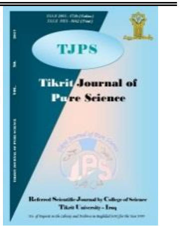
IASJ
المجلات الاكاديمية العراقية

Tikrit Journal of Pure Science

ISSN: 1813 – 1662 (Print) --- E-ISSN: 2415 – 1726 (Online)

Journal Homepage: http://tjps.tu.edu.iq/index.php/j



Investigate the Structural and Optical Properties of RF-Sputtered V_2O_5 thin films deposited at different Power

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https://doi.org/10.25130/tjps.v25i1.219

ARTICLE INFO.

Article history:

-Received: 22 / 6 / 2019
-Accepted: 10 / 11 / 2019
-Available online: / / 2019

Keywords: RF Sputtering, Vanadium pentoxide, Structural and Optical properties

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ABSTRACT

In this work, the structural and optical properties of V_2O_5 have been presented. Thin films were manufactured by the RF magnetron sputtering process. The nanostructures and some optical properties of deposit thin films at different sputtering RF power in a plasma chamber were investigated. The structural investigation was performed with X-Ray Diffraction (XRD) measurements and Atomic Force Microscopy (AFM). The results obtained from both methods have revealed that as-deposited films were polycrystalline in nature. The texture of the films was observed that , the crystallite and grain size were increased with increasing the sputtering power. Optical properties were determined by transmission measurements in the spectral range from (250 to 1100 nm) . An Optical energy gap of sputtered films and its dependency to sputtering power of plasma have been measured. It was found that the energy gap decreased with increasing the used power. The energy band gap was found to be in the ranged of (3.02 eV to 2.90 eV) when the sputtering power varying from (75 nm to 150 Watt).

Introduction

Multivalency, thermal and chemical stability, and excellent thermoelectric properties are characteristics that make vanadium pentoxide (V_2O_5) a favourable material for window glazing, optoelectronic electrochemical, and microelectronic device. V_2O_5 thin films have found diverse applications in technological fields, such as thermal and phase dependent electrical switches, optical switches, lithium batteries, electronic information displays, artificial muscles, smart windows, memory devices, and infrared detectors [1-4]. Vanadium Oxide is a material that shows a phase transition of semiconductor to metal when is heated around of a critical temperature. For the V_2O_5 compound , the phase transition occur at 257+5^{O}C [1]. As V_2O_5 has oxygen content more than other vanadium oxides, it shows that more transparency in the infrared region and is typically yellowish in colour [5]. Growth conditions greatly affect the microstructure and optical properties of V_2O_5 films [6]. It was found that, when raising the deposition temperature of substrate from (259 to 573) K the optical band gap of films decreased from (2.47 to 2.12 eV) for amorphous and crystalline films respectively[6]. Thin films of V_2O_5have been prepared by using several techniques, such as radiofrequency, sputtering[7], D.C-magnetron sputtering[8],flash evaporation[6], sole-get technique [9], plasma enhanced chemical vapour deposition [10] and pulsed laser deposition (PLD) [11,12,13]. In this work we have studied the structural and optical properties and constant properties of V_2O_5 thin films deposited on to glass substrates by RF magnetron sputtering.

Experimental details

In our study, thin films of V_2O_5 were deposited on glass substrates by using R.F sputtering technique. The thin film was deposited by R.F sputtering of a V_2O_5 target (99.99 % purity) with diameter (5cm) and a thickness (3mm) and then sintered it for (4hour) at 500˚C with different condition (power=75-150 Watt), (sputtering time=2h, pressure = 7.4×10^{-3}mbar). These preparations are important to improve the sputtering and excellent sample preparation. The substrates glass are on anode electrode and V_2O_5 target on cathode electrode, and the distance between the target and substrate was maintained at 4cm, the depositions were carried out at constant argon flow rate of 40 sccm (Centimetre standard cube). The chamber was closed to obtain the suitable vacuum in two stages, the first stage by using rotary pumps to attain pressures as low as (10^{-2} mbar), the next stage was reached by using pumps to obtain a vacuum equal (10^{-5}mbar), then sputtering gas such as argon gas (inert gas, heavy gas atoms, no reaction with target material) was allowed to flow in the chamber via a pressure value and pressure gauges to monitor the operating pressure in the system to about (5×10^{-2}mbar) read by the pirani pressure gauge , and applied voltage (1000 V) between the electrodes using a power supply until creating a glow discharge and plasma is creation, plasma creating is centred as small beam shape . Glow discharge was created at this low pressure which is called unusual negative glow, as a result of ionization the charged particles which include positive argon ions will knock target surface to take off atoms from the target by momentum exchange between argon ions and target atoms, at the end these atoms collected on substrate surface to form the film.. Sequentially, The crystal structures of the deposited film were measured by X-ray diffraction (XRD) using a (Shimadza XRD - 6000) diffract meter, employing CuK_α (1.54 Å) radiation. The optical and surface topography of properties of the films done by UV-VIS Spectrometer (Shimadzu uv-1800) and Atomic Force Microscope AFM type (NT- MDT NTEGRA) , respectively .

