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Effect of the AgO content on the surface morphology and electrical properties of SnO_2 thin films prepared by PLD technique

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Abstract
Tin dioxide doped silver oxide thin films with different x content (0, 0.03, 0.05, 0.07) have been prepared by pulse laser deposition technique (PLD) at room temperatures (RT). The effect of doping concentration on the structural and electrical properties of the films were studied. Atomic Force Measurement (AFM) measurements found that the average value of grain size for all films at RT decrease with increasing of AgO content. While an average roughness values increase with increasing x content. The electrical properties of these films were studied with different x content. The D.C conductivity for all films increases with increasing x content. Also, it found that activation energies decrease with increasing of AgO content for all films. Hall measurements confirmed that all the intrinsic films are n-type charge carriers. The variation of carriers concentration increase with increasing x content. Hall mobility decreasing with increasing x content for all films. Also the variation of Drift velocity, carrier life time and free mean path decrease with increasing of x content.

Key words
SnO_2: Ago thin films, structural properties, electrical properties, PLD technique.

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تأثير محتوى AgOعلى الخصائص التركيبية والكهربائية للاغشيه الرقيقة SnO_2 المحضرة بتقنية PLD

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الخلاصة
تم تحضير أغشية SnO_2: AgO لنسب مختلفة من التراكيز (0, 0.03, 0.05, 0.07) وبدرجة حرارة الغرفة بتقنية الترسيب بالليزر النبضي. وقد تم دراسة تاثير نسب مختلفة من التراكيز على الخصائص التركيبية و الكهربائية للاغشية المحضرة. من دراسة سطح الأغشية بواسطة مجهر القوة الذرية تبين إن حجم الحبيبات لكل التراكيز بدرجة حرارة الغرفة يقل بزيادة نسب التراكيز بينما قيم معدل الخشونة تزداد بزيادة نسب التراكيز. أثبتت الخصائص الكهربائية لهذه الأغشية لنسب التراكيز المختلفة ودرجة حرارة الغرفة أن التوصيلية الكهربائية للأغشية تزداد بزيادة نسب التركيز كذلك تم حساب التركيز للحاملات وسرعة الانجراف وزمن عمر الحاملات ومعدل المسار الحر لنسب التراكيز المختلفة وبدرجة حرارة الغرفة.

Introduction
Tin dioxide (SnO_2) is n-type wide-band gap semiconductor (E_g= 3.6 eV) [1]. Some unique properties of SnO_2 such as; high electrical conductivity, high transmittance in the ultraviolet (UV)– visible (VIS) region, high infrared reflectance, abundance in nature and absence of toxicity [2]. These properties of SnO_2 make the material useful for many applications like in solar cell arrays [3], light emitting and laser semiconductor devices, detectors, gas sensors [4],

oxidation catalysts, surge arresters and flat panel displays [5]. SnO_2 doping with silver oxide, silver oxide with energy gap between 1.2 to 3.4 eV depending on the stoichiometric ratio between the oxygen and silver and it is p-type material [6]. It is a fine black or dark brown powder that is used to prepare other silver compounds and used in some silver-oxide batteries [7]. In this paper, we have focused our attention to investigate the effect of AgO on the surface morphology and electrical properties of SnO_2 thin films using the pulse laser deposition method (PLD) at room temperatures (RT) using Nd:YAG laser with λ=1064 nm, average frequency 6 Hz and pulse duration 15 ns on glass substrate. PLD is a simple and versatile technique for high –quality thin film deposition and nano particles generation [8, 9].

Experimental part

Thin films of SnO_2 doped with AgO were deposited on glass substrates by pulse (PLD) technique at (RT) using Nd:YAG laser with λ=1064 nm, frequency 6 Hz and puls duration 15 ns. High purity (99.999%) of (SnO_2 and AgO) from nano shell company mixed in gate mortar till we get a homogenous mixture. After that, the mixture was pressed at 5 Ton to form a target with 2.5 cm diameter and 0.3 cm thickness. Surface morphology of SnO_2 doped AgO films were examined by Atomic Force Microscopy analysis. From studying the electrical properties of films deposited on glass with different x content, we found that D.C conductivity increases with increasing x content. The measurements of D.C conductivity have been done using sensitive digital electrometer type Keithley 616 and electrical oven. Hall measurements were measured at room temperature which contains D.C power supply (0-40) volt and two digital electrometers (type Keithley 616).

Results and discussion

Fig. 1 and Table 1 show 3D AFM images for thin films at different x content (0, 0.03, 0.05, and 0.07) at RT. In general, AFM measurement shows that the grain size values for all films decrease with increasing AgO content. While the average Roughness values increase with increasing AgO content. Our results were a good agreement with C. Nassiri [2].

