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The Influence of RF power, pressure and substrate temperature on optical properties of RF Sputtered vanadium pentoxide thin films

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Abstract

The V_2O_5 films were deposited on glass substrates which produce using radio frequency (RF) power supply and Argon gas technique. The optical properties were investigated by, UV spectroscopy at "radio frequency" (RF) power ranging from 75 - 150 Watt and gas pressure, (0.03, 0.05 and 0.007 Torr), and substrate temperature (359, 373,473 and 573) K. The UV-Visible analysis shows that the average transmittance of all films in the range 40-65 %. When the thickness has been increased the transhumance was decreased from (65-40) %. The values of energy band gap were lowered from (3.02-2.9 eV) with the increase of thickness the films in relation to an increase in power, The energy gap decreased (2.8 - 2.7) eV with an increase in the pressure and substrate temperature respectively.

Key words

V_2O_5, RF sputtering, thin films, optical properties.

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تاثير الطاقة والضغط ودرجة حرارة الركيزة على الخصائص البصرية للاغشية الرقيقة لخامس اوكسيد الفاناديوم باستخدام الترذيذ بالترددات الراديوية

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الخلاصة

تم ترسيب أغشية رقيقة من خامس اكسيد الفاناديوم على ركائز زجاجية التي تنتج باستخدام طاقة التردد الراديوي وتقنية غاز الأرجون، وتم بحث الخواص البصرية بواسطة دراسة مطيافية مرئية فوق بنفسجية عند قدرة التردد الراديوي من 75 - 150 واط وضغط الغاز 0.03 تور، 0.05 تور و 0.007 تور، ودرجة حرارة الركيزة (359، 373، 473 و 573) كلفن. أظهر التحليل الطيفي المرئي و للأشعة فوق البنفسجية أن متوسط نفاذ جميع الأغشية يكمن في نطاق 40-65 ٪ و عندما زاد السمك انخفضت نسبة الانتقال مــن (65 -40) %. و انخفضت فجوة النطاق الضوئي للغشاء من 3.02 إلى 2.9 الكترون فولت، مع زيادة سماكة الأغشية مقارنة بالزيادة في القدرة، من ناحية أخرى انخفضت فجوة النطاق من 2.8 إلى 2.7 الكترون فولت، مع زيادة الضغط ودرجة حرارة الركيزة على التوالي.

Introduction

V_2O_5 promising materials for electronic compounds considered as a and photovoltaic applications [1]. Vanadium oxide (V_2O_5) is an n-type semiconductor that is both more stable and has a high oxidation state [2]. It has an abundant interesting advantage, inclusive multi-valance, layered structure, a broad optical energy gap (2.44 eV), perfect chemical and thermic stabilization, excellent thermoelectric properties [3]. The V_2O_5 is an effective material in the industrialization of many solid state devices, such as the sensors, optical-electrical switches [4]. The (V_2O_5) is the most stable juncture among all mangle phases (VnO_{2n+1}), exhibits interesting electrical, optical and electrochemical properties [5]. V_2O_5 thin films have been prepared by various methods such as sputtering [6], vacuum evaporation [7], sol-gel [8], pulsed laser deposition [9], chemical vapor deposition [10], electron beam evaporation [11], thermal evaporation[12] and spray pyrolysis [13]. They have been processed in a thin film configuration to develop electrical and optical devices. The deposition technique and the precipitation parameters such as evaporation rate, substrate temperature, sputtering power, and pressure determine the properties and thereby applications of the thin films. In non-interactive sputtering, the process gases such as oxygen or nitrogen are not added up with the inert working gases such as argon or helium. non-reactive sputtering can be employed for both DC and RF excitation. when it is exercised with DC sputtering, the major advantage lies in high deposition rate, whereas in the case of RF sputtering, various types of targets can be used [14]. Vanadium pentoxide (V_2O_5), a transition metal oxide semiconductor, shows a wide range of applications in thin film due to its multiagency. It is a promising compound for smart window applications, but the intercalation process is slow because of its low electrical conductivity and diffusion coefficient of ions [15]. Nanoparticle V_2O_5 thin films are used to overcome this issue by increasing the surface area and decreasing the diffusion distance [16].

