2.4) Energy gap.

## 3.1 Introduction

Thin films preparing method is deposited thin films, spectrophotometer used and optical constants calculating software.

## 3.2 Preparating Conditions

- $Ta_2O_5$ thin films prepared by thermal evaporating method at substrate temperature 100° c and under 1 atm pressure.

-$Ta_2O_5$ thin films prepared by using different thickness about (20-40-60-80-100) nm with the wavelength range (190-1100) nm.

- Optical properties calculating software was used to find optical constants and optical energy band gap [88].

## 3.3 UV-Visible Spectrophotometer:

The UV-1800 uses the Czerny-Turner mounting for its monochromatic, and boasts the highest resolution in its class, a bright optical system, and a compact design. Available in standalone or PC-controlled models, Shimadzu's compact, double beam UV-1800 Spectrophotometer provides outstanding performance and functionality at an incredible price. UV-1800 UV-Vis Spectrophotometer Features: Wide Photometric (Up to 4 Abs).

Figure (3.1) spectrophotometer

**3.4 Trics Company Software for simulation:**

A special software for thin films behaaviors from Trics company was used to obtain absorbance spectra, the absorbance spectra, the transmittance spectra, the reflectance spectra, the absorption coefficient, extinction coefficient, refractive index, real and imaginary parts of the dielectric constant, the optical conductivity, optical energy band gap [88]

**3.5 Optical properties software :**

A localy software for calculating and ploting transmittance and reflectance spectra and other optical constants was used.

## 4.1 Introduction

This chapter contain the results of the experimental measurements of the nano thin films $Ta_2O_5$ with thickness (20-100) nm prepared by thermal evaporating method with different thicknesses.

## 4.2 The Absorbance Spectra

Figure (4.1) displays the variation of optical absorbance with wavelength for nano thin films $Ta_2O_5$ with different thicknesses about (20-100) nm prepared by thermal evaporating method were registered in the region 200-1000 nm. The spectra show high absorbance band in the range of the wavelengths (210-230) nm and there is a single peak with about absorbance for all spectra, the position of peak differs according to the thickness , as the absorbance value increases with increasing thickness and these peaks have red shifts towards the longer wavelength this behavior can be explain by interacting with atoms , which causes the photon to be emitted .When wavelength reduces, incident photon interacts with the material, and the photon absorbs. The absorbance increases as the thickness of the nanomaterials increase. This is due to free electrons absorb the incident light.

