Effect of Thickness on Some Optical Properties of Fe_2O_3 Thin Films Prepared by Chemical Spray Pyrolysis Technique

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Abstract

The paper reports the influence of the thickness on the some optical properties of Fe_2O_3 thin films,which were prepared by chemical Spray pyrolysis technique on glass substrate heated to 400˚c.The thickness of thin films (250,280,350)nm were measured by using weighting method. The optical properties include the absorbance and reflectance spectra,extinction coefficient,and real and imaginary part of the dielectric constant.The result showed that the optical constant($k,\varepsilon_r,\varepsilon_i$)decreased with the increase of the thickness.

Keywords : Fe_2O_3, Spray pyrolysis technique, Optical properties

Introduction

Fe_2O_3 is one of the most important transition metal oxides with a bandgap of 2.2 eV. It received an extensive attention due to its good intrinsic physical and chemical properties, such as its low cost, stability under ambient conditions, and environmentally friendly properties [1] .Due to these properties, Fe2O3 nanostructures can have wide applications in many fields including magnetic recording materials, catalysis, optical devices, gas sensors, photochemical and pigments.[2] .

Thin films of Fe_2O_3were prepared using many deposition techniques such as Aerosol – assisted chemical vapor deposition (AAC-VD)which is simple to operate and very versatile.[3] and of Fe_2O_3were prepared using technique pulsed laser deposition(PLD)[4],Sol-gel[5],Sputtering [6,7] and from aim of research Rajendra N.Goyal et al[8]. reported the preparation and characterization of iron oxide nanocrystalline thin films by ultrasonic spray pyrolysis technique iron oxide films were grown on quartz substrate at different deposition temperatures varing from(400-700)˚C.So the notice of both orientation and the size of the crystalline thin films revealed the magnetite to hematite phase transformation with on increase in substrate temperature and they showd the deposited thin films exhibited the estimated direct band gap (Eg) in range 2-2.2eV ,in addition to that, the films deposited on quartz substrate at different temperatures had low conductivity and thus are not suitable for electrochemical sensing .While Qing Wei et al.[9] were reported thedifferent morphologies of$\alpha-$Fe2O3 films including particles,porous,granular and nanosheets , which have been prepared by directly oxidizing the as-deposited Fe films in air ,also the effect of the heating temperature ,duration of time and rate of heating were reported by adjusting the rapidly oxidation condition .They noticed that ,one can easily control the morphology of α - Fe2O3filmsfrom clusters of particles to porous films ,inaddition ,through the oxidation process at the low heating rate , α- Fe2O3 nanosheets can easily fabricated on the Si subsitrate .

Expermintal

Thermal Spray pyrolysis method is basically a chemical process, which consists of a solution that is sprayed into a substrate held at high temperature, where the solution reacts forming the desired thin film.Fe_2O_3 films were grown onto glass substrates, using a typical spray pyrolysis system. The spray solution was prepared by mixing the appropriate volumes of ferrite nitride dehydrate ($Fe(NO_3)_3.9H_2O_3$) (molecular weight404.02 g/mol)which is a solid material with white color when it is completed dray while it has an orange color when it is dissolved in the water . The solution was prepared with (0.2 mol/L) by mixed (8.0804 gm) from ($Fe(NO_3)_3.9H_2O_3$) with (100ml) deionized water in magnetic stirrer to facilitate the complete dissolution of the solute in the solvent to obtain clear solution. Finally, the solution was spray in to a spray pyrolysis deposition chamber. The flowing equation is used to obtain the required weight according to the calibration above:

$$M=\left(\frac{Wt}{Mwt}\right).\left(\frac{1000}{V}\right) \qquad (1)$$

Where :M is the concentration molars , V is the volume of water, Wt is the required weight and M_{Wt} is the molecular weight of ($Fe(NO_3)_3.9H_2O_3$).

The following chemical equation is used to obtain the Fe2O3 thin films:

$$4Fe(NO_3)\rightarrow 2Fe_2O_3 + 12NO_2\uparrow + 3O_2 \qquad (2)$$

The substrate temperature was fixed at 400ºC and was controlled within ± 5 ºC with carrier air pressure ($10^5 N/m^2$) , flow rate of solution ($10cm^3/min$) and the substrate to nozzle distance is 30cm.Spraying was done in short time intervals (15sec) ,subsequent the deposition is stopped about 5min in order to returned the temperature into its original value. Optical transmission data were obtained with an UV-Visible Shimadzu 3101 PC double beam spectrophotometer.The effect of the thickness on the optical properties was investigated.

