Structural and morphological Properties for Zinc Oxide Doped with Silver Nanoparticles (ZnO:Ag) Deposited on a Polymer Substrate

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Abstract

Zinc Oxide doped with silver nanoparticles ($AgNP_S$) were deposited onto flexible polypropelene carbonate (PPC) substrate with different concentrations of Ag of (2,4, and 6wt%), and deposited at constant substrates temperature of 250°C using the pulse laser deposition (PLD) . The crystalline structures and morphologies of the prepared films were investigated by X-ray diffraction (XRD) patterns and atomic force microscopy (AFM) analysis, respectively. XRD spectra indicated that the films posses a hexagonal wurtzite crystal structure, with preferred orientation (002) . AFM analysis showed that the film surface became rougher when the ZnO concentration was increased.

Keywords: poly propelene carbonate (PPC); Thin films:Pulsed-laser deposition.

خلاصة

رسبت جسيمات الفضة النانوية (AgNPs) المشوبة باوكسيد الخارصين (ZnO) على قواعد البولي بروبلين كاربونات (PPC) باختلاف نسب تراكيز مادة الفضة(2,4, and 6 wt%) وثبوت درجة حرارة القاعدة (250°C) باستعمال تقنية الترسيب بالليزر النبضي (PLD).

درس التركيب البلوري والسطحي للاغشية المحضرة بوساطة حيود الاشعة السينية (XRD) ومجهر القوة الذرية (AFM) على التوالي. تشير نتائج حيود الاشعة السينية تشير الى ان الاغشية تمتلك تركيب بلوري سداسي متراص، مع اتجاه عمودي على محور C–axis بشدة عالية على المستوي (002). تحليل مجهر القوة الذرية تظهر ان سطح الغشاء اصبح اكثر خشونة بازدياد نسب التراكيز.

1.Introduction

Transparent, conducting oxides have important uses for a variety of applications, including flat panel displays, touch screens, IR reflectors, solar cells and optical sensors[1]. Nowadays, there is great interest in replacing glass with polymer substrates, particularly in flat-panel display technology [2], where low volume, light weight and robustness are relevant. In flexible applications, there is a trade-off between using thick layers to reduce the resistivity and thin layers that can with stand greater strain in the substrate. In addition, the added flexibility of polymeric substrates opens new application fields that utilize curved surfaces, for example large-area, flexible position-sensitive detectors [3].

Transparent conducting films deposited on polymer substrates have many merits, compared with those deposited on a conventional glass substrate. They are lighter, smaller, have greater impact resistance, ease of transport and flexibility [4]. However, polymer substrates have some disadvantages, such as lower thermal resistance,weaker mechanical strength and a higher coefficient of thermal expansion, as compared to glass substrates [5]. Deposition of TCO films on polymer substrates presents a significant problem, because the substrate temperature needs to be relatively low [6]. In In this work, ZnO :Ag materials has been deposited as thin films on PPC substrates by pulsed laser deposition method with substrate temperature 250°C to different Ag doping percentage . The doping and PPC substrate polymer were purposed to enhance thin films that act as solar cell for future . Structural, surface morphology, and optical properties of ZnO :Ag thin films have been investigated.

2. Experimental details

Pure ZnO powder with high purity (99.999%) (Aldrich chem. Co. ,Inc) and powders doped with different concentrations for Ag (2,4,6)% were prepared. The prepared powders were pressed till 5 tons to form a target with 2.5 cm diameter and 0.4 cm thickness. The target should be dense and homogenous as can as possible to ensure good quality of the deposits. It was mounted in locally design vacuum chamber and ablated by a double frequency with Q-switched Nd:YAG pulsed laser operated at 532 nm, pulse duration of about 10 ns and 0.8 J/cm^2 energy density was focused on the target to generate plasma plume. Poly propelene carbonate (PPC) was used as substrates and grown in oxygen environment with O_2 partial pressure of 10^{-2} mbar at substrate temperature of 250°C. The deposited nanostructures were grown typically 10 min after cooling to room temperature .The mentioned technique has been utilized to test the overall structures of lattice constants, identification of unknown materials, orientation of single crystals and polycrystals, defects, stresses, etc. In this work, X-ray diffractometer (XRD)(SHIMADZU, USA) and power diffraction system with Cu-Kα x-ray tube (λ = 1.54056 A°) were used. The XRD was performed between 2θ values of (30°-70°). The surface morphology was examined by atomic force microscopy (AFM-Digital Instruments NanoScope) working in tapping mode.

