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Structural and Optical Properties of SnO_2:MgO Thin Films Preparing by Pulse Laser Deposition Technique at 423K

الخصائص التركيبية والبصرية لأغشية SNO_2 : MgO المحضرة بتقنية ترسيب الليزر النبضي عند 423 K

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Abstract

Transparent conducting magnesium oxide-doped tin oxide(SnO_2:MgO) films have been deposited on glass substrates by pulsed laser deposition.structural, and optical, properties of these films have beeninvestigated. The films crystallize in a tetragonal structure and X-ray diffractionmeasurements have shown that the polycrystalline SnO_2 films .The optical properties of the SnO_2:MgO films have been investigated as a function of MgO-doping level and substrate deposition temperature ,average optical transmittance of(82%) in the visible range, and optical band-gap of (3.45eV) were obtained for (423K) SnO_2:MgO films.

الخلاصه

تم في هذا البحث دراسة ترسيب اغشيه اوكسيد القصدير المطعمهباوكسيد المغنسيومعلى قواعد من الزجاج باستخدام تقنية الليزر النبضي، الخصائص التركيبيهوالبصريه تم دراستها اذ اوضحت النتائج التركيبيه ان الاغشيهالمحضره متعددة التبلوروذات تركيب رباعي الزوايا اما القياسات البصريه فقد درست النفاذيهالبصريه وتجاوزت حوالي 82% من المنطقهالمرئيه وقيمة فجوة الطاقة التي حصلت عند درجة حرارة23 4 كلفن بلغت(3.45) الكترون- فولت

Acknowledgements

SnO_2Thin films ; Pulsed laser deposition; optical properties ;structural properties

Introduction

The SnO_2 films are n-type semiconductors with a direct optical band gap of about 3.4–4.3 eV [1] Tin dioxide (SnO_2) has many unique physical properties such as high electrical conductivity, high transmittance in the UV-visible region and unusual ferromagnetism, due to its n-type semiconductor behavior and wide band gap. As one of the most import transparent conductive oxide (TCO), SnO_2 and its alloys have been widely used in photovoltaic devices, solar cells, transparent -gassensors[2] There are many different techniques used for depositing tin oxide films including chemical vapor deposition[3,4],spray pyrolysis[5,6], thermal evaporation[7] and sputtering[8,9,10] , Each of these methods are difficult to evaporate the material tin oxide because it has a high melting point, the researchers were able to evaporation materials by the laser pulse[1] .However, the growth of MgO-doped SnO_2 films by (PLD) has not yet been reported.(PLD) films needed lower substrate temperatures compared to other physical vapor deposition processes due to the high kinetic energies[11,12].

Experimental details

SnO_2 thin films were fabricated by pulsed laser deposition system using a Nd:YAG laser. Thin films were grown in a vacuum chamber with background pressure of $1*10^{-2}$mbar. The Nd:YAG laser was operated at the wavelength of (λ=1064nm),(power supply = 220V),(pulse energy=600 mj),(repetition frequency=6Hz)and pulse duration of (10ns). The distance between target and substrate was (1.5cm). SnO_2 composite targets with concentrations (MgO x=0.0,10,20,30 and 40) were used during the deposition. The composite targets were obtained by the standard pressing and sintering method. The resultant powder was ground again and was pressed into round pellets with two-inch diameter. The targets were finally obtained after the pellets were sintered in oven under

vacuum at 150 °C for one hour as shown in figure(1). Glass was used as substrates for growing these SnO_2 thin films. The substrates have the thickness of 1 mm . Before loaded into the vacuum chamber, substrates were cleaned with standard chemical method, by which the substrate was first cleaned in acetone and then cleaned in methanol for 15 min in ultrasonic bath. Thin films were grown in oxygen environment with O_2 partial pressure of (10^{-2} mbar) at substrate room temperature. The deposition time was typically 30 min.

Figure (1): The target before and after being ablated by the laser.