Weighting Method

Ground glass is weighted before and after deposition completion of the re-depositionprocess and weighted again ,and weight difference ,which represents the weight of film material and the density of the material deposited area of the film can be calculated by the thickness of the thin film of the following equation :

$$\text{The thickness of the thin film} = \frac{\text{weight film material}}{\text{The thickness of the thin film material X area of the film}}$$

Results and Discussion

The absorption spectrum of Fe_2O_3 thin films in the spectral range (340-1100)nm was prepared at substrate temperature of 400C and different thickness is shown in Figs.(1).It is clear from this figure that the spectral characterization is affected by thickness. The optical absorption spectrum decreases as the wavelength extends toward the visible region. The absorption decreases significantly and from590-1100 nm becomes linear into the infrared region. The presence of an absorption tail between 590 and 1100 nm indicates probably the existence of sub-band gap states[10].

Also, we can observe from Fig.(1) that the Absorbance increases with the increase of thickness and shifted to longer wavelengths. This may be attributed to the creation of levels at the energy band by increasing thickness and this leads to the shift of peak to smaller energies. Also we studied the spectrum of the reflectance as shown in Fig.(2). It is obvious that their behavior is increased up to 480nm and than decreses with increase of wavelength.

It can be observed that the reflectance increases with increasing of thickness this is attributed to the increase in the absorbance and decreases in the transmittance.

Optical constant of Fe_2O_3 thin films were studied with the help of Absorption spectra in the UV–Visible region.Fig (3) shows the extinction coefficient of Fe2O3 thin films recorded in the range(340-1100)nm at different thickness. We can observe from this figure that the extinction coefficient, in general, decreases with the increase of wavelength for all films. Also its value increases by the increase of thickness in the range(250,280,350)nm. This is attributed to the same reason mentioned previously in the absorption spectrum.

The fundamental electron excitation spectrum of the film was described by means of a frequency dependent of the complex electronic dielectric constant. The dielectric constant is defined as, $\varepsilon(\omega)=\varepsilon r(\omega)+i\varepsilon i(\omega)$ and real and imaginary parts of the dielectric constant are related to the n and k values. The ε1 and ε2 values were calculated using the formulas [11]
,

$$r(\omega) = n^2(\omega) - k^2(\omega)$$

$$i(\omega) = 2n(\omega)\ k(\omega)$$

The εr and εi values dependence of wavelength are respectively shown in Fig. 4 and Fig. 5. The εr values are higher than that of εi values. It is seen that the εr and εi values decrease with increasing of thickness.

Conclusion

Fe_2O_3 thin films were prepared using spray pyrolysis technique onto glass substrate at temperature equal to 400˚C and different thickness (250,280&350)nm .From UV-Visible spectrometer , the absorption spectrum was measured .Also, the optical constant such as extinction coefficient real and imaginary dielectric constant were determined and indicated that they decreased with the increase of the wavelength and the thickness.

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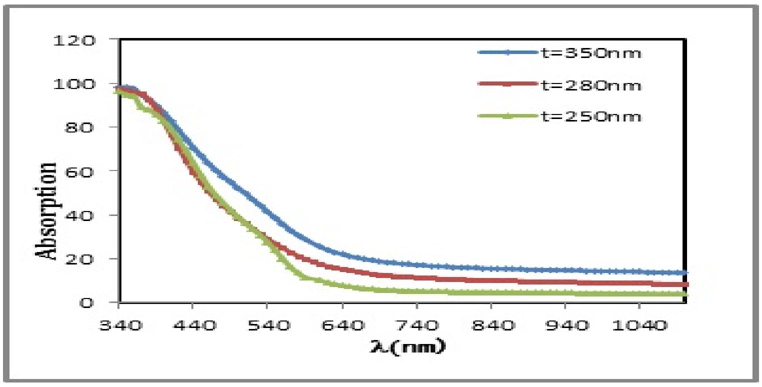

Fig.(1): Absorption spectrum as a function of wavelength for Fe_2O_3 films at different thickness

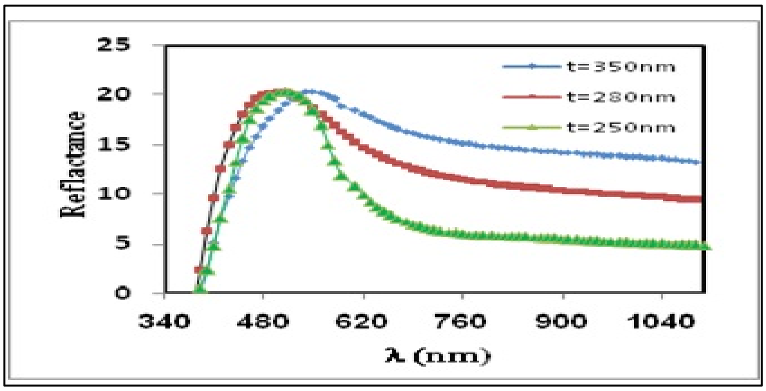

Fig.(2): Reflectance spectrum as a function of wavelength for Fe_2O_3 films at different thickness

