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Zinc oxide on Polymethyl Methacrylate prepared by Pulsed Laser Deposition in Artistic and Aesthetic application

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Abstract

Modern furniture manufacturer's work to give their products a high aesthetic and taste, especially those made of PMMA, and make adjustments to treat surfaces that are capable of giving high visual and waterproof properties.Thin films of zinc oxide (ZnO) were prepared using pulsed laser deposition (PLD) technology on PMMA. A pulsed Nd: YAG laser operating at a wavelength of 355 nm was used in which the sample preparation was evaporated from a ZnO target material at weight of 0.5% and thus deposited on a PMMA substrate at 25ºC .The characterization by structure and optical properties were examined by X-ray diffraction and transmittance measurement. The sedimentation was performed under a background pressure of 10^{-3} Tor and the best films were obtained at (2 J/ cm^2 that the best of value compare with (0.5, and 1J/cm^2)) an ambient oxygen pressure of 1-2 mTorr. The precipitated coating was diagnosed with atomic force microscopy, optical properties, and wettability properties: roughness was 4.62 nm, permeability in the visible area was 96.5%, and contact angle and hydrophobic wettability were increase to 70.58 ° C. Results of X-ray diffraction appear s c-axis ina plane (002) oriented thin films and that mean grown have a polycrystalline wurtzite structure

Key words: Zinc oxide, pulsed laser deposition, artistic and aesthetic, contact angle.

1. Introduction

The complex compounds of organic and inorganic materials are of fundamental importance and wide applications in technology to produce materials with unique physical properties from their complexity and of importance in the application and manufacture of modern furniture [1]

Polymer Poly methyl methacrylate (PMMA) that known as acrylic polymer ave a highly transparent polymer thermoplastic is often used to make laminates as an alternative to lightweight or shatter-resistant glass [2]. It has a high

transmittance, often up to 92% in visible light (with a thickness ~ 3 mm) and also gives reflectance of approximately 4% because that (n=1.4905 at 589.3 nm) [3]. PMMA polymer is used in a variety and many technological applications due to its good physical and chemical properties such as tensile strength, bending strength, transparency, high melting point (within160°C), refinement ability, high impact strength, low manufacturing cost, high flexibility, and toxicity. Low, high stability that is suitable for applications with aesthetic and color [4].

PMMA is used in environmentally stable outdoor applications because it is a hydrophobic polymer in nature whose environmental stability surpasses most other plastics such as PS and PE polymers, and therefore this quality is important in the polymer for its choice in art and beauty [5]. The polymer is prepared with nanocomposites currently in a number of ways, including using deposition techniques, such as magnetron spraying, and (PLD) to obtain a thin film substrate. PLD is a type of experimental PVD in which a laser of high energy density and narrow band-width is used as a source to vaporize the desired material and deposit it onto surfaces. In PVD, a high-energy PLD

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beam is interred inside vacuum in chamber to hit when the target that will be deposited [6]. Thus, this material evaporates from the target (forming a plasma column), making it a thin layer on a base of polymer or surface, and this process occurs in a very high vacuum and the presence of gas In inert, such as the oxygen that is commonly used when oxides are precipitated to fully supply oxygenated films of the precipitated film [7].

Zinc oxide (ZnO) used in possesses a number of important properties, including optical, semi-conductive, piezoelectric, electro-optical, and photoelectric properties, and a non-toxic and anti-microbial and anti-bacterial material, and if it is manufactured in a thin film, the membrane used in important applications in many electronic devices; this includes sensors, motors, transducers, and surface high-frequency sound waves (SAW) devices [8]. ZnO has an energy gap of about (Eg = 3.37) that mean it transparent in the visible light range and have a high n_r also UV protection properties with high thermal conductivity [9].

Major studies used that growth ZnO thin films on a polymer surface by used any of one method of self-assembly growth and electrochemical precipitation, but the best way to coating ZnO in low temperatures that used pulsed laser deposition PLD to make the surface more hydrophobic and thus maintain it [10, 11].

Important applications of ZnO films include using thin or thick film growth techniques in screen printing, thermal oxidation of metallic zinc films, spray pyrolysis, colloidal solution gel synthesis, ion beam-assisted reactive precipitation, spraying, electron modification, source of cyclotron resonance (ECR), vapor deposition Chemotherapy (CVD), pulsed laser deposition (PLD), molecular beam epitaxy (MBE) [12]. Whereas, ZnO thin films of high quality were manufactured at low temperatures (room temperature) on a base of solid polymers which usually have a higher glass transition temperature (~ 105 ° C for [20]). In addition to other manufacturing methods; such as spraying, radio frequency (RF), chemical vapor deposition (CVD), sol-gel method, and molecular beam amplification (MBE) [13, 14].