Results and Discussion

A- Structural properties

From XRD measurements ,we observed that SnO_2 films are polycrystalline structure where many peaks appeared. Figure (2) shows the XRD patterns of thinSnO_2 films with thicknesses *t*=400 nm for different concentrations doping. It can be seen that the films (SnO_2pure,10%MgO)are polycrystalline and contain tetragonal structure [**13**] where (SnO_2 pure) diffraction peaks are located at 2θ=26.5429, 2θ=33.8992, 2θ=37.9841, 2θ=51.7949, 2θ=54.8541,corresponding to the(110), (101), (200), (211) and (220).At (10%)wt. concentration, diffraction peaks are located at 2θ=26.6490, 2θ=33.9169, 2θ=38.0902, 2θ=51.7772, corresponding to the(110), (101), (200) and (211) peaks respectively as shown in table(1) where the peaks position of the plane was shifted to high (2θ) values while the films (20%,30%,40%) have amorphous structure. The results showed that the greater the proportion concentration will increase random metals with increasing amounts of MgO content. The FWHM of SnO_2 decreases with increasing of MgO concentrationcalculate average Grain Size is calculated ofScherrer's relationship [14]:

$$D_{av} = \frac{0.9\lambda}{B\cos\theta} \quad \text{.....(1)}$$

It said: B is the width of the curve in the middle of the great peak (FWHM).

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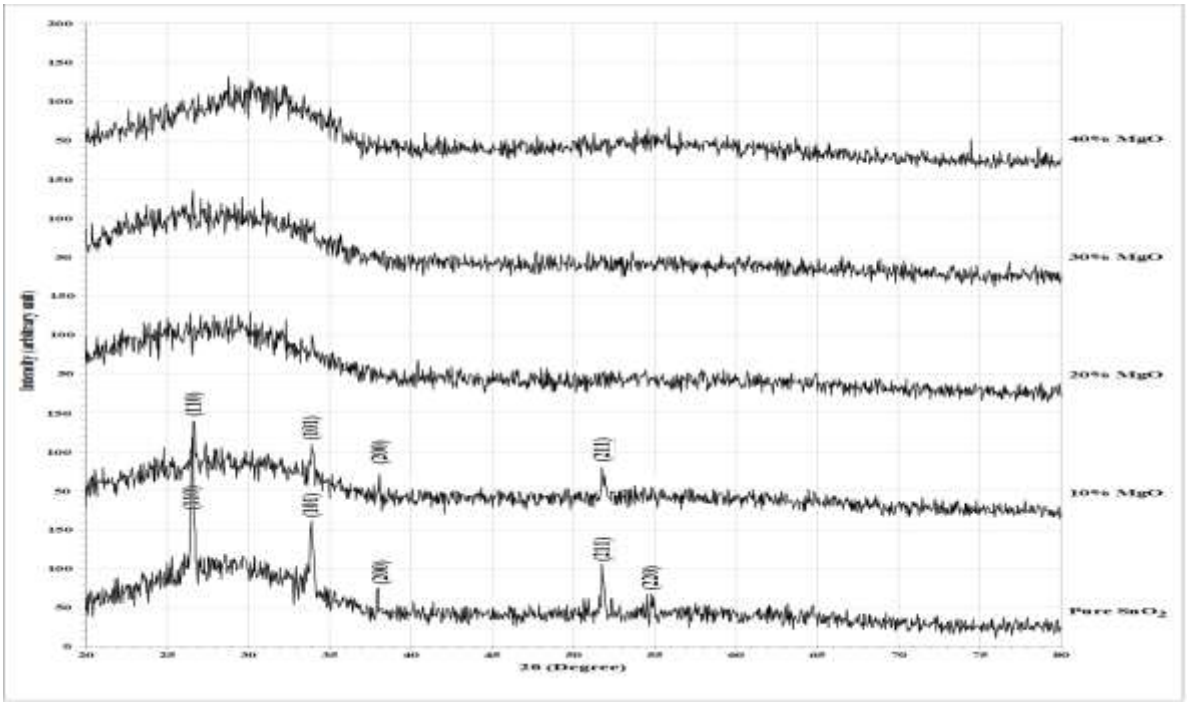

Fig.(2) :X-ray diffraction pattern for SnO_2 films with differentMgOconcentrations doping

