Effect of Sb-doping on Optical Properties of Fe_2O_3 Thin Films

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Abstract

Fe_2O_3 and Sb doped Fe_2O_3 thin films with deferent percentage were intended via spray pyrolysis technique. Effect of Sb doped on optical parameters was studied utilizing Double beam spectrophotometer in order to locate transmittance spectra. Absorbance was raised with accretion of Sb concentration, same behavior was noticed for extinction coefficient. Energy gap was decreased from 3.25 eV for undoped film to 3.0 eV on 3% Sb-doping., while Reflectance, absorption coefficient and refractive index were shown the opposite behavior by decrease their values with increasing of Sb.

Key words: Fe_2O_3, doping, optical parameters, Energy gap.

تاثير التشويب بالانتمون في الخصائص البصرية لاغشية اوكسيد الحديديك الرقيقة

حضرت اغشية اوكسيد الحديديك واكسيد الحديدك المشوب بنسب مختلفة بطريقة التحلل الكيميائي الحراري. درس تاثير التشويب على الخواص البصرية باستخدام مطياف الاشعة المرئية – فوق البنفسجية للحصول على اطياف النفاذية . تزداد الامتصاصية بزيادة تركيز الانتمون ، نفس السلوك فيما يتعلق بمعامل الخمود . انخفضت فجوة الطاقة بزيادة تركيز الانتمون من 3.25 eV الى 3 eV عند تركيز 3% ، بينما انخفضت الانعكاسية ، معامل الامتصاص ومعامل الانكسار بزيادة تركيز الانتمون.

الكلمات المفتاحية : اوكسيد الحديديك ، االتطعيم، الخواص البصرية ، فجوة الطاقة

Introduction

Rocks and soils are sources for ultimate firm iron oxide [1, 2]. Hematite is based upon hexagonal close packed of O^{2-} ions with two-thirds of octahedral sites occupied by Fe^{3+} ions. [1, 2]. This oxide was suitable for many applications like photocatalyst, photoanode, gas sensor, [3-12]. α-Fe_2O_3 is n-type semiconductor, it is a stable, nontoxic, corrosion-resistant, low cost and abundant. These features render it suitable for numerous promising applications, such as photocatalysts [13-15]. Doping of hematite can be useful in enhance the optical and structural parameters [1,2]. The process of doping plays a role in occupying substitutional and interstitial octahedral sites [16-17]. This work was subjected to prepare Fe_2O_3:Sb and study their optical properties.

Experimental

Iron chloride ($FeCl_3.6H_2O$) of 0.1M as matrix material and Antimony trichloride $SbCl_3$ (supplied from BDH Chemicals) which used as a doping agent was added to the matrix solution to obtain doping ratio of 1% and 3 %. This aqueous solution was sprayed onto a preheated glass substrate kept at 400°C. The spray pyrolysis achieved by using glass atomizer, which has an output nozzle of 1 mm. optimal conditions to obtain homogenous films obtained at the following parameters, spray time was 10 sec. stopping period was 1.5 min minutes, in order to avert immoderate substrate cool. Carrier gas (filtered compressed air) was preserved at a pressure of 10^5 N/m^2, the space between nozzle and substrate was 28 cm, solution flow rate 5ml/min. Samples thickness was measured via gravimetric method and its values was around 400 ± 30 nm. Optical transmittance and absorbance were recorded in a wavelength range of (300-900nm) using UV-Visible spectrophotometer (Shimadzu 1640).

Results and Discussion

Absorbance spectra of the pure Fe_2O_3 and (1, 3) wt. % Sb: Fe_2O_3 thin films were displayed in Fig. (1). it can be noticed that absorbance (A) decreases with the increased in wavelength and increases with increasing Sb concentration.