Results and discussions

In Table (1), the thickness of R.F sputtered V_2O_5 thin films were determined using optical interferometer method. The thickness of V_2O_5 thin films are presented as a function of power. Present results are in agreement with published work [14], since the roughness of the deposited film is increasing with thickness.

Table (1) represents the Thickness of Vanadium pentoxide for different power

Power (Watt)	Thickness (nm)
75	60.88
100	137
125	310
150	512

Figure (1) shown XRD patterns of V_2O_5 thin films, deposit at different R.F sputtering powers on glass substrate. The analysis of XRD patterns demonstrate that V_2O_5 thin films with low power were amorphous nature i.e at (75 and 100)Watt, the deposited (V_2O_5) thin films become polycrystalline structure when deposited at high power i.e, at (125and 150Watt) with (200), (001) and (011) direction identify with standard peaks [card. No(96-901-2222)]. It is noticed that with increasing the working sputtering power, the diffraction peaks of V_2O_5 was increased and becomes sharper[15]. The increased intensity of peak may be due to an increase in the crystallite size mention previously shown in Table (2). All the XRD patterns show same behavior where the FWHM decreases with increase of the RF power with increasing the crystallite size. The crystallite size, D, determined from the XRD measurements by Scherer's formula[15].

$D = K\lambda / \beta\cos\theta$.........(1)

D: is the crystallite size (C.S)

K: is a constant (0.94)

θ: is the Bragg's angle

λ is the X-ray wavelength (1.546A°),and β is full width half maximum (FWHM) of the preferential plane .

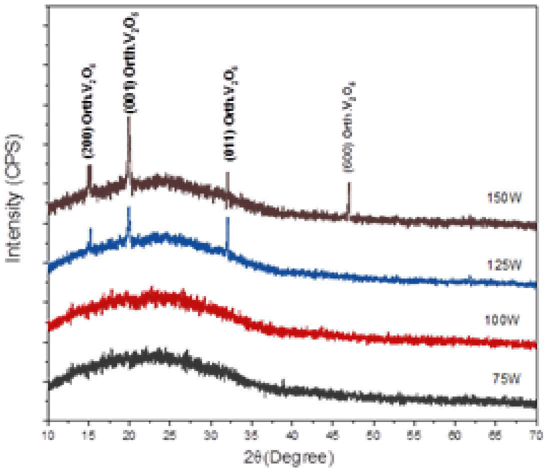

Fig. 1: X-ray diffraction patterns for V_2O_5 thin film deposited by different R.F powers

Table (2) : Structural data for V_2O_5 thin film deposited at different R.F power.

Power (W)	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp. (Å)	C.S (nm)	d_{hkl} Std. (Å)	hkl	card No.
75	**Amorphous**						
100	**Amorphous**						
125	15.0532	0.4654	5.8808	17.2	5.7720	(200)	96-901-2222
	20.1134	0.2990	4.4418	27.0	4.3830	(001)	96-901-2222
	32.0850	0.2992	2.7939	27.6	2.7685	(011)	96-901-2223
150	15.1197	0.3989	5.8550	20.5	5.7720	(200)	96-901-2222
	20.1134	0.2800	4.4418	28.8	4.3830	(001)	96-901-2222
	32.9012	0.2327	2.7911	35.8	2.7685	(011)	96-901-2223
	47.0490	0.2700	1.9260	32.1	1.9240	(600)	96-901-2222