MgO %	2θ (Deg.)	FWHM (Deg.)	d_{hkl} Exp.(Å)	G.S (nm)	d_{hkl} Std.(Å)	Hkl	card No.
0	26.5429	0.1945	3.3555	42.0	3.3498	(110)	96-900-9083
	33.8992	0.2476	2.6423	33.5	2.6439	(101)	
	37.9841	0.2122	2.3670	39.6	2.3686	(200)	
	51.7949	0.2299	1.7637	38.4	1.7642	(211)	
	54.8541	0.3006	1.6723	29.8	1.6749	(220)	
10	26.6490	0.1768	3.3424	46.2	3.3498	(110)	
	33.9169	0.3183	2.6409	26.1	2.6439	(101)	
	38.0902	0.2122	2.3606	39.6	2.3686	(200)	
	51.7772	0.3360	1.7642	26.3	1.7642	(211)	
20	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-
40	-	-	-	-	-	-	-

Table (1): Parameters of XRD pattern for SnO_2 films with different concentrations doping

B-Optical properties

The optical characteristics which involve the absorption coefficient , the optical energy gap (E_g) , and the optical constants (i.e. refractive index (n) , extinction coefficient (k) , real dielectric constant (ε_r) and imaginary dielectric constant (ε_i)) , are studied within the range (400-1100) nm for thin SnO_2films. The transmission spectra of SnO_2 thin films were studied by UV-visible spectroscopy at423K in the range (400-1100) nm. Fig. (3) illustrate the variation of transmission spectra as a function of wavelength for SnO2:MgO films at different concentration .

, the transmittance increases with the increasing concentration of MgO and this is due to the increase of the surface roughness promoting the decrease of the surface scattering of the light [15].according the (AFM)

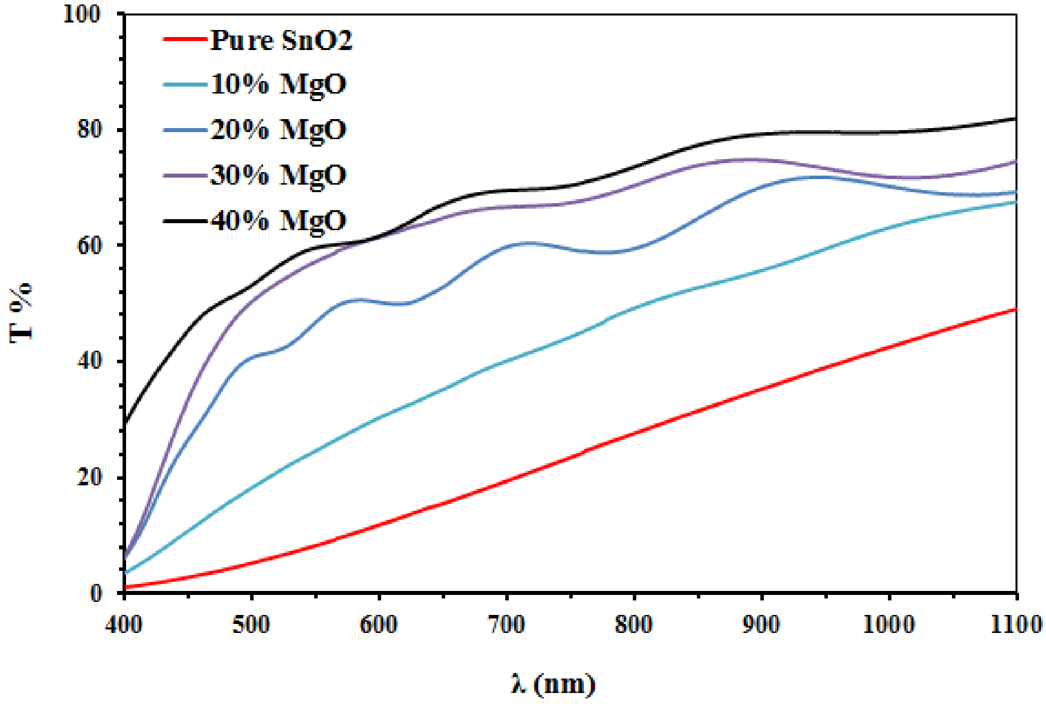

Fig. (3):Transmittance versus wavelength for thin SnO_2 films with differentMgO concentrations doping

The absorption coefficient (α) was calculated from absorptance spectrum by using the following equation [16] :

$$\boldsymbol{\alpha} = 2.303\,\frac{A}{t} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where (À) is absorbance