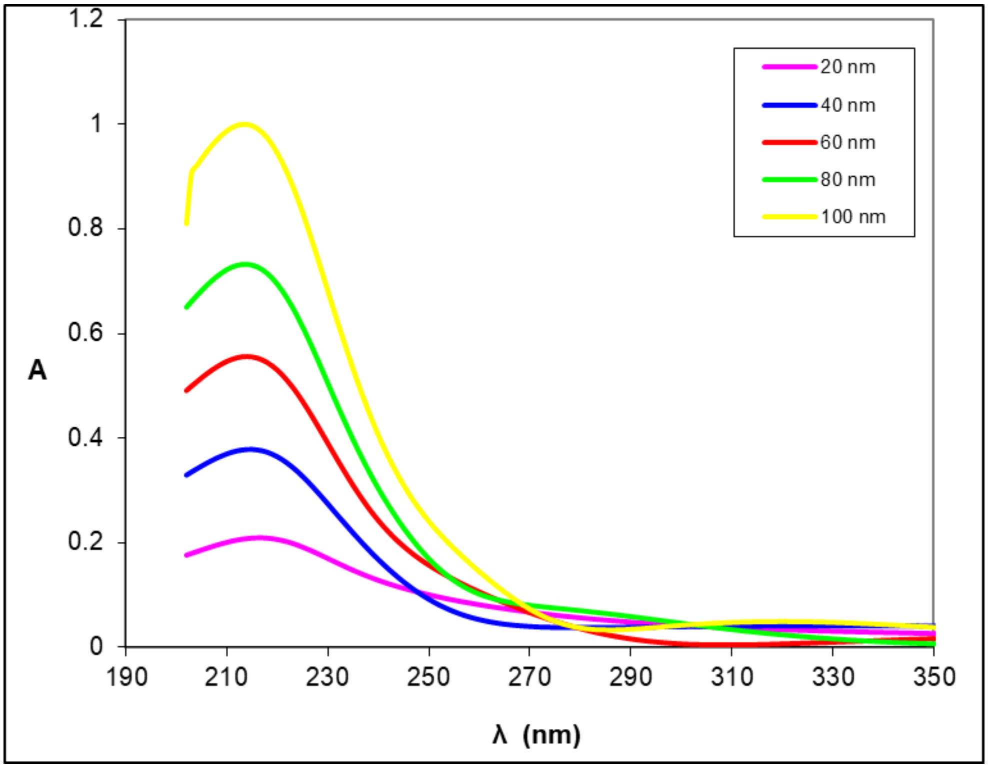


Figure (4.1) The Absorbance spectra of nano thin films $Ta_2O_5$ with different thickness.

## 4.3 The Transmittance Spectra

The figure (4.2) shows transmittance of nano thin films $Ta_2O_5$ with wavelength of photon. As show in this figure, the transmittance decrease with the rise of the thickness of $Ta_2O_5$, The spectra show that the transmittance increased gradually in the range of the wavelengths (220-1000) nm for all samples while the minimum transmittance at the range (200-210) nm . the transmittance of samples differ according to the thickness of thin films .This behavior may be because of the increase in the absorbance and increase in film thickness which decreases the transmittance value.

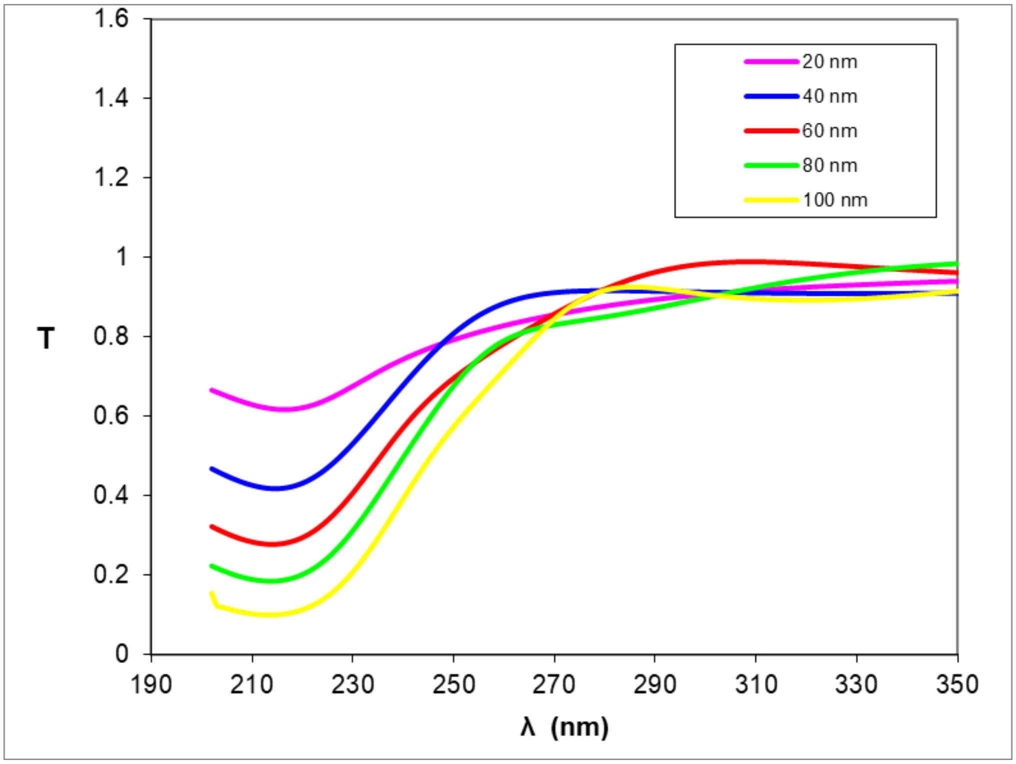


Figure (4.2) Transmittance spectra of nano thin films $Ta_2O_5$ with different thickness.