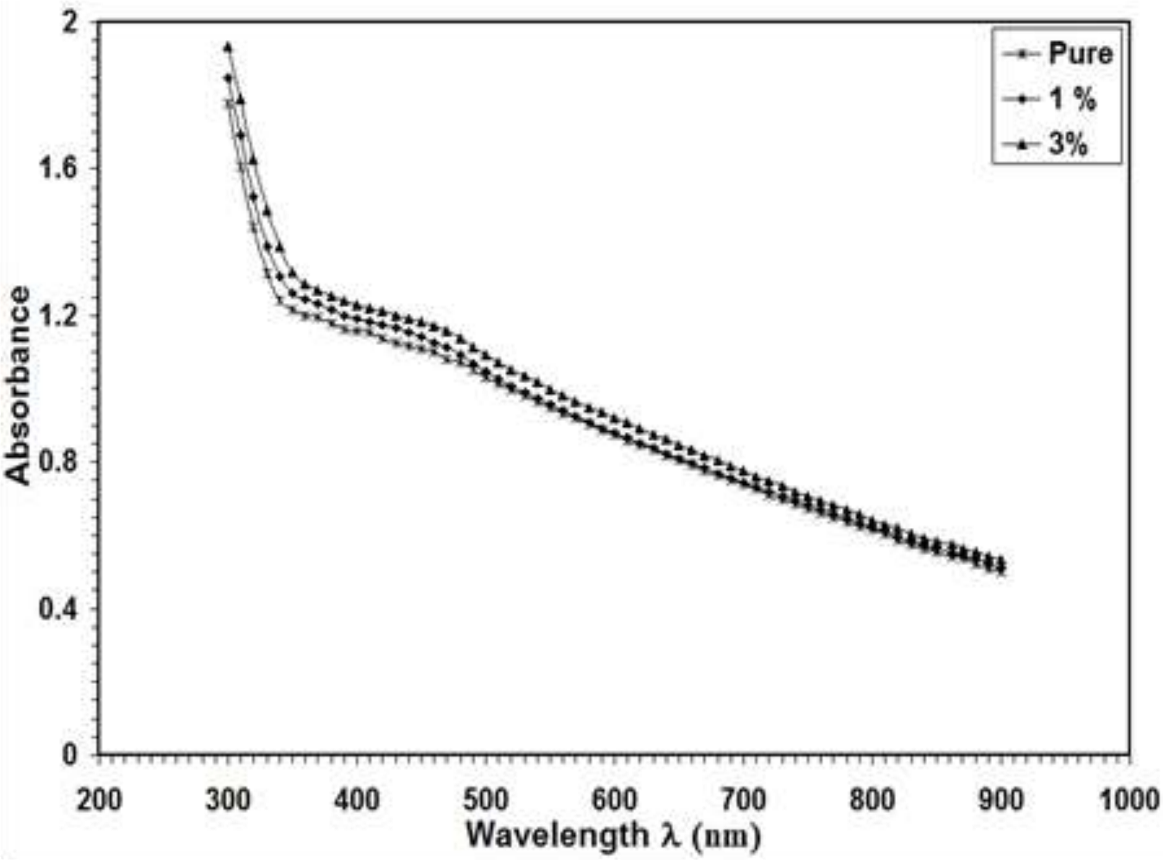

Fig.1: Absorbance with wavelength for Fe_2O_3 thin films and different doping of Sb concentration.

Absorption coefficient (α) was evaluated from absorbance using the relation [18];

$$\alpha = \frac{2.303A}{t} \qquad (1)$$

Where (A) is Absorbance, (t) is thickness. Fig. (2) Shows the relation of α versus wavelength. It can be noticed that absorption coefficient increases by increase Sb content and progressively increased with wavelength.