Figure 2 shows three - dimensional (3D) images of AFM for (V_2O_5) films deposited on glass substrate to under the influence of different R.F power. The images at the low power confirm that the films are uniform and the substrate surface is well covered with grains, that are nearly uniformly distributed. The particles formation observed in deposited films microstructure and some small grains agglomerated to form greater grains as a consequence of increasing power. A Surface roughness of V_2O_5 films increased with the increasing of sputtering power because of increasing the thickness of the film and this is can be explained to more creation of localized state in the structure of the film. The increment in sputtering power promotes the growth of crystalline and induces an improvement in crystallinity of the film. The film will suffer from the bombardment of highly energized particles, resulting in internal defects of the film. This behaviour is similar and agreement with the results obtained in references. V_2O_5 thin films deposited at sputtering power of (75-150 Watt) clearly show that there is a remarkable change in surface morphology and roughness of the deposited films depending on the sputtering power as showing in Figure (2) and Table (3).The most likely reason for the dramatic topographic change is the recrystallization in the films due to substrate thermal increment which is in agreement with the previous results[16].

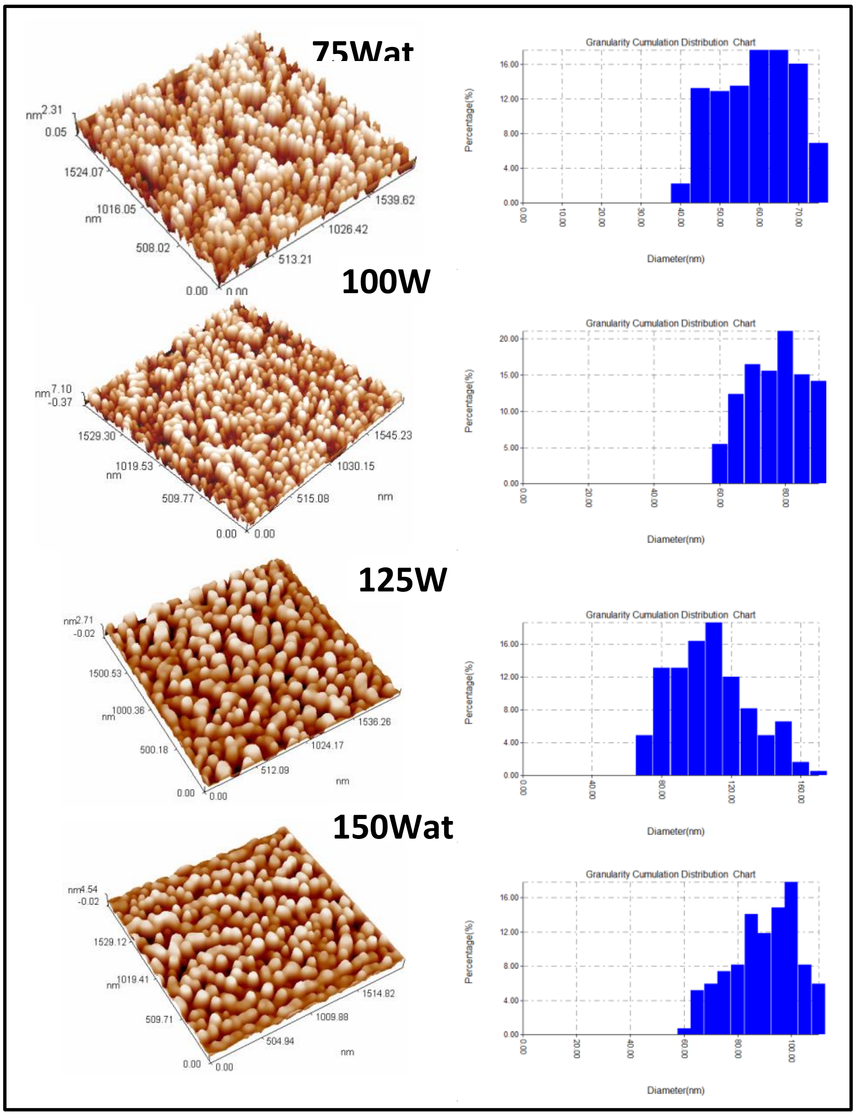

Fig. 2: AFM images of V_2O_5 thin films with granularity and the height distribution analysis image at different RF power.