## 4.4 The Reflectance Spectra

Figure (4.3) exhibit the computed reflectance as a function of wave length ,the curve of displays decreasing in the reflectivity with the increasing of wavelength to the lowest reflectivity value that occur at 210 nm wavelength for all samples. The maximum values of reflectivity are 21% at (230-240) nm wavelength for thicknesses (60, 80 and 100) nm respectively. The Reflectivity increases with increasing thickness. This is demonstrated that the reflectivity occurs in the middle and far UV.

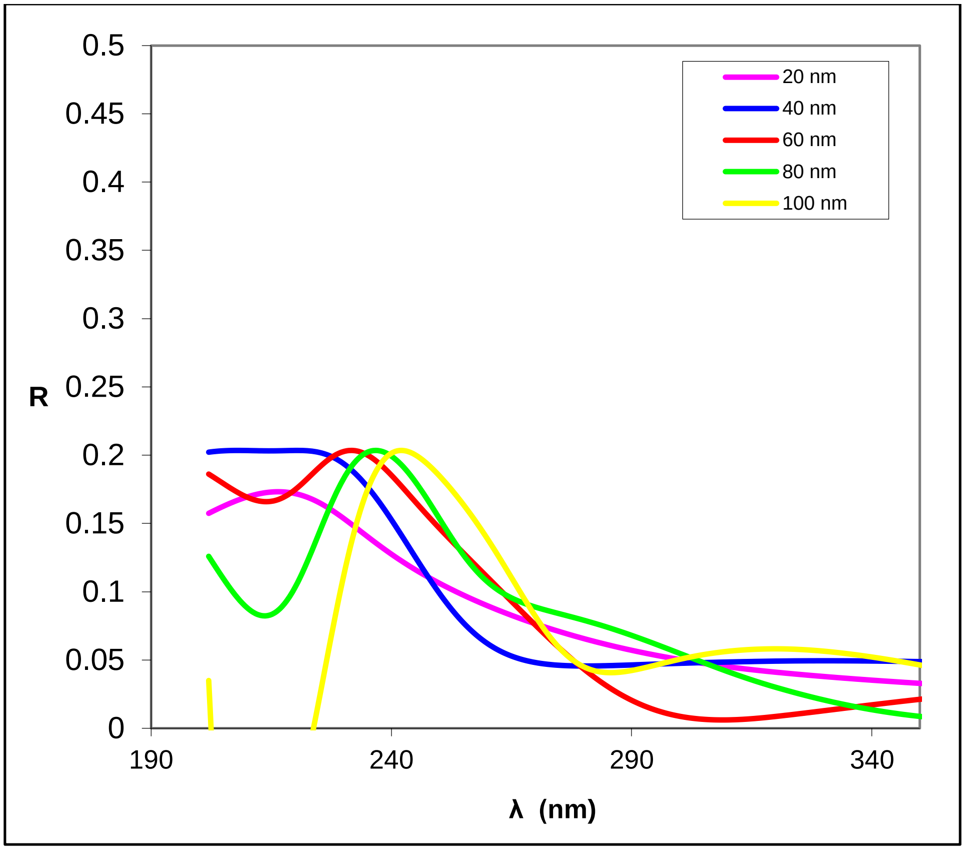


Figure (4.3) The Reflectance spectra of nano thin films $Ta_2O_5$ with different thickness.

## 4.5 The Absorption Coefficient

Absorption coefficient for nano thin films $Ta_2O_5$ with thicknesses of (20-100) nm prepared by thermal evaporating method were calculated for the region 200-1000 nm as shows in figure (4.4). The figure (4.4) shows that the maximum value for the absorption coefficient at wavelength (200 nm) for all thicknesses and then gradually decreases, the absorption coefficient has semi constant values for the range of wavelengths (300-1000) nm. All values of absorption coefficient greater than $10^4$ $cm^{-1}$ so from this value can be determined the energy band gap is a direct transition.