It is observed that the absorption coefficient (α) decrease with increasing the concentration of MgO, and this is due to the increasing of energy gap with concentration of MgO as shown fig(**4**)

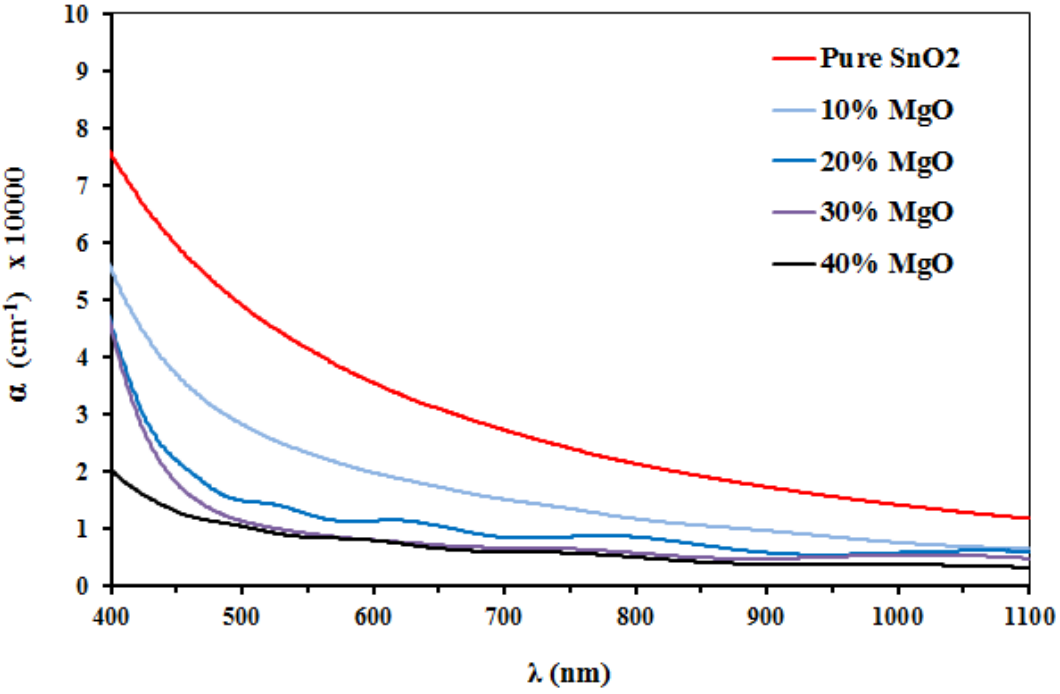

Fig. (4): The absorption coefficient versus wavelength for thin SnO_2 films with differentMgO concentrations doping

A plots of$(\alpha hv)^2$ verses photon energy (hv) of the SnO_2:MgO films at different concentration of MgO at(423K). The direct Egopt increases from (3.1 to 3.7), when MgO concentration increases from (10% to 40%) as shown in the figure (5). These result is in agreement with [Zayed et.al,1994][17], [Falah Mustafa et.al,2009][18] and [Kulal et.al,2011][19]. This is due to the decrease of the density of state inside the optical gap, the increasing concentration of MgO leads to decreases from the secondary levels and structure defects, which lead to the contract tails region and this leads to expand in the optical energy gap.