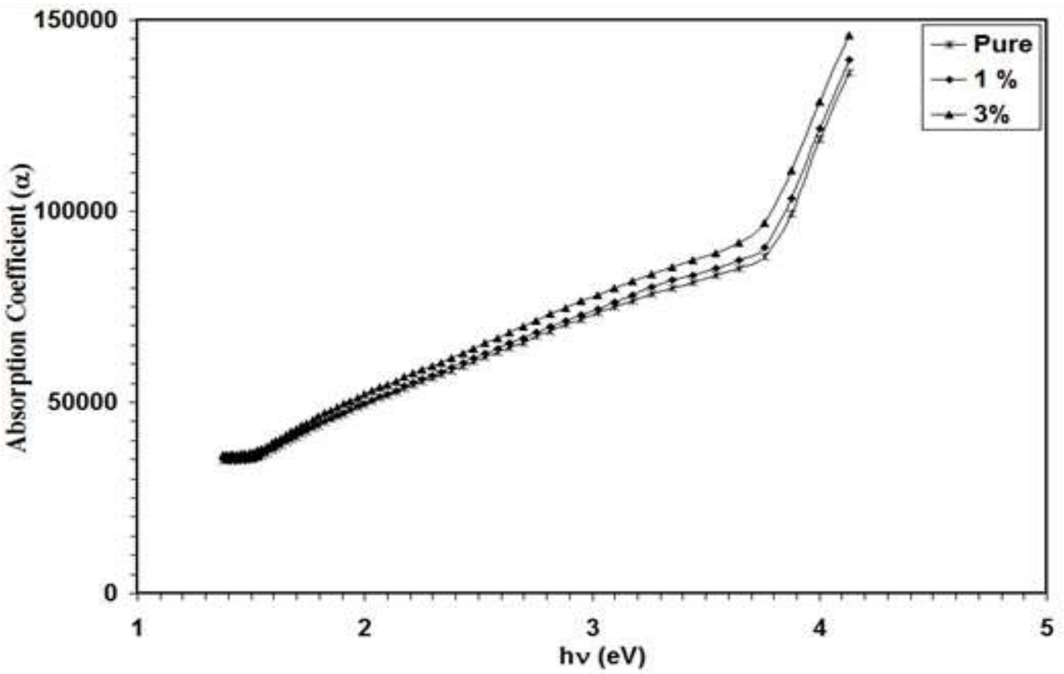

Fig. 2: α against wavelength for Fe_2O_3 thin films and different doping of Sb concentration.

Figures (3, 4, 5) show that the energy gap decreases with increasing Sb-doped Fe_2O_3 thin films from 3.25 eV for undoped Fe_2O_3 film to 3.1 eV for 3% Sb-doped Fe_2O_3 thin films.

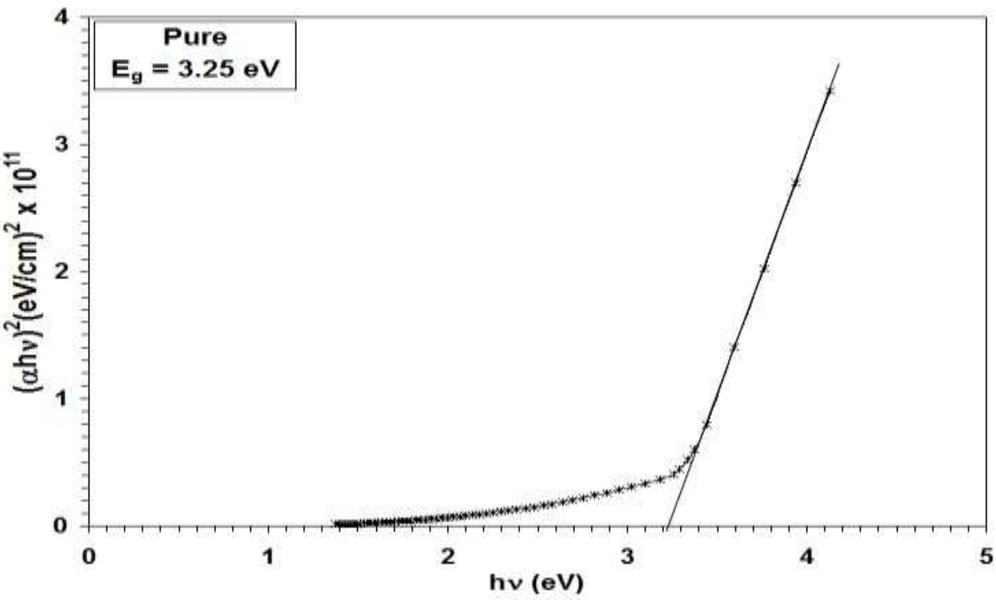

Fig.3: $(\alpha h\upsilon)^2$ against photon energy for Fe_2O_3 thin films.