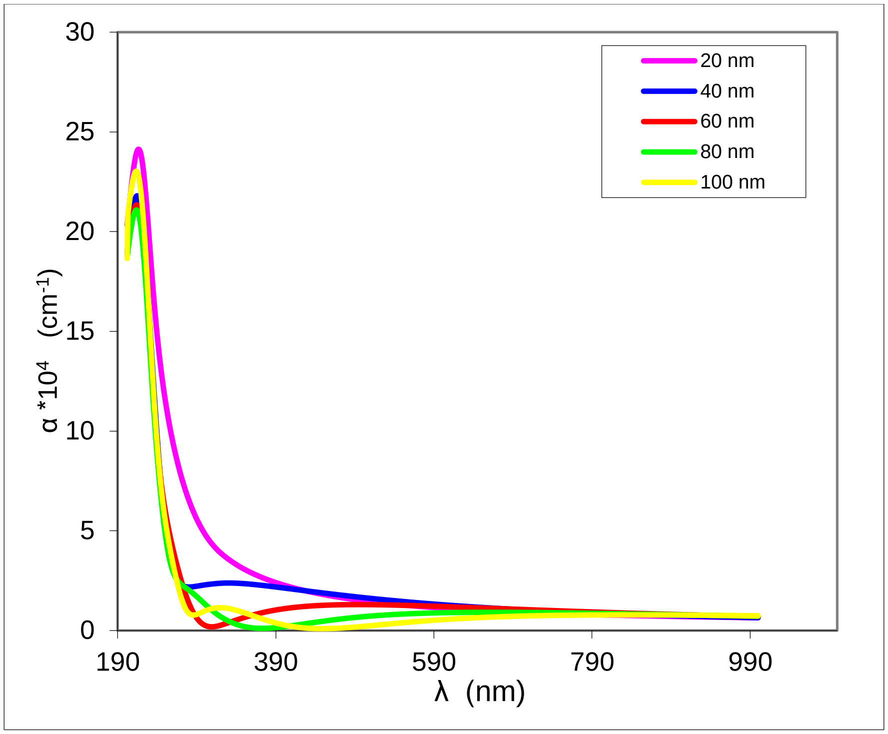


Figure (4.4) The Absorption coefficient for the nano thin films$Ta_2O_5$ with different thickness.

## 4.6 Extinction Coefficient

Extinction coefficient for nano thin films $Ta_2O_5$ with thicknesses of (20-100) nm prepared by thermal evaporating method were calculated for the region (200-1000) nm as shows in figure (4.5). The figure (4.5) shows the maximum attenuation in for the electromagnetic waves at the wavelengths (200) nm while have the save value for the range of wavelengths (600-1000) nm.