3. Results and discussion

An XRD spectrum as shown in Fig. (1) reveals the Ag doping percentage (2,4 and 6 wt%) on the structure of the ZnO/PPC films. As the doping increases the intensity of the ZnO (002) increases, for all the films no Zn and O peaks were observed, and only ZnO (002) and (101) diffraction peaks were observed. That is orientation growth (002) plane of the ZnO/PPC thin film is dominant, the ZnO (002) diffraction peaks location were at 2θ=34.0, 34.2, 34.3 And 34.4 respectively . It was observed that (002) diffraction angle gradually shifted from 34.0 to 34.4 With increasing doping. The XRD result indicated that (ZnO grown on PPC plastic substrates at 250°C temperature) the films are polycrystalline with hexagonal wurtzite crystal structure, and preferred orientation (002) at laser energy 0.8J is very high as compeer to the other planes. We can observe that the intensity of (101) peaks increases with increasing Ag-content whereas (002) peaks also become more intense as the Ag-content increases, this indicates that the degree of nanocrystalinity increase with increasing Ag-content in the films. For all the ZnO:Ag films. The angle position of the (002) peak moves toward greater values with increasing Ag-content, which indicates that Zn^{+2} ions which are successfully substituted by Ag^{2+} in the ZnO lattice.

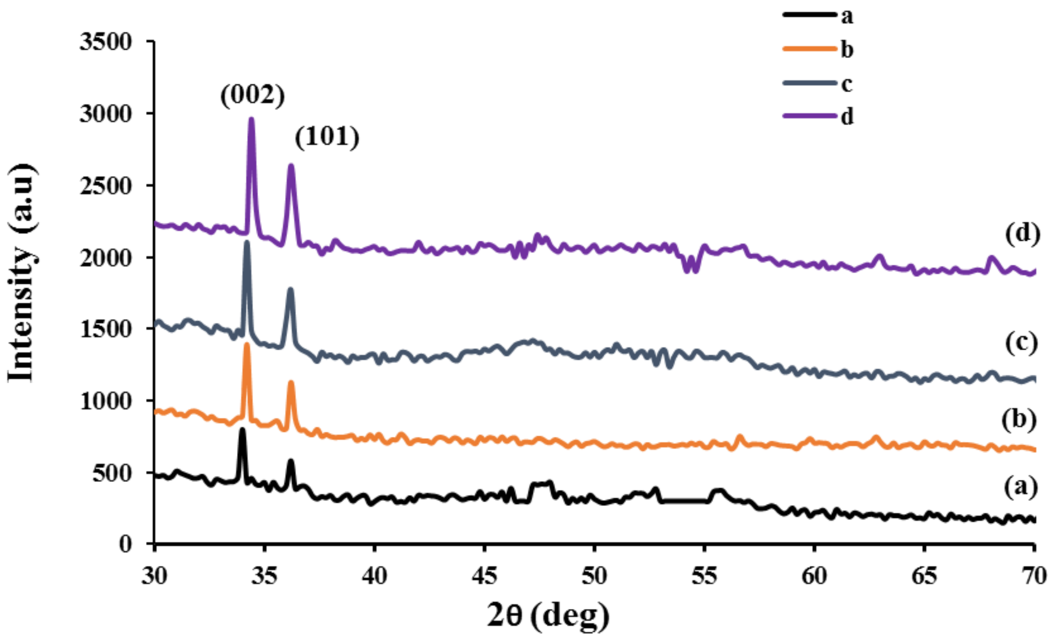


Fig (1): XRD patterns of ZnO and ZnO:Ag nanostructure with concentration (a) ZnO pure (b) ZnO:Ag at 2% (c) ZnO:Ag at 4% (d) ZnO:Ag at 6%