Table (3) : Surface morphology data for V_2O_5 thin film deposited at different RF power.

Power (Watt)	Average grain size(nm)	Root mean square (nm)	Average Roughness (nm)
75	56.66	0.652	0.565
100	74.27	2.16	1.87
125	102.73	0.729	0.6210
150	87.11	1.17	0.994

Optical analysis of V_2O_5 thin films deposited on glass substrates using different R.F sputtering power was studied from transmission percentage vs. Wavelength curve in the wavelength range (300 nm to 1100 nm), which is shown in figure 3.The transmittance pattern for all deposited thin films increases with increase of wavelength. On the other hand, in figure 3, the transmittance decreased to lower than 64.62% with the increase of RF power . The film deposited with sputtering power of (150W) showed the lowest optical transmittance, caused by increase of the surface roughness promoting the increase of the surface scattering of the light with increasing sputtering power.

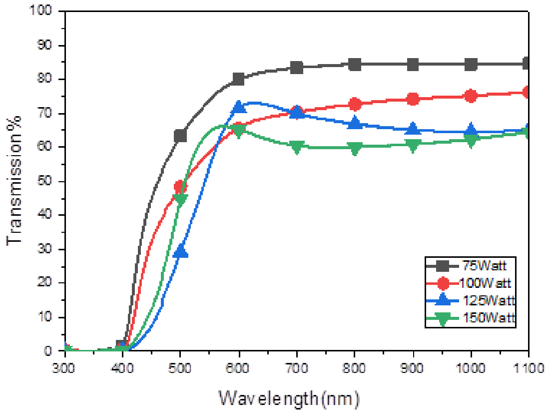

Fig. 3: Optical transmittance of the V_2O_5 thin films deposited at different sputtering power

Figure (4) shows that the absorbance spectra of V_2O_5 thin films at different sputtering power. It is obviously from the same figure that the films have high absorbance at short wavelength approximately at (390-510) nm and decreasing at long wavelength, because the incident photon cannot excited the electron and remove it from the valence band to the conduction band, because the energy of incident photon less than energy gap of semiconductor[17]. In addition, the increase of atoms absorbed optical radiation thus increases absorbance[18] .

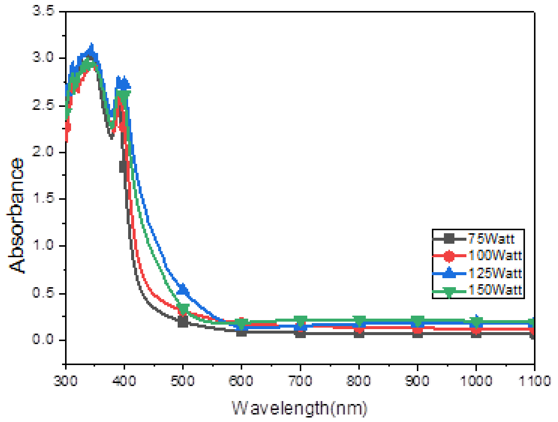

Fig. 4: The optical absorbance of V_2O_5 thin films deposited at different sputtering power .

From the plot of $(\alpha h\nu)^2$ vs. hν the band gap is determined by extrapolating the straight line portion of the plot to the energy axis. Figure (5) shows that the intercept on energy axis gives the value of band gap energy which was found to be (3.02 to 2.90 eV) with the increase of power from 75 to 150 W, which is showing in Table (4). The decrease of the optical band gap with 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 [19].

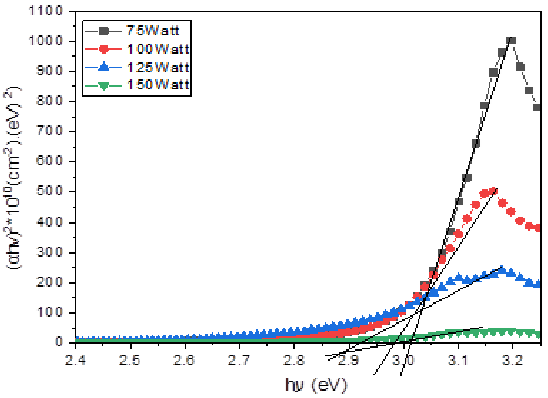

Fig. 5: $(\alpha h\nu)^2$ as a function of photon energy of V_2O_5 thin film at different sputtering power.