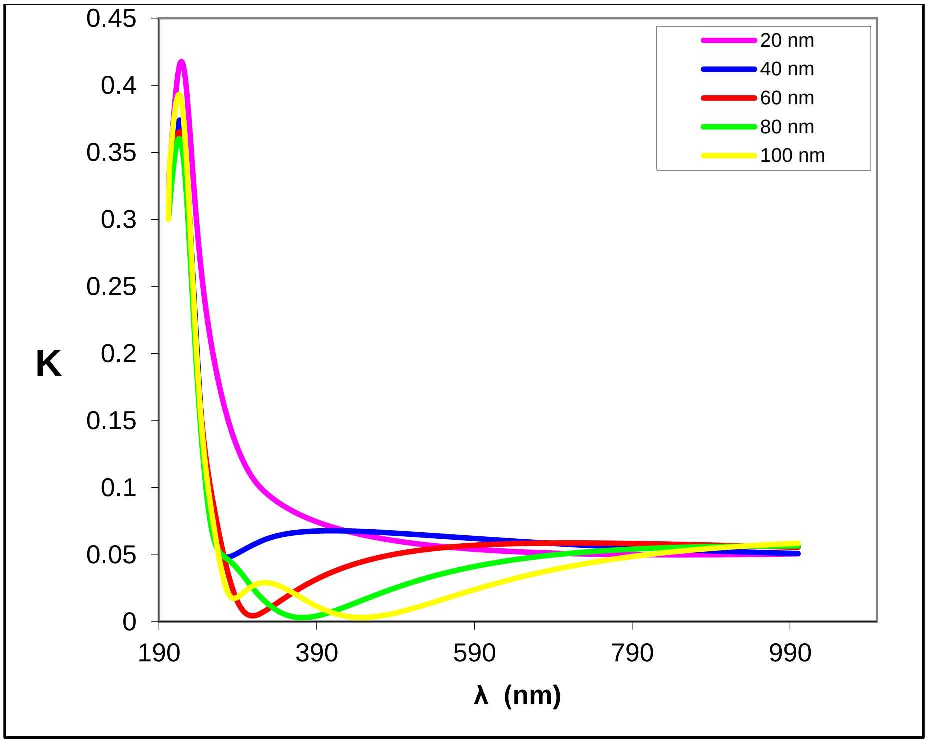


Figure (4.5) The Extinction coefficient for the nano thin films $Ta_2O_5$ with with different thickness.

## 4.7 Refractive index

Refractive index for nano thin films $Ta_2O_5$ as a function of wavelength with thicknesses of (20-100) nm prepared by thermal evaporating method were calculated for the region (200-1000) nm as shows in figure (4.6).

The figure below shows that there is a discrepancy in the refractive index values at wavelength 200 for the studied samples, where the samples with thickness (20 -40)nm gave high values for the refractive index, while samples with thickness (60-100)nm decreased and then increased in the refractive index values and after wavelength 240 nm the refractive index values converge and start Decreasing with the increase of the wavelength, and then we notice that the absorption coefficient is stable with the length of the wavelength and for all thicknesses from (600-1000) nm and we also notice that after the wavelength 600 nm increases the refractive index with increasing thickness

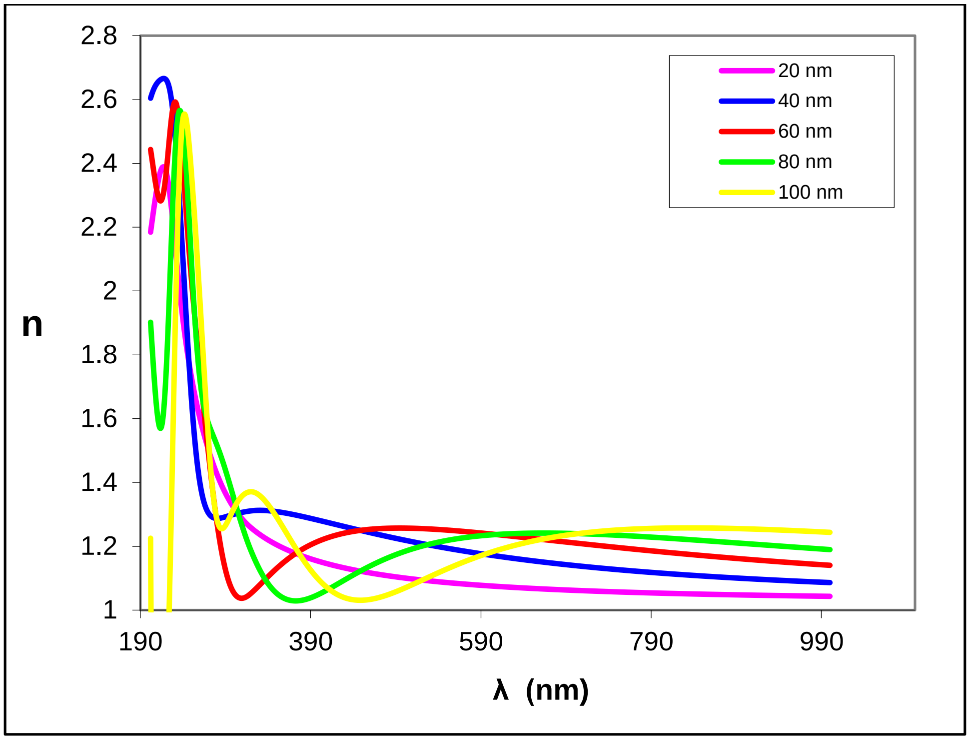


Figure (4.6) Refractive index for the nano thin films Ta2O5with different thickness.