Kun Tian et.al [15] synthesized thin films of ZnO on polymer an elastomeric base such as polyamide and polyethylene phthalates, at 25ºC and also 100°C using method Pulsed Laser Deposition. The prepared samples showed improved in optical and also obtained low in thermal activation energy. It has good optical conductivity to UV rays and good optoelectronic properties of these films.

In the current study, ZnO thin films were successfully deposited via pulse laser deposition (PLD) technology on the polymer surface where the PLD is relatively simple, uncomplicated and versatile compared with other physical vapor deposition techniques also the contact angle and visible properties of the zinc oxide thin films were determined examined also the hydrophilic behavior shifted. For the polymer surface to hydrophobic surfaces and low the wettability (contact angle) of the substrate that useful in many applications.

Nazia S. et al. [16] used the different laser beam wavelengths inter thin PMMA films prepared with PLD technology. Initially, PMMA films are deposited onto the glass at room temperature as well as at 300 ° C, it was concluded that films deposited at 300 ° C have a lower field compared to large amounts of PMMA and film deposited at 25ºC. The surface of the deposited film at 25ºC showed an irregular distribution of particles size and thicknesses and also showed that increased uniformity. Then, 1064 nm, 632.8 nm and 248 nm lasers were deposited through these precipitated thin films. The results showed that PMMA films deposited on the substrate at 300 ° C show minimal diffusion losses for 1064 nm, 632 nm and 248 nm.

2. Experimental

A coating of polymethyl methacrylic PMMA was prepared with a thickness of 110 µm, then cut into pieces with dimensions of about (3 x 20) mm and cleaned of impurities using acetone. The target material was prepared and compressed from ZnO with a weight of 0.5% after pressing under pressure of 107 Newton / m^2 with a diameter (1.2 cm) and thickness (0.3 cm) for 3 minutes using a hydraulic press, where the sedimentation process took place inside the sedimentation chamber of the Nd-YAG laser system. Pulse laser under the discharge pressure of Torr 10-3, as the deposition process includes the interaction of the laser beam with the target material, which is a ceramic disk, and the plasma is formed inside the chamber, which is caused by the laser radiation, and thus the membrane is deposited on the polymeric coating at room temperature and at the low vacuum pressure and was energy. The suitable laser is approximately 800 mJ / cm^2 at a frequency of 6 Hz. The room was pumped to Tor prior to precipitation at 25ºC. For the PMMA and ZnO substrate, ZnO films were deposited under O_2 at 1 ~ 2 mTorr, and the distance between the target and the starting point of the laser beam was 15cm.

The ultraviolet optical transmission spectra of the thin films were recorded by (Shemadzu UV-160 / UV-Visible Spectrophotometer.

Atomic force microscopy (AFM) images were acquired using images captured in tapping mode at 23 ° C and 50% relative humidity.

The wettability and hydrophobic / hydrophilic nature of the material before and after deposition determined by the contact angle. The contact angle value was determined by measuring the angle between the flat surface tested and the shadow produced by a drop of liquid on the boundary of that object at room temperature using a goniometer at an interval of 60 seconds.

Characterizations of the thin films Structural were determine by X-ray diffraction in θ–2θ with CuKα with source of X-ray diffraction data power of 40kV *30 mA.

3. Results and Discussion

Fig (1) shows relationship appearing between the transmission (T) and the wavelength that ranges between 300-850 nm, as the highest permeability appeared in the polymeric envelope of PMMA which is around 98.6%, and the permeability of the thin ZnO layer deposited on PMMA is about 98% within the visible region from these results of samples that is good to use in artistic and aesthetic application.