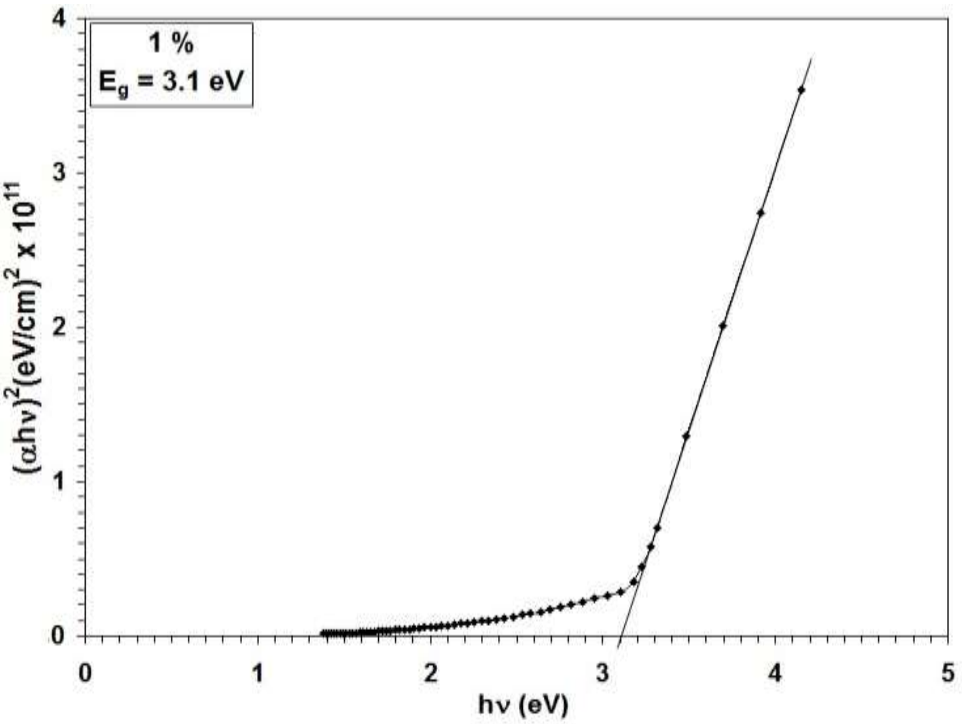

Fig.4: $(\alpha h\upsilon)^2$ against photon energy of Fe_2O_3:1%Sb concentration.