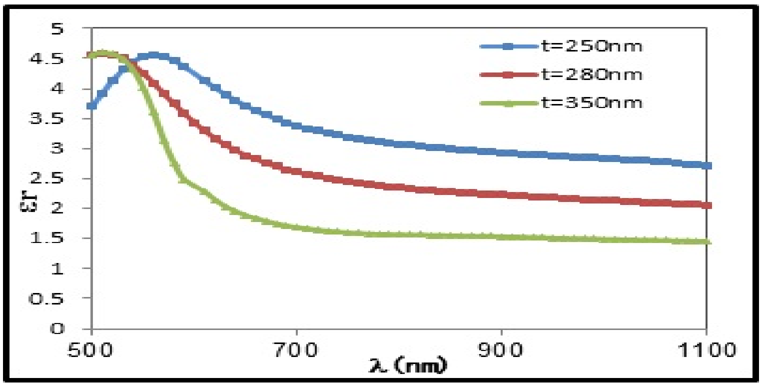

Fig. (3): Extinction coefficient as a function of wavelength for Fe_2O_3 thin films at different thickness

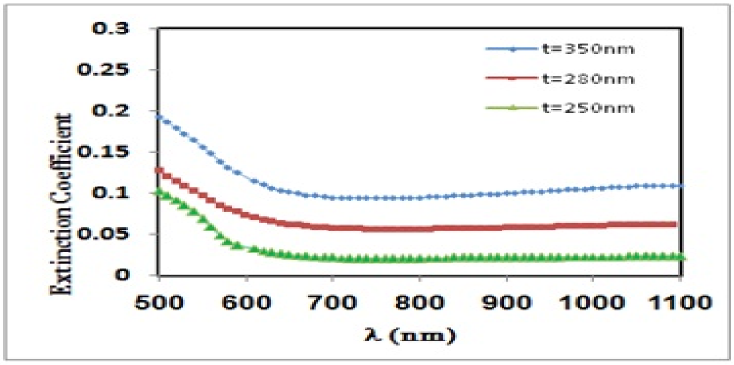

Fig.(4) Variation of ε_r as a function of wavelength forFe$_2$O$_3$films at different thickness

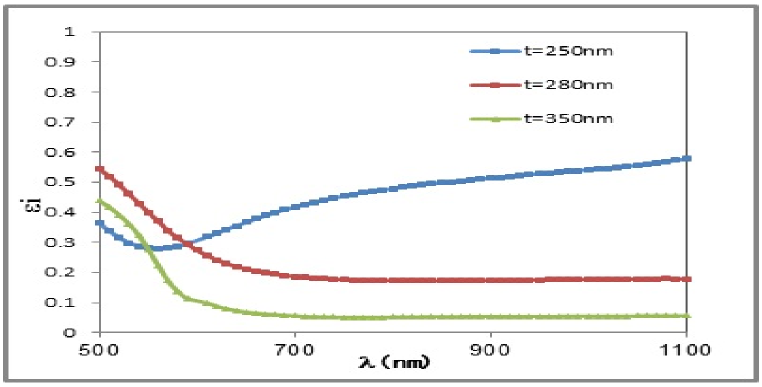

Fig.(5) Variation of ε_i as a function of wavelength for Fe_2O_3films at different thickness

تأثير السمك في بعض الخواص البصرية لأغشية Fe_2O_3 الرقيقة المحضرة بطريقة التحلل الكيميائي

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الخلاصة

حضرت أغشية Fe_2O_3الرقيقة بطريقة التحلل الكيميائي على أرضيات زجاجية وبدرجة حرارة 400°c وبسمك متغير من 250,280,350)nm)وقيس سمك العينات المستخدمة بالطريقة الوزنية .الخواص البصرية تم تحديدها بأستخدام المطياف الخاص بدراسة الخواص البصرية وللمدى من 340-1100)nm)كذلك درست الثوابت البصرية التي تتضمن معامل الخمود ،ثابت العزل بجزئيه الحقيقي والخيالي .يحدد معامل الخمود من القياسات المباشرة للامتصاصية والانعكاسية .وتشير النتائج الى أن الثوابت البصرية للاغشية الرقيقة تقل بزيادة السمك.

الكلمات المفتاحية : ثلاثي أوكسيد الحديدوز ، ،التحلل الكيميائي ،الخواص البصرية