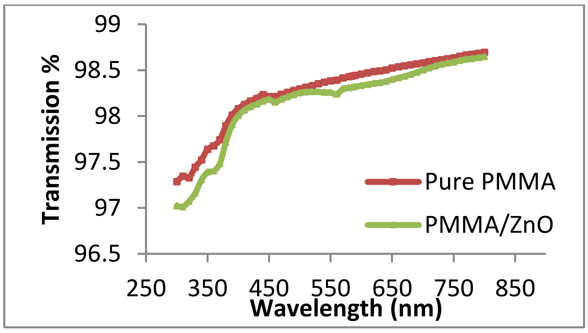

Fig (1): The Transmission curve of Zinc oxide thin films deposited on PMMA polymer

Absorption coefficient is observed through the following relationship appear in eq. (1):

$$\alpha h\upsilon = A(h\nu - Eg)^n \quad \text{.....1}$$

Where that A: is constant, Eg; is the energy gap, and n: number takes values of (1/2 and 3) that according to the nature of the electronic transition between the conduction band and the trivalent band. In the case of a permissible direct bandgap semiconductor, the Absorption data with Equation (2) for n=1/2 is :

$$\alpha h\upsilon = A(h\nu - Eg)^{1/2} \quad \text{...............2}$$

And can calculate the absorption coefficient from equation (3);

$$\alpha = \ln(1/T)/d \quad \text{..................3}$$

Where *T:* is the Transmittance and d; is the thickness of the film.

When the plot between $(\alpha h\upsilon)^2$ vs $h\upsilon$ is accomplished using Formula Tauc equation (2). The energy gap value of the produced PMMA is 2.7ev and decreased to 2.3ev for ZnO films for PMMA is calculated by the optical method that is obtained by extrapolating the linear portion of this graph to $(\alpha h\upsilon)^2$.

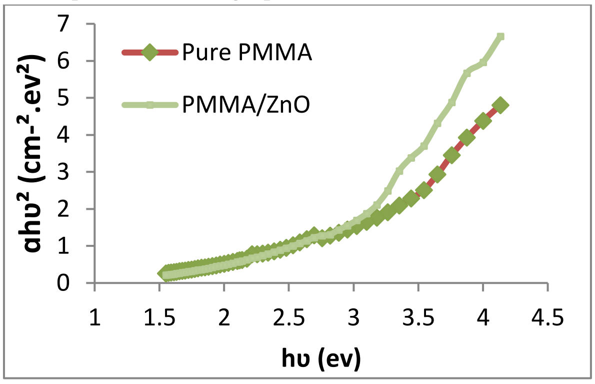

Fig (2) : $(\alpha h\upsilon)2$ versus $h\upsilon$ of Zinc oxide thin films deposited on PMMA polymer

3.1. Wettability and contact angle

Water has an effective role in the processes of chemical and microbiological deterioration in the technical and aesthetic applications in the external effects that give the appropriate appearance to the external forms water on the surface [17].

the wettability of a solid surface by a liquid is described by

$$\sigma SL = \sigma S - \sigma L \cos \Theta \quad \text{............4}$$

It is appear from a balance of the surface energy between the liquid and the solid σ SL, the surface energy of the solid σS and the surface tension of the liquid σL including the contact angle ϴ at the three phase points of liquid, solid, and surrounding atmosphere, the wetting (ϴ = 0º), a partial wetting (0º< ϴ < 90º), a partial non-wetting (90º < ϴ < 180º) and a total non-wetting (ϴ = 180º) can be distinguished[18].

The results of the contact angle measurements are illustrated in Fig. 3 that a statistically significant low in the contact angle value of ZnO in sedimentation by

PLD compared to the control of PMMA.The contact angle of PMMA was (56.67 ° left and 57.54 ° right) and (70.58 ° left and 69.30 ° C), which means an increase in water resistance and the surface became more hydrophobic after zinc oxide deposition due to reduced surface energy of rough surfaces.

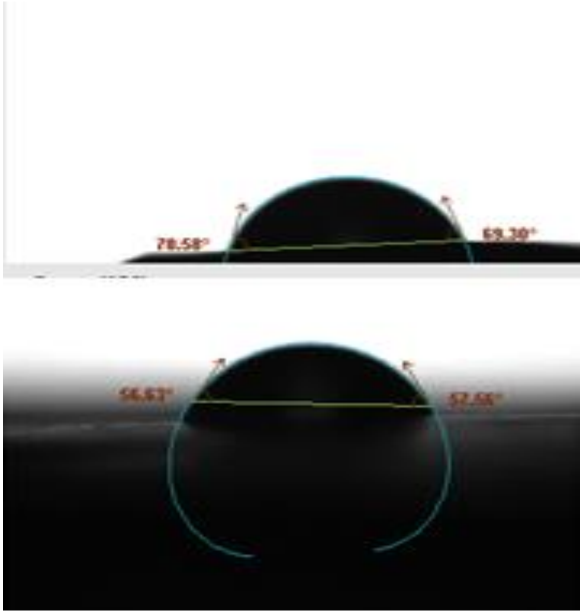

Fig (3); the Wettability and contact angle wettability and contact angle of PMMA and PMMA deposition by ZnO