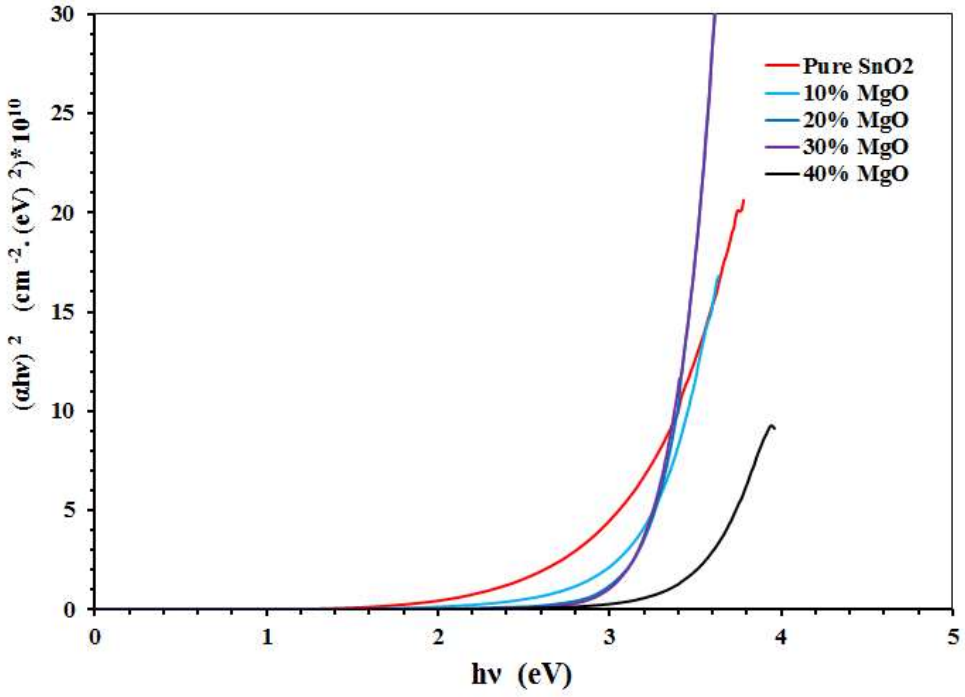

Fig. (5) :Variation of $(\alpha h \upsilon)^2$ versus hυ for thin SnO_2 films with different MgOconcentrations doping

The extinction coefficient, which is related to the exponential decay of the wave as it passes through the medium can be determined by using equation [20]:

$$k = \frac{\alpha\lambda}{4\pi} \quad \text{.. (3)}$$

where λ: is the wavelength of the incident radiation.

We can observe from these fig(6)that the extinction coefficient, in general, decrease with increasing of MgO content for all films. Decreasing in k value can be ascribed to increasing in degree of cystallinity which leads to eliminate the density of localized states by the effect of addition of MgO content.

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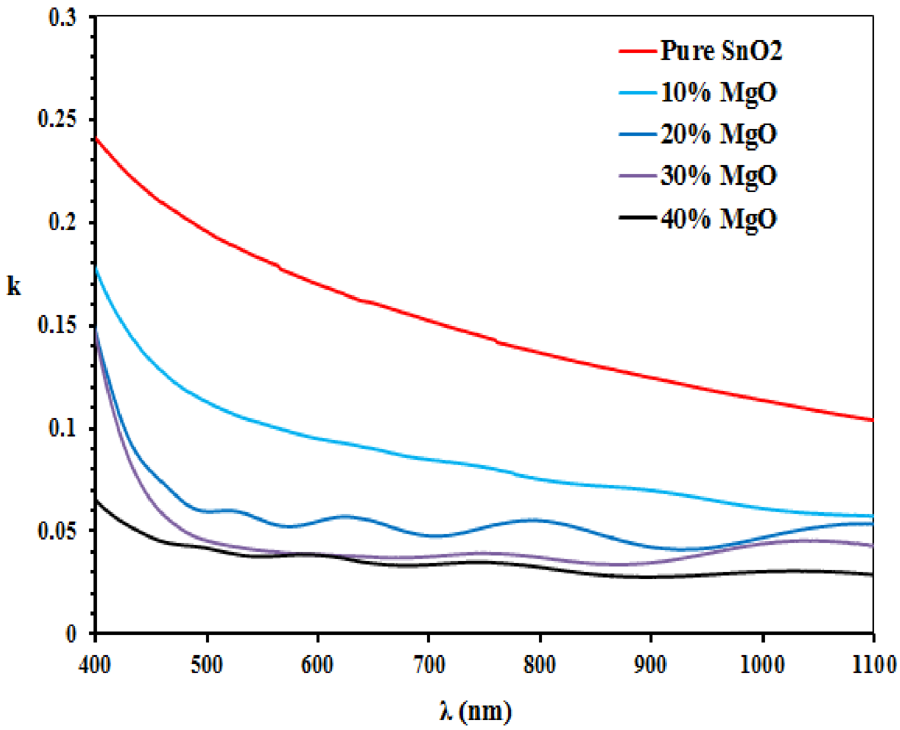