Experimental

In this work, V_2O_5 films were prepared by the RF magnetron system (CRC600 CO. Manufactured in the USA). Prepared thin films on glass Substrate in different power, pressure and substrate temperatures. The chamber was evacuated under low pressure (3x 10^{-5}) Torr. The glass slides were sequentially cleaned in an ultrasonic bath with acetone and ethanol. Finally they were rinsed with distilled water and dried. . The optical properties measurements for (V_2O_5) thin films obtained by using the UV-Visible recording Spectrometer (UV-2601 PC Shimadzu software 1700, 1650), made in Japan. The thickness of the films has been calculated by using Device the FT-650 Film Thickness (FT) Probe System. Use the V_2O_5 deposition of RF Sputtering in pure argon gas (99.9%) with pressure (0.03, 0.05 and 0.007 Torr). With different of RF power (75, 100, 125, and 150 watts), with various substrate temperatures were (359, 373, 473 and 573 K) respectively.

Results and discussion

Optical properties

1. Transmission (T)

Fig.1 (a, b, c) show the optical transmission spectra of V_2O_5 thin films in the wavelength range of (300-1100) nm prepared at different RF power, work pressures and temperature substrate. The transmission spectra have expressed opposite behavior of absorbance, where transmittance (T) is given by the ratio of the intensity of the rays (I_T) transmitting through the film to the intensity of the incident rays (I_o) as following equation [17]:

$$T = I_T / I_o \qquad (1)$$

For whole deposit films, the patterns of transmittance increased with wavelength increasing. Fig.1a. shows the transmittance degradation in range of (73-54) % with the increasing RF power. The lowest opted transmittance has observed for deposited films when the applied power was 150 W. At the power of 150 W, the V_2O_5 have been transported to a semiconductor state. So that its transference was increased. As depicted in ref [18]. Fig.1b displays the lowering of transmuting for 40% as a result of higher applied pressure. So that, the thickness was decreased. Show that the Fig.1 c the optical transmittance increase from 42.82 to 64.62 % with the increase of substrate temperature. This effect could relate to the excess in the degree of the crystallinity of films structure by increasing the grain size. Which are indicated by x-ray examination results.