3.2. AFM images and Roughness analysis

The surface topography and surface roughness of ZnO samples were studied by atomic force microscopy (AFM). Fig. (4) indicates the AFM images of ZnO thin films deposited on PMMA substrates in two dimensions with the surface of the films was reasonably smooth with the roughness 4.62nm with root mean square (rms) value of 5.29 nm showing highly homogeneous distribution.

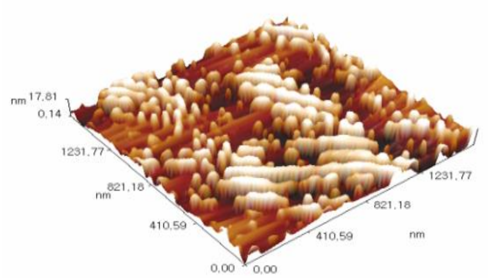

Fig (4): AFM (2D) images shows surface morphology for the ZnO deposition on PMMA substrate

3.3. X-ray diffraction

The 2θ XRD curve of pulsed laser deposited Zinc oxide thin films on polymer PMMA is appeared in Fig(5). X-ray of film ZnO deposition on PMMA showed strongest peak observed at Bragg's angle (2Ө= 31º)can be attributed to the (002) plane of the hexagonal ZnO [19] . The (101) and (110) peaks were also observed at 36° and 44° respectively but these peaks are of lower intensity than the (100) ,also showed appear little intensity peaks refer to planes(100) at 2Ө = 24º that also recorded that means the film is polycrystalline.

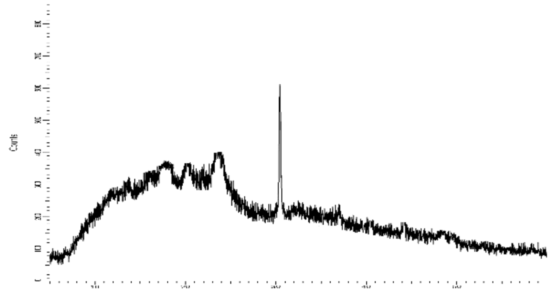

Fig (5): X-ray diffraction for the ZnO deposition on PMMA substrate polymer

The d- spacing measured by Bragg's law in eq. (5):
d=nλ\ 2sinӨ ……………. 5

Where n: number of diffraction take =1, λ : is the wavelength of used X-rays , the diffraction angle of the plane (100) and for the hexagonal lattice ,d-spacing appear in the following equation (6):

$$\frac{1}{d^2} = \frac{4}{3}\left(\frac{h^2+hk+k^2}{a^2}\right)+\frac{l^2}{c^2} \quad \textbf{.........6}$$

That h, k and l are the Miller indices of the plane, a and c are the lattice constant for the hexagonal unit cell and Eq. (6) can calculated the values for the lattice constants (a and c) .

Table (1); The values of XRD analysis of ZnO deposition PMMA Lattice spacing, Lattice constant and Crystalline size of plane (002)

Sample test	**d-sapacing (nm)**	**a-Lattice constant (nm)**	**c-Lattice constant (nm)**	**Crystalline size (nm)**
ZnO deposition PMMA	0.244	0.322	0.584	35.11

4. Conclusion

In this current work ZnO thin films were deposited on PMMA substrates at room temperature by using Nd –YAG at 355 nm laser. The best films were obtained at (2 J/ cm^2 that the best of value compare with (0.5, and 1J/cm^2)). The optical properties of films found to be highly transparent of ZnO with lower optical bandgap to 2.3ev. The results of AFM shows grown ZnO on PMMA polymer at 25ºC exhibit surface morphology. The X-ray diffraction results show that the structure of ZnO films is polycrystalline with hexagonal wurtzite structure with preferential orientation in the plane (002) . The contact angle of ZnO increased in hydrophobic nature creating a self-protection surface that is suitable as a surface coating for Artistic and Aesthetic application.

5. Conflicts of interest

There are no conflicts to declare

6. Formatting of funding sources

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