Fig. (6) :The extinction coefficient versus wavelength for thin SnO_2 films with differentMgO concentrations doping

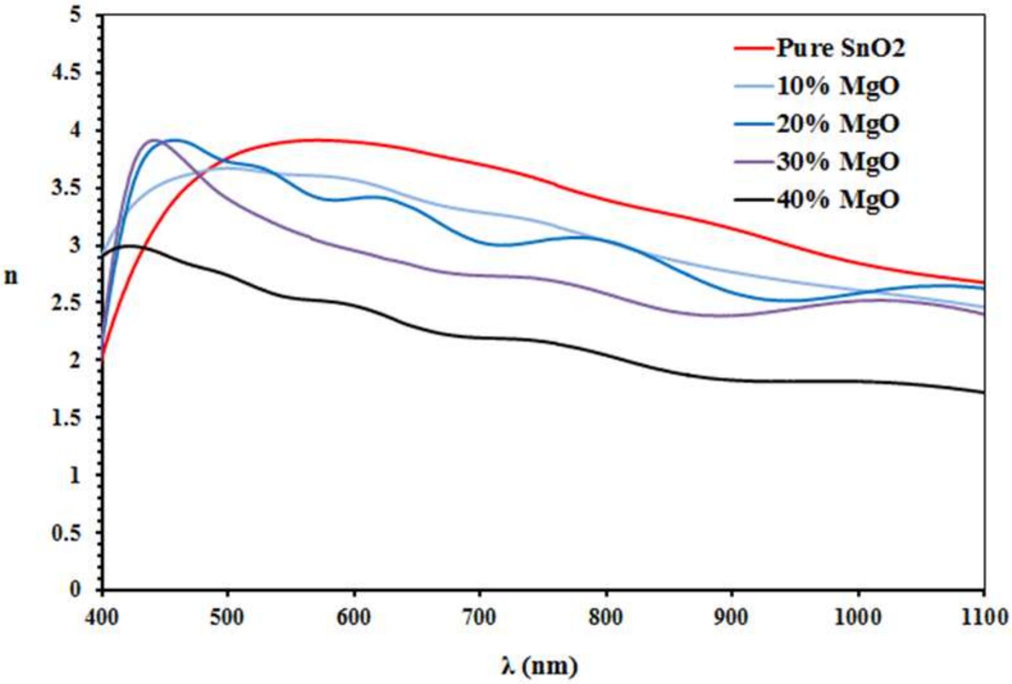

Fig. (7): The refractive index versus wavelength for thin SnO_2 films with different MgOconcentrations doping

We can notice the refractive index decreases with increasing of concentrations doping .This is in agreement with AI-Haddad.et.al[21].

The refractive index (n) can be calculated from the following equation [22].

$$n=\left[\frac{4R}{(R-1)^2}-k^2\right]^{1/2}-\frac{(R+1)}{(R-1)} \quad \text{.. (4)}$$

where R is the reflectance and given by the equation:

$$R=\frac{(n-1)^2+k^2}{(n+1)^2+k^2} \quad \text{.. (5)}$$

The complex dielectric constant is given by the following equation [23] :

$\varepsilon=\varepsilon_r+\varepsilon_i=(n+ik)^2$……(6)

Where ε_r , and ε_i are the real and imaginary parts of ε and $(n+iK)^2$ is the complex refractive index. From equation (6) we obtain:

$\varepsilon r=n^2+k^2$ and $\varepsilon i=2nk$…..(7)