## 4.8 Real and Imaginary parts of the Dielectric Constant

The electromagnetic field of the incident radiation affects the orientation of positive and negative charges in a thin film. The electric current resulting from this field constitutes conduction and dipole displacement current.

Real dielectric constant is also called real permittivity. Real permittivity indicates the radiation energy transmitted through a material medium. the major optical properties of materials are connected with their imaginary part in the dielectric function.

In figures (4.7) and (4.8), there is only one major peak for nano $Ta_2O_5$ thin films as a function of wavelength with thicknesses of (20-100) nm prepared by thermal evaporating method were calculated for the region (200-1000) nm ,both the real and imaginary parts of the dielectric function for occur at wave length 210 nm . The first peaks are mostly due to the transitions of the direct electron from the valence band to conduction band. The main peaks in the real and imaginary parts of the dielectric constant are discovered to move towards the region of lower energies, which points out that the incident photons are completely reflected in this region. This is so-called redshift. It is well known that in the dielectric function, the imaginary part has a substantial effect on the absorption of the medium.

The existence of a number of peaks in imaginary part alludes the transition from band to band. Thus, a single peak in the imaginary part means that there is a single inter-band transition, which occur between the valence band and conduction band.

The real dielectric constant which it means the storage energy while the imaginary dielectric constant which it means the loosing in energy of electromagnetic waves in thin films material decreases sharply at the range of wavelengths (300-390) nm while have the same value for the range of wavelengths (600-900) nm with the same wavelength range the dielectric constant increases with increasing thickness.

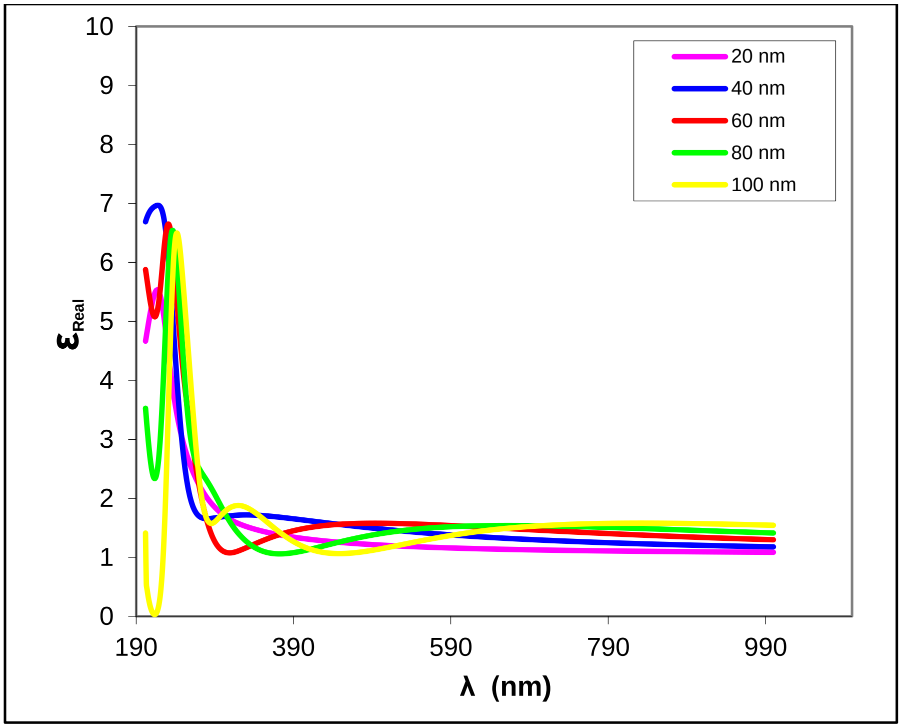


Figure (4.7) The Real dielectric constant for the nano thin films $Ta_2O_5$ with different thickness.