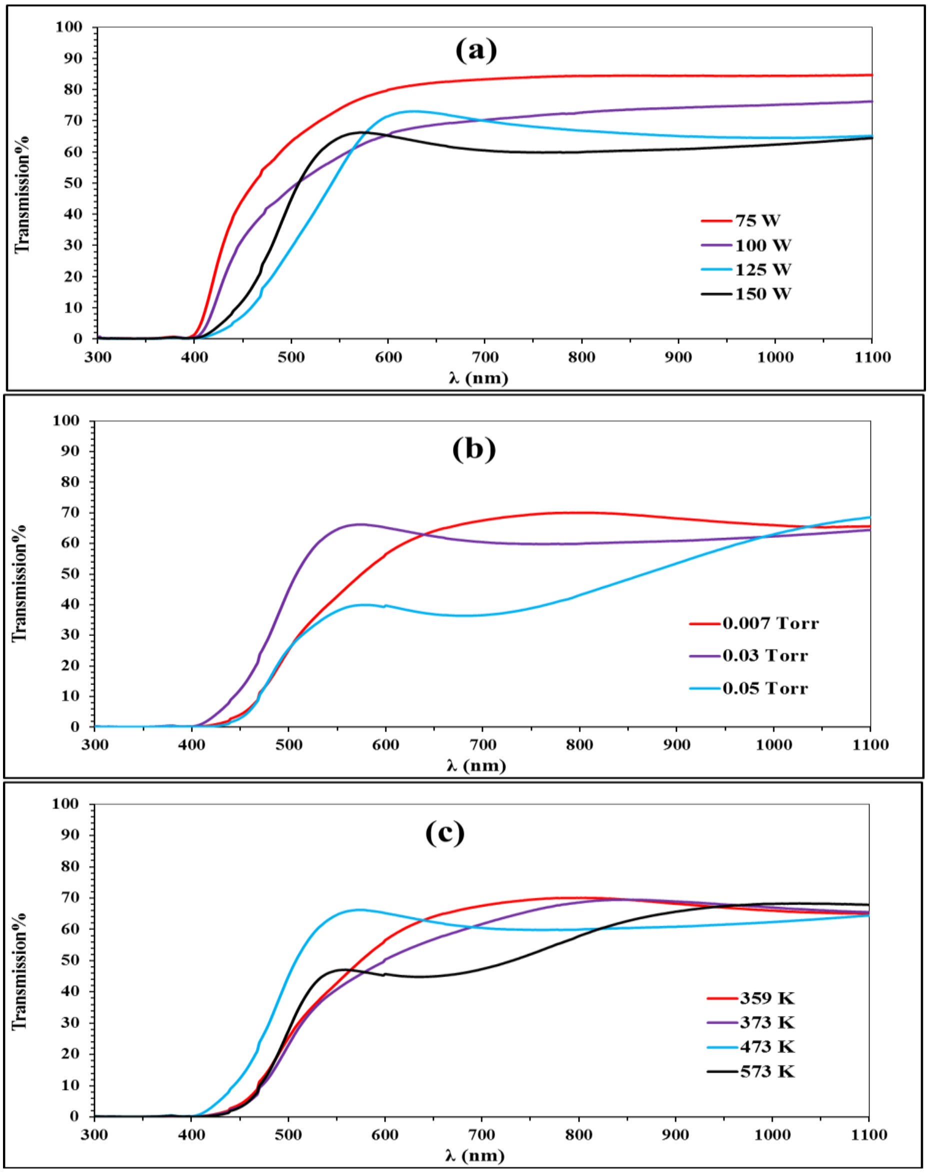

Fig.1: The transmittance of the (V_2O_5) thin film deposited at different sputtering power, working pressure and temperature substrate versus wavelength.

2. Optical Energy gap (Eg)

Energy gap was determined for all samples according to the absorption factor calculations (α) extracted from measured absorption data in the range (300-1100) nm. The average of these data was calculated and normalized as shown in Fig. 2 (a, b, c).

Absorption limits are the wavelength corresponding to an interruption in the diversity of the absorption coefficient of a material with a wavelength of radiation. It is also known as absorption limit, which is defined as a severe cutoff in the absorption spectrum of the substance. This occurs when the energy of the photon absorbs the energy of the atom cortex. Basing on this, the energy-band gap (E_g) was specific to the relationship between $(\alpha h\gamma)^2$ and (hγ), and the data of (E_g) was between 2.7 and 3.02 eV. Using the following equation [19]:

$$\alpha h\gamma = A(h\gamma - E_g)^n \qquad (2)$$

The value of n was determined to be about 0.5, which evidence that the energy band gap is direct.

The energy gap values depends in general on films crystal structure, the arrangement and distribution of atoms in the crystal lattice, also it is affected by crystal regularity. Eg value is calculated by extrapolation of the straight line of the plot of $(\alpha h\nu)^2$ versus photon energy for the different sputtering power of V_2O_5 films. It is observed that the optical band gap of the films decreased from 3.02 to 2.90 eV with the increase of RF power from 75 to 150 W, as shown in fig. 2 a and Table 1. The decrease of the optical band gap of thin films deposited with increase RF power could be due to the oxygen depletion from the growing surface and, hence the oxygen vacancies. Excess electrons are localized at the empty 3d orbitals of vanadium atoms which are closer to the oxygen vacancy and thus localized states are developed in the band gap and hence a decrease in the band gap energy [20].

From Fig. 2b and Table 1, the V_2O_5 thin films have the energy gap in the range (2.8 to 2.7) eV, it can be observed that (E_g) is decreasing with the increase of pressure. This is because of the increase in the carrier concentration which results in filling the bottom of the conduction band that leads to "the decrease in the hole between (C.B.) level and (V.B.) level that leads to zoom out the energy gap band. This indicates that the is caused by deviations from the ideal single crystal structure i.e., oxygen vacancies, interstitial atoms, and dislocations acting as conducting electron donors [21].

Fig. 2c and Table 1. show the optical band gap of the films which decreases with increase in substrate temperature in the range (2.8 to 2.7) eV. The decrease of the optical band gap of thin films deposited at high (Ts) may be due to the formation of oxygen ion vacancies in the films and thus create localized energy states in the band gap [22]. The relatively high value of band gap can be caused by high degree of non-stoichiometric disorders in the film. These results were also close to the results in references [23, 24].

Table 1 shows in general, the optical constants for thin films decreasing with increasing power, pressure and substrate temperature.