The refractive index was evaluated from the transmittance measurements and its variation with wavelength. The refractive index for V_2O_5 thin films deposited on glass substrates at different sputtering power from (75 to 150) Watt was found to increases form(2.128 to 2.363), as shown in figure (6) and Table (4). The higher value of the refractive index may probably due to high porosity and surface roughness of the films, which is mainly attributed to larger grain size[20].

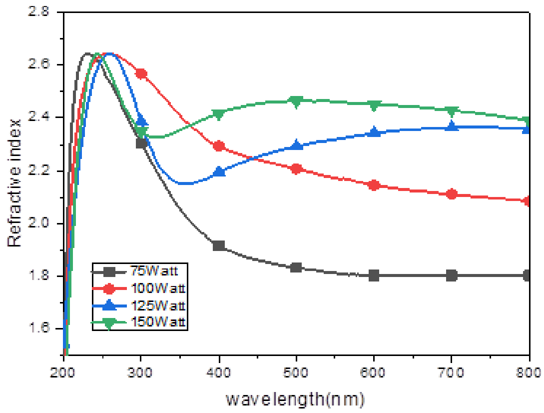

Fig. 6: The refractive index (n) as a function of wavelength (λ) For V_2O_5 thin films deposited at different sputtering power.

Table (4) : Optical Constants for (V_2O_5)) thin film at different sputtering power

Power (W)	Thickness (nm)	T%	n	Eg (eV)
75	60.88	73.82	2.128	3.02
100	137	58.51	2.489	2.98
125	310	54.19	2.560	2.90
150	512	64.62	2.363	2.95

Conclusion

The influence of the operation RF sputtering power on structural and optical properties of V_2O_5 thin film have been investigated. The XRD deposited thin films are amorphous converts polycrystalline at high sputtering power of the films and the crystalline size increased from (~12 to 35 nm). The increase in surface roughness of V_2O_5 thin films with higher sputtering power .The optical transmission spectra of the as deposited films deposited by varying RF power have increased in transmission with increase in RF power. The indirect optical band gap is found to decrease with increase in RF power equal to(3.02 to 2.95eV) which confirm these are good semiconducting films and Sensing applications.

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دراسة عن الخواص التركيبية والبصرية للغشاء الرقيق V_2O_5 ذي الترددات الراديوية المرسبة بطاقات مختلفة

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الملخص

في هذا العمل، تم عرض ودراسة الخصائص التركيبية والبصرية للأغشية الرقيقة لخامس اوكسيد الفناديوم V_2O_5 المحضرة بطريقة بلازما الترذيذ الماكنتروني للترددات الراديوية. فحصت البنى النانوية وكذلك بعض الخصائص البصرية للأغشية الرقيقة المحضرة بقدرات مختلفة لحجرة بلازما الترذيذ. تم إجراء التحقيق التركيبي والطبوغرافي باستخدام قياسات حيود الأشعة السينية (XRD) ومجهر القوة الذرية (AFM). كشفت النتائج التي تم الحصول عليها من كلتا الطريقتين أن الأفلام المحضرة كانت متعددة التبلور. وقد لوحظ من خلال التركيب البلوري للأغشية انه حجم التبلور والحبيبات البلورية ازداد مع زيادة طاقة الترذيذ . تم تحديد الخصائص البصرية عن طريق قياسات النفاذية البصرية في المدى الطيفي من 250 إلى 1100 نانومتر. قيست فجوة الطاقة البصرية للأغشية المرذذة واعتماديتها على قدرة الترذيذ للبلازما، ووجد أن قيمة فجوة الطاقة تقل بزيادة قدرة الترذيذ المستعملة. تم ايجاد قيمة فجوة الطاقة بحدود3.02 الى 2.90الكترون فولت عندما تتراوح قدرة الترذيذ المستخدمة من 75 واط إلى 150 واط.