The X-ray parameter values which measured by XRD instrument of diffraction angle (2θ), Interplanar spacing (d) and full width at half maximum (FWHM) are summarized in table (1).The lattice parameters a and c were calculated from the XRD pattern using the equation[7]:

$$\frac{1}{d^2} = \left[\frac{h^2 + hk + k^2}{a^2}\right] + \frac{l^2}{c^2} \ldots\ldots\ldots..(1)$$

The micro strain (ε) can be calculated from the relation [8]:

$$\varepsilon = \left[\frac{|C_{ASTM} - C_{XRD}|}{C_{ASTM}}\right] * 100\% \ldots\ldots\ldots..(2)$$

If the micro strain is positive, the biaxial micro strain is tensile; if the micro strain is negative, the biaxial micro strain is compressive.

According to the values in table (1), the interplanar spacing (d) is increasing with the increases of silver doping due to the ion size of the Ag^{+2}(r=0.144nm) interstitial in Zn^{+2} (r=0.074nm)[9].

Table (1):XRD patterns,lattice parameterd spacing,FWHM and micro strain for ZnO,ZnO:Ag nanostructure films deposited at 250°C on PPC plastic substrates

Doping(%)	2θ(deg)	d(A°)	hkl	a(A°)	c(A°)	Micro strain	FWHM (deg)
0	34.0	2.60	002	3.19	5.21	-0.35	0.40
	36.2	2.60	101				
2	34.2	2.60	002	3.20	5.22	-0.38	0.42
	36.25	2.45	101				
4	34.3	2.60	002	3.22	5.26	-1.15	0.51
	36.38	2.47	101				
6	34.4	2.61	002	3.25	5.30	-1.92	0.57
	36.40	2.49	101				

The average grain size Dg was calculated by scherer equation [10]:

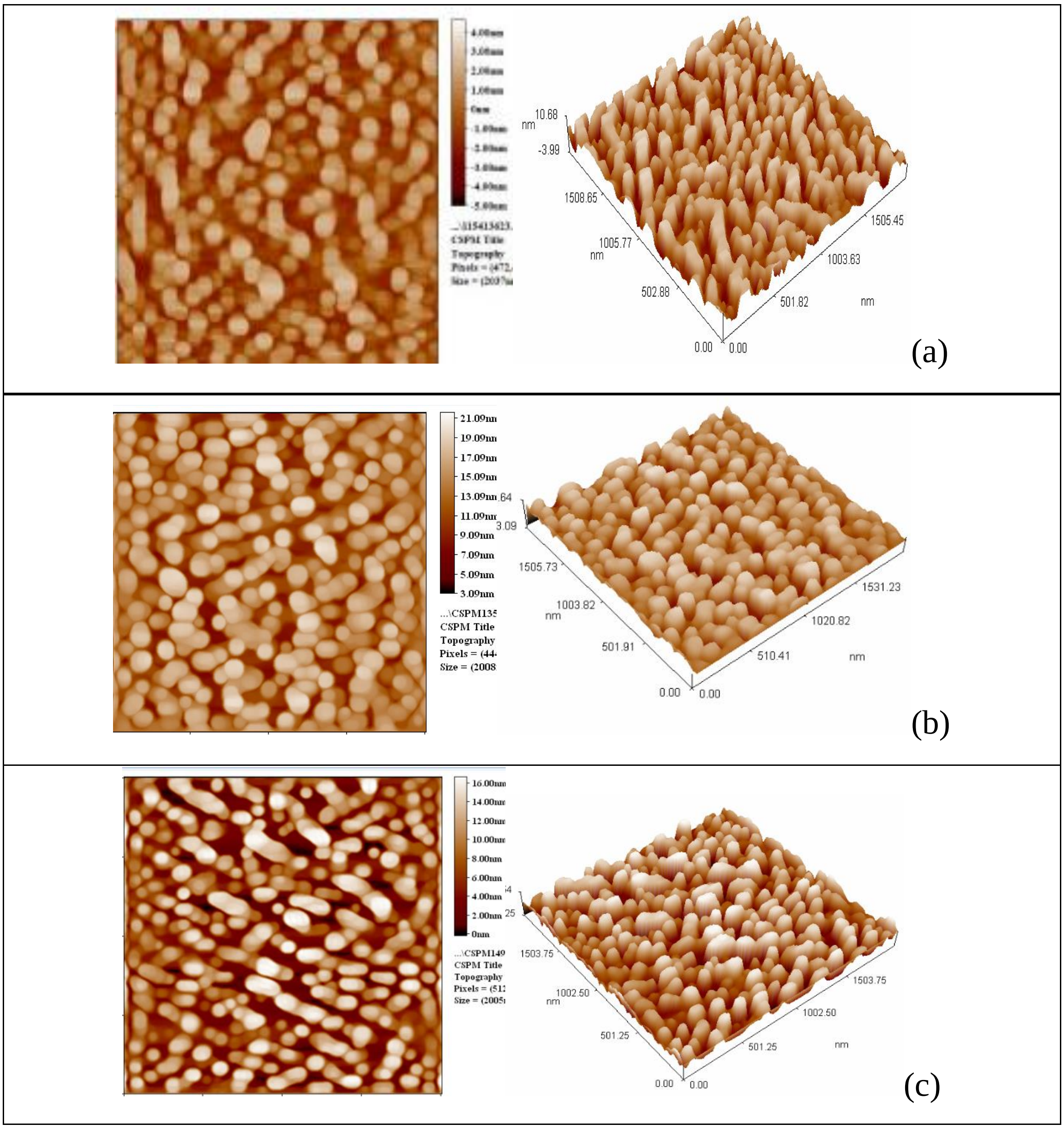
$$D = \frac{0.9\lambda}{\beta \cos\theta} \quad \text{.....(3)}$$