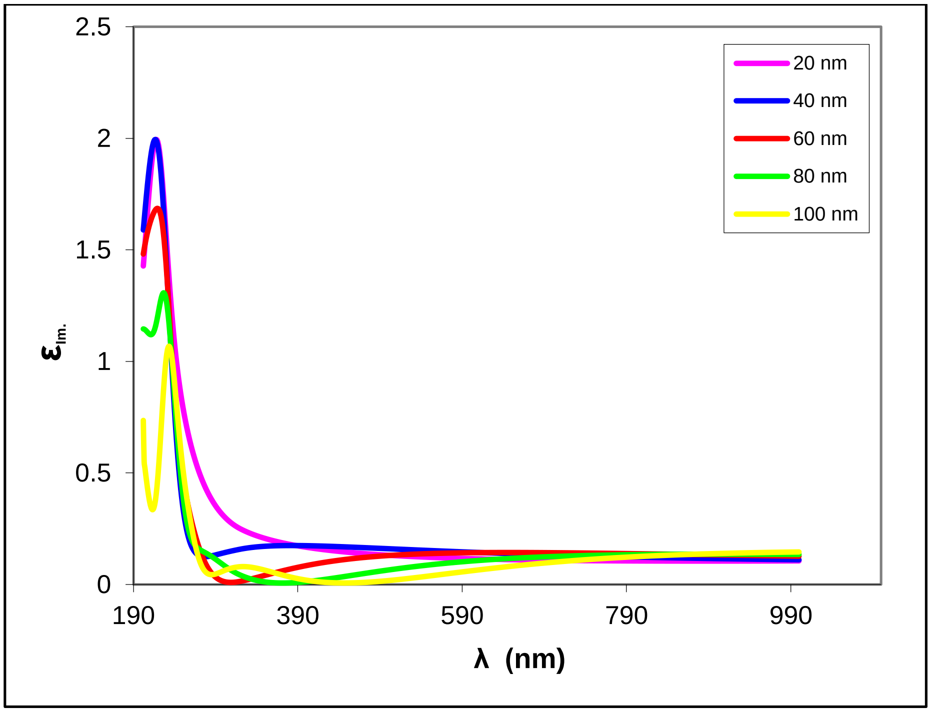


Figure (4.8) The Imaginary dielectric constant for the nano thin films $Ta_2O_5$ with different thickness.

**4.9 The Optical Conductivity**

The figure (4.9) shows of optical conductivity of the nano thin films $Ta_2O_5$ with wavelength. The optical conductivity of all thin films samples decreases as the wavelength increases; this behavior, which is attributable to optical conductivity, is dependent on the wavelength of radiation incident on samples; the increase in nano thin films optical conductivity at a low wavelength of the photon is due to the high absorbance of all nano thin films samples in the field.

$\sigma_{op}=\alpha nc/4\pi$…………………………….(4.1)