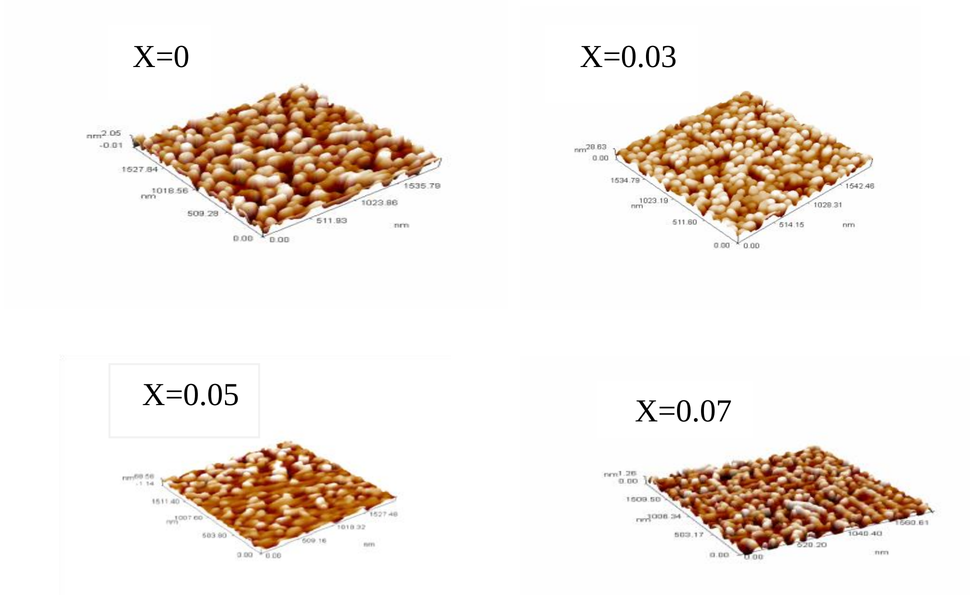

Fig. 1: AFM images for films with different x content at RT.

Table 1: Average grain size, average roughness and Peak- Peak for films with different x content.

x	Ave. grain size (nm)	Ave. Roughness (nm)	Peak- Peak (nm)
0	98	0,473	2.06
0.03	91	0.611	27.4
0. 05	70	4.73	1.26
0.07	68.75	10.8	69.7

Fig. 2 and Table 2 show that the D.c. conductivity for all deposited films increases from 1.02×10^{-5} to 2.1×10^{-5} $(\Omega.cm)^{-1}$ with increases of x content from 0 to 0.07. The electrical activation energies (Ea_1) decrease from 0.017 to 0.08 eV with increasing for x concentration. Also, it found that the activation energies (Ea_2) decrease from 0.8 to 0.4 eV with increasing x content for all films [10].

The decrease in the activation energy may refer to creation of defect states which reducing the band gap between the valance and conduction band and this led to reduce the activation energy that need for electron to transition from balance band to condition band [11].

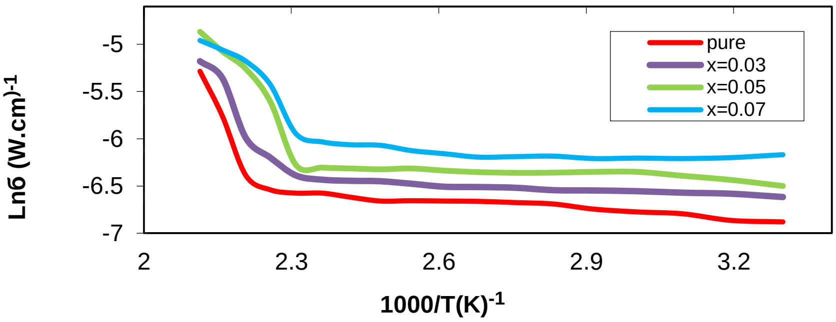

Fig. 2: Ln σ d.c versus 1000/T films with different x content at RT.

Table 2: $\sigma_{(R.T)}$ parameters for films with different x content at RT.

T_a (K)	X content	$\sigma_{(R.T)}X10^{-5}$ $(\Omega.cm)^{-1}$	Ea_1 (eV)	Temp. Range (K)	Ea_2(eV)	Temp. Range (K)
RT	0	1.02	0.017	303-433	0.8	443-473
	0.03	1.33	0.016	303-413	0.57	423-473
	0.05	1.5	0.013	303-433	0.43	443-473
	0.07	2.1	0.008	303-413	0.4	423-473

Hall measurements confirmed that all the thin films are n-type, carriers concentration increases with increasing of x content. Fig.3a shows that the carriers' concentration increases with increasing of x content, while the Hall mobility decreases with increasing of x content are shown in Fig.3. The variation of carriers concentration increase with increasing x content, and this may be refer that the vacancies will be fill and this will reduce the centre of trap which causes the increase in the number of charge carrier which led to increase the probability of collision between them and this decrease the mobility of the carrier so we found that the drift velocity and life time and mean free path decrease with increase of x content. We also observed that drift velocity (V_d), carrier life-time (τ) and mean free path (ℓ) decrease with increasing of x content were shown and listed in Fig.3 (c, d, e) and Table 3 [12].