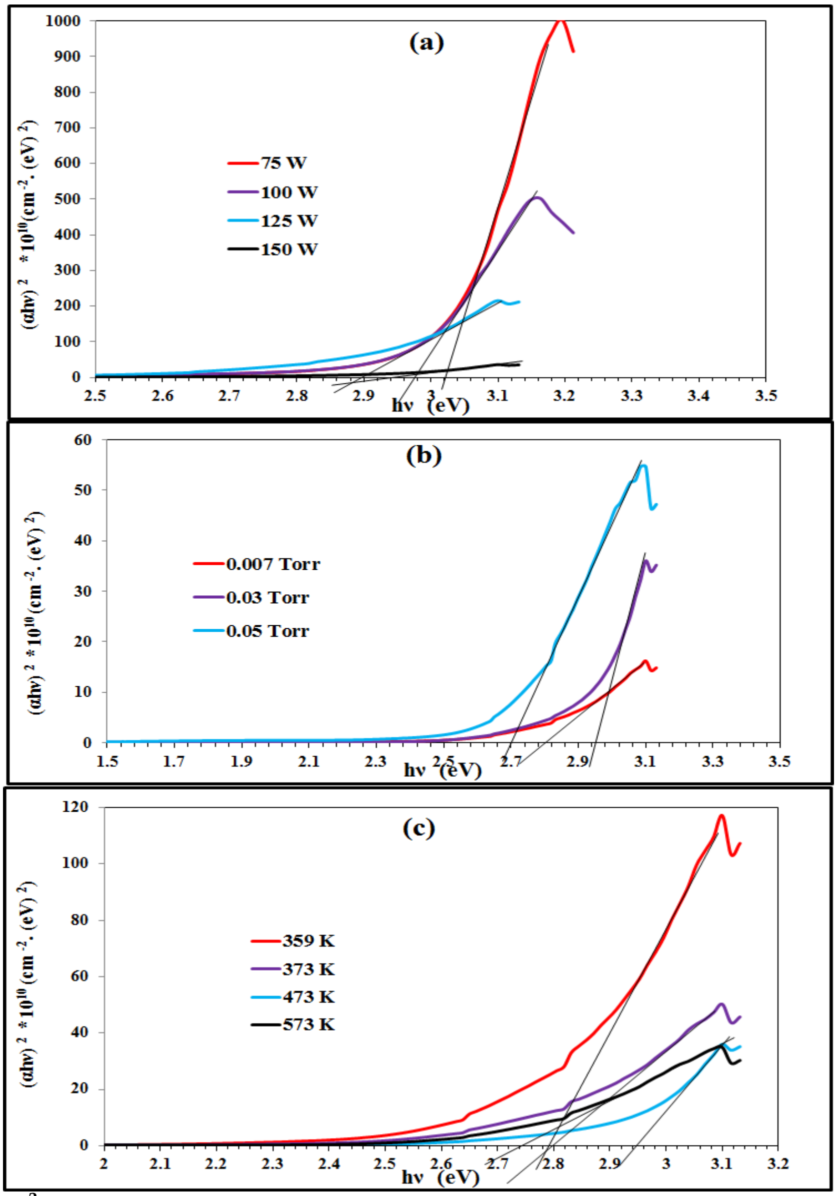

Fig. 2: $(\alpha h\nu)^2$ as a function of photon energy of (V_2O_5) thin film at different sputtering power, working pressure and temperature substrate.

Table 1: Optical constants (at λ=500 nm) and thickens for (V_2O_5) thin film at different sputtering power, working pressure and temperature substrate.

		T%	α (cm^{-1})	E_g (eV)	Thickness (nm)
P(W)	**75**	73.82	49924	3.02	60.8
	100	58.51	63048	2.98	85
	125	54.19	46164	2.90	132.7
	150	64.62	14085	2.95	310
Pressure (Torr)	**0.007**	42.82	16553	2.80	512.4
	0.03	64.62	14085	2.95	310
	0.05	40.09	33892	2.70	285.6
Temp. (K)	**359**	42.82	44525	2.80	190.5
	373	40.81	30602	2.80	292.9
	473	64.62	14085	2.95	310
	573	46.85	21237	2.74	375

Conclusions

In this study, the effect of RF power, working pressure, and substrate temperature on the optical properties of the V_2O_5 film on the glass substrate was also precipitated by RF magnetron spraying technique. The results showed that visible measurements of UV radiation showed that transmittance decreased with increasing RF power, and with working pressure and increase with increasing substrate temperature. The optical band gap of the films decreased with the increase RF power, working pressure, and substrate temperature.

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