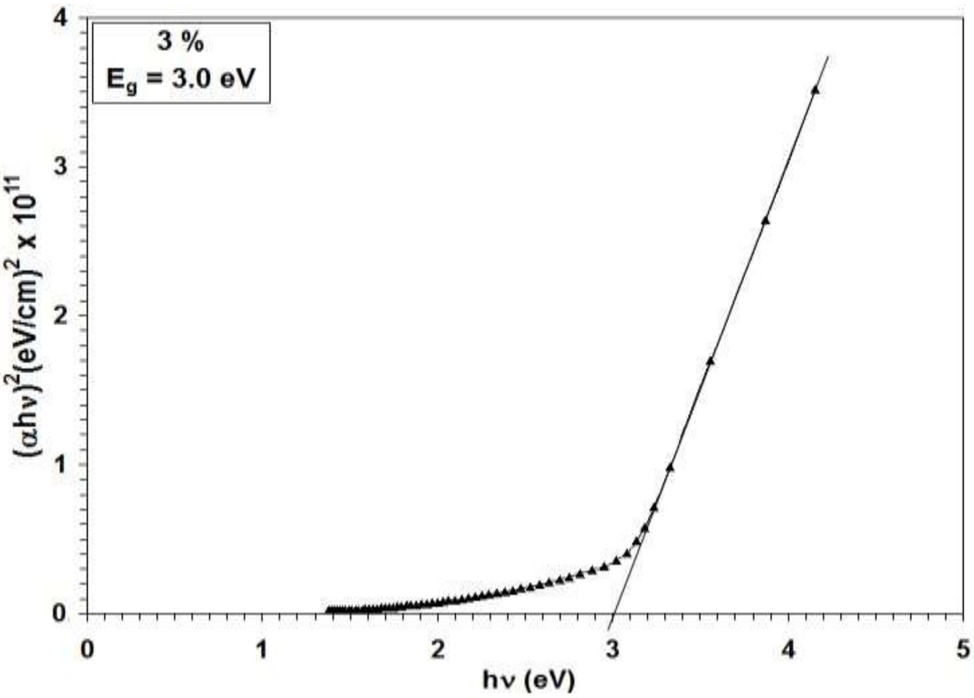

Fig.5: $(\alpha h\upsilon)^2$ against photon energy of Fe_2O_3:3%Sb concentration.

The extinction of electromagnetic wave in material is represented by extinction coefficient (k) and could be calculated by the next formula [19]:

$$k = \alpha\lambda / 4\pi \qquad (2)$$

where (λ) is the wavelength. It can be seen that k decreased with increasing Sb contents for the as deposited films as shown in Fig. (6).

Reflectance (R) was obtained by the next formula [20]:

$$A + T + R = 1 \qquad (3)$$

Where T is the transmittance. Reflectance spectra of Fe_2O_3 with different doping of Sb: Fe_2O_3 thin films are shown in Fig. (7). It shows that reflectance increases with increasing Sb contents.

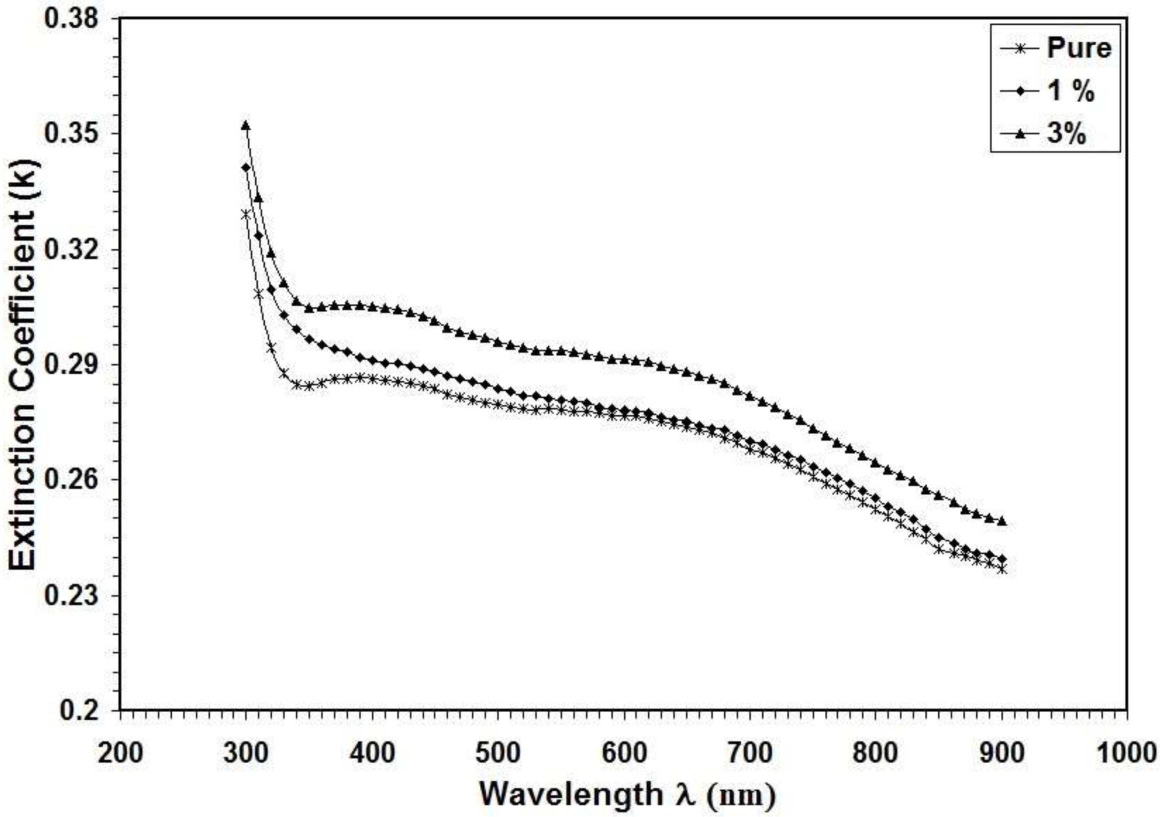

Fig.6: k for Fe_2O_3 with different doping concentration of Sb:Fe_2O_3 thin films versus wavelength.