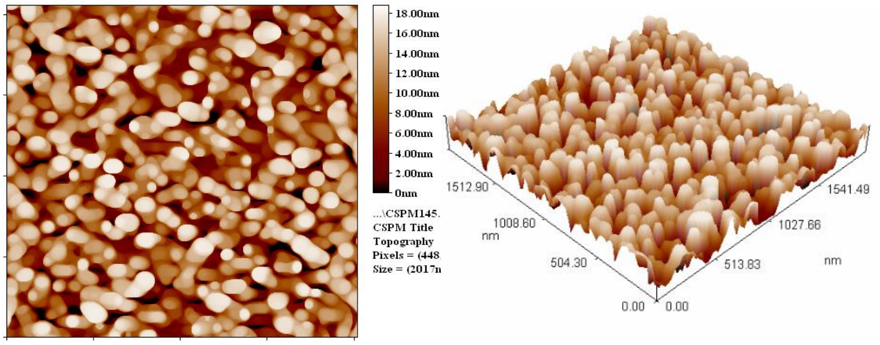
λ is the XRD wavelength (A^o), β is FWHM(radian). θ: diffraction angle of the XRD peak (degree) .$k = 2\sqrt{\frac{\ln 2}{\pi}} = 0.94$ called (scherer's constant).

Figure (2) shows The AFM images of the ZnO pure and ZnO:Ag nanostructure films at various doping concentrations : 2, 4 and 6 % . As shown in the figure, the surface morphology changed with the varying doping. For the film doped with 6% , the films surface morphology was rough and rugged. one can see that at pure case and low doping concentrations the grains are distributed uniformly and the film seems to be with large particles size as shown in figure (2a). As the doping rates increases, the grain size decreased, but the roughness and the root mean square (RMS) increases, as shown in table (2). This result was in agreement with the reported results by Wang et al [12] .

Table (2): The surface roughness, RMS, and particle size for ZnO and ZnO:Ag films deposited on PPC plastic substrates.

Sample	Surface roughness (nm)	RMS (nm)	Average diameter size (nm)
Pure	2.63	2.80	20
2%	2.37	2.87	20.07
4%	3.66	4.27	16.45
6%	4.05	4.78	14.36





(d)

Fig (2): 2Dx3D AFM images of ZnO,ZnO;Ag deposited on PPC substrates (a) ZnO pure (b) ZnO:Ag at 2% (c) ZnO:Ag at 4% (d) ZnO:Ag at 6%.

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