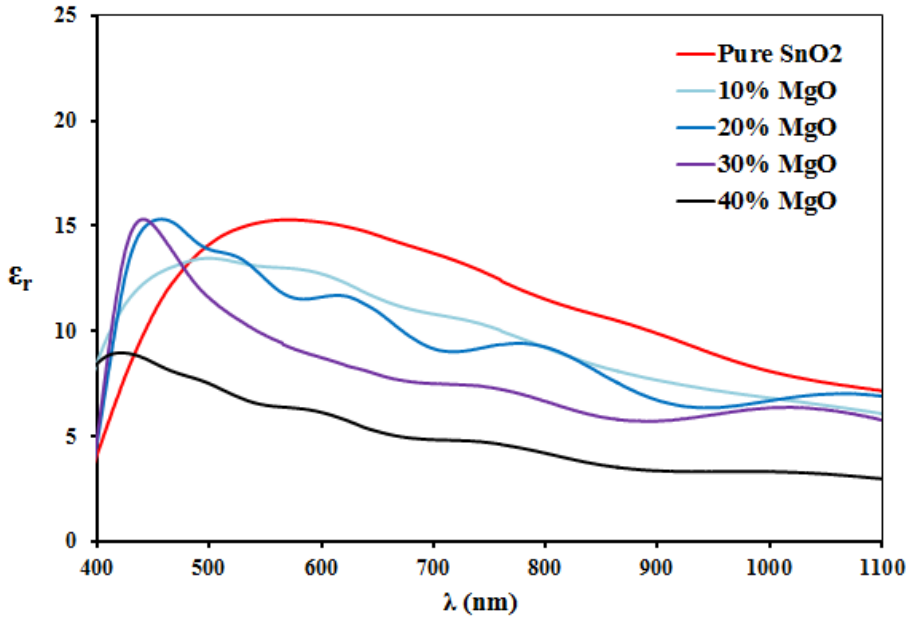

Fig. (8): Real dielectric constant versus wavelength for thin SnO_2 films with differentMgO concentrations doping

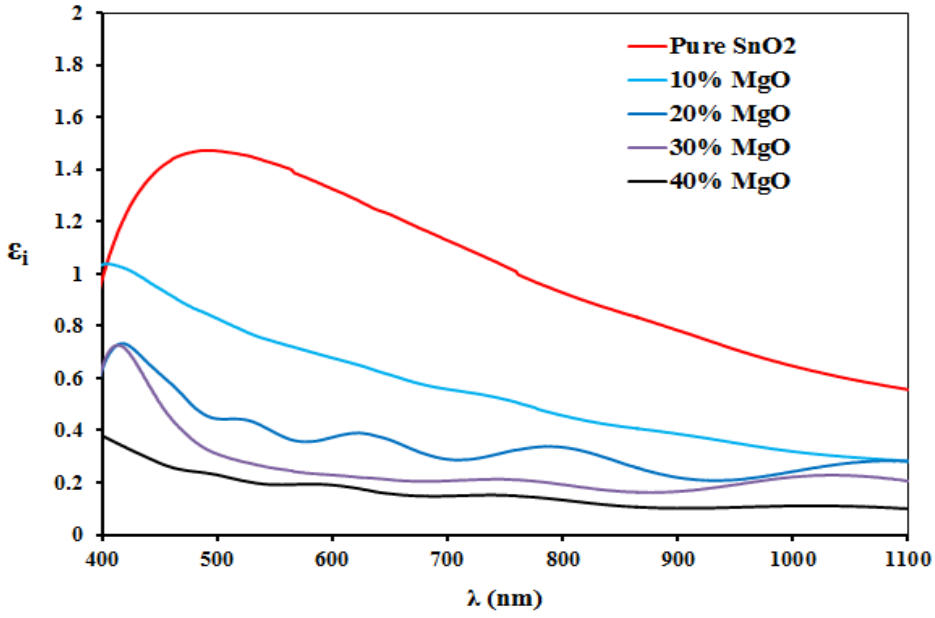

Fig. (9): Imaginary dielectric constant versus wavelength for thin SnO_2 films with differentMgO concentrations doping

We can notice that ε_r and ε_i decreasewith increasing amount of MgO.this behavior is in agreement with results of Roy .et al [24].

Conclusion

High quality SnO_2:MgO films were grown on glass substrates by pulsed laser deposition.The structural propertiesof the SnO2:MgO films can be seen that the films (SnO2pure,10%MgO)are polycrystalline and contain tetragonal structure while the films (20%,30%,40%) have amorphous structure. The results showed that the greater the proportion concentration will increase random metals with increasing amounts of MgO content. Theoptical properties of the SnO_2:MgO films were investigated the transmittance increases with increasing of MgO concentrations doping .the energy band gap increase with increasing of MgO concentrations doping. The refractive index , extinction coefficient, real and imaginary parts of the dielectric constant decrease with increasing of MgO concentrations doping.

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