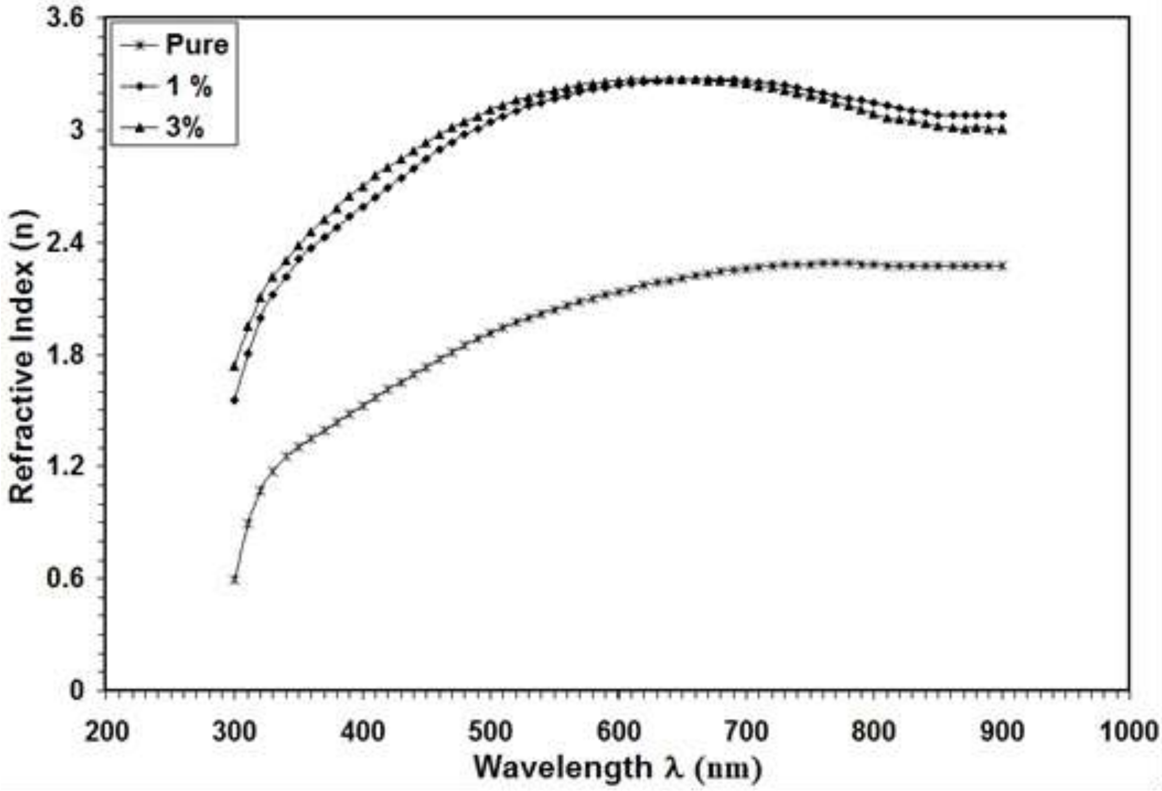

Fig. 7. Optical reflectance spectra for Fe_2O_3 with different doping concentration of Sb:Fe_2O_3 thin films versus wavelength.

Conclusion

The Fe_2O_3 thin films were deposited on glass substrates with different concentrations of Sb using spray pyrolysis technique. From this study optical properties were calculated. Absorbance increased by increasing Sb-contents. The energy gap for Sb-doped was decrease from 3.25 eV for undoped film to 3.1 eV for 3% Sb content, also reflectance and absorption coefficient were increased via Sb contents.

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