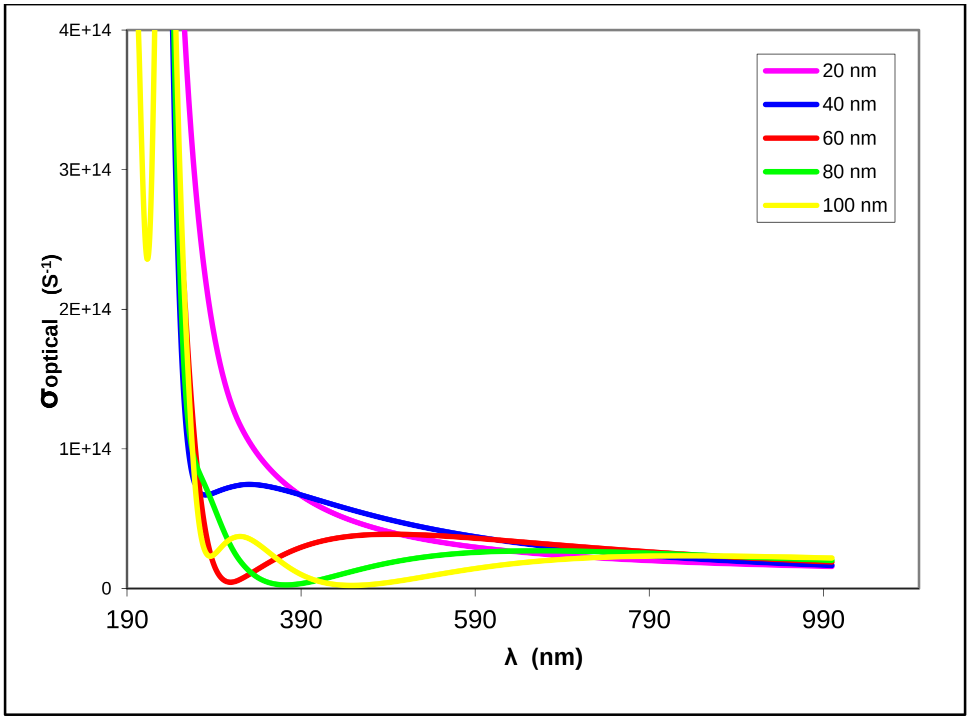


Figure (4.9) The optical conductivity of the nano thin films $Ta_2O_5$ with different thickness.

## 4.10 Optical Energy Band Gap

The optical energy gap values ($E_g$) for nano thin films $Ta_2O_5$ with thickness of (20-100) nm prepared by thermal evaporating method for the region (200-1000) nm have been determined by using Tauce equation which is used to find the magnitude of Eg and the type of the optical transition. The electronic transition when determined as direct transition. The value of the optical energy gap increases with increase in thickness for nano thin films, as shown in Figure (4.10) which display direct translation between top valance band and down conductivity band. This behavior is due to the increase in thickness leads to an increase in crystal defects and thus an increase in the energy levels between the valence and conduction bands and as a result the energy gap decreases with increased thickness.

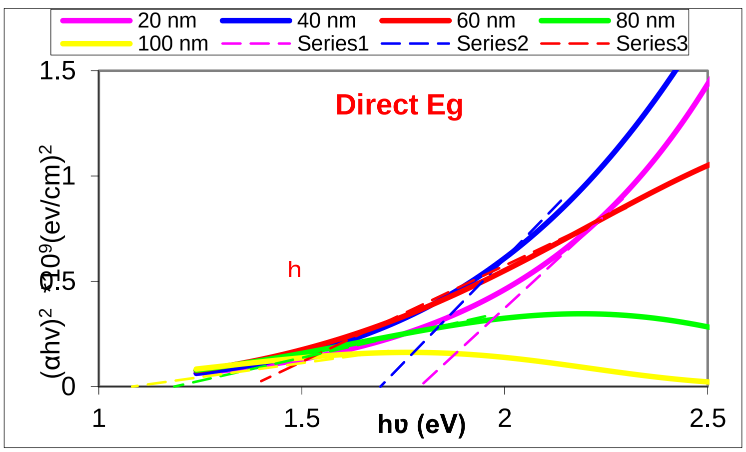


Figure (4.10) The direct optical energy band gap for the nano thin films $Ta_2O_5$. with different thickness.

## 4.11 Conclusions

1. $Ta_2O_5$ nano thin films are good absorbers for the visible region which can be used as a filter to visible light to get pure red beam.
2. The Absorbance increases as the thickness of thin films.
3. The reflectivity increases with increasing thickness, this is occurs in the middle and for UV.
4. A good stability of optical constants at the range of wavelengths (600-1000) nm when the contributing for different thickness.
5. The optical conductivity of $Ta_2O_5$ decreases as the wavelength.
6. The increases in optical conductivity at allow wavelength of the photon is due to the high absorbance of all samples in the field.
7. The optical energy gap $E_g$ decrease with increasing thickness due to creating of localized states in the energy gap.

## 4.12 Future Work

1. Studying the structural properties of nano thin films $Ta_2O_5$ with different thickness.
2. Studying the electrical properties of nano thin films $Ta_2O_5$ with different thickness.
3. Studying the optical properties of nano thin films $Ta_2O_5$ with Fabricated by pulse laser deposited method.
4. Studying effect of substrate on the optical properties of nano thin films $Ta_2O_5$ with different thickness.
5. Studying nano thin films $Ta_2O_5$ with other materials.

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