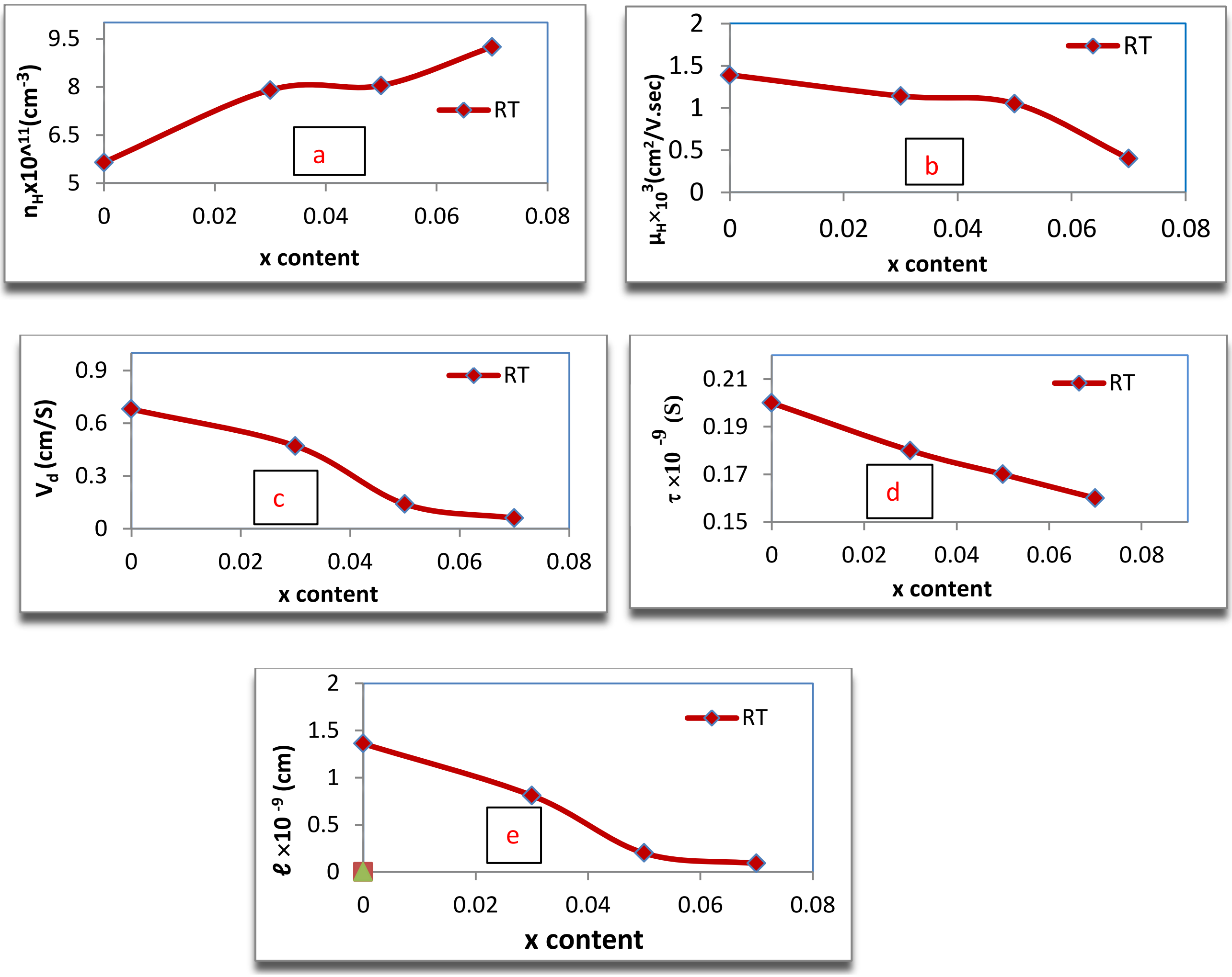

Fig.3: Shows Hall parameters' of thin films with different x content at RT.
a-concentration (n_H), b –Hall mobility (μ_H), c-drift velocity (V_d), d- Lifetime (τ), e-mean free path (ℓ).

Table 3: Hall parameters for films at different x content at RT.

(K)	x	$\sigma_{H(R.T)}$×10^{-5} (Ω.cm)$^{-1}$	n_H×10^{11} (cm^{-3})	μ_H×10^3 (cm^2/V.sec)	V_d (cm/s)	τ×10^{-9}(s)	ℓ × 10^{-9} (cm)	type of charge carrier
RT	0	3	2	18	0.93	1.30	1.20	n-type
	0.03	4	3	5.5	0.62	1.16	0.72	n-type
	0.05	54	41.9	1.5	0.24	1.12	0.26	n-type
	0.07	79	80	0.24	0.18	0.86	0.16	n-type

Conclusions

In conclusion, Tin dioxide (SnO_2) doped with silver oxide (Ago) were deposited on glass substrate by Pulse laser deposition technique at RT using Nd:YAG laser with λ=1064 nm, average frequency 6 Hz and pulse duration 15 ns. AFM measurements showed that that the average grain size values for films at RT decrease with increasing x content. While the average Roughness values increase with increasing x content. The D.C conductivity for all films increases as the x content increases. Hall measurements showed that the films with n-type charge carriers. Also the carrier concentration increases with increasing of x content while Drift velocity, carrier life time and free mean path decrease with increasing of x content for all films.

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