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Influence of Ar gas on Optical and Morphology Properties of Films (CdS) Prepared by Pulse Laser Deposition (PLD) Technique

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ABSTRACT

Cadmium sulfide thin films, formed by pulse laser deposition method, resulted in CdS thin films deposited on glass substrate with different Ar gas (5, 10 and 15) torr. Structural (X-ray) diffraction, morphological (atomic force microscope) and optical (transmittance and absorption) spectra of CdS films have been investigated. The high value of transmittance determined from optical transmittance spectra was 72%. Direct band gap energy of prepared films are (2.54, 2.16 and 2.72) eV with different pressure of Ar gas. X-ray diffraction synthesis proved CdS films in crystalline with hexagonal structure. By using Scherrerś equation, average grain size about 80nm was determined. AFM image shown the morphology of formation films and the effect of gas pressure on nanostructure.

Key words: Cadmium Sulfide, Pulse Laser Deposition, Structural, Morphological and Optical Properties

1. INTRODUCTION

Most of the modern electronic devices depend on their materials which have physical and chemical properties. These semiconductor materials possess the properties of insulators at low temperature, and it has the ability to conduct electrical transmission at a high temperature to a certain extent [1]. Extensive researches have been conducted to identify the structural, optical properties as well as the electrical power of these materials and the possibility of using them in many applications [3, 4].

Cadmium sulfide is a chemical compound with the formula of CdS. The binary semiconductors belong to the group VI-II of the periodic table. They are formed as a result of a combination of two elements; the first from the second column (II) which is Cd and the second from the sixth column (VI) which is S [5]. CdS is a polycrystalline compound, whose crystal structure is either hexagonal wurtzite (which is more stable at room temperature) or lattice-type cube (which is similar to diamond in its composition), where it can be It is obtained by heat treatment [6]. The sulfur and cadmium ions are linked by a resulting covalent bond about the sharing of two electrons between the sulfur atom and cadmium. It should be noted that the presence of CdS in one of the preceding structures are controlled by the preparation conditions [7]. Cadmium sulfide CdS is an n-type semiconductor with an intrinsic and at room temperature, this material has almost wide band gap ($E_g \approx 2.42$ eV) [1].

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These properties have made CdS material enter into many applications, such as light emitting diodes [8], photovoltaic [9], solar cell [10, 11], environmental pollution control [12] as well as optical waveguides and non-linear optical devices. [13]. There are several techniques have been used to produce cadmium sulfide films, such as, thermal evaporation [14], chemical bath deposition [15], sputtering [16], spray pyrolysis [17] and pulsed laser deposition PLD [18] which is considered as very interesting technique to format multi-component thin films, due to its feasibility and the stoichiometric deposition of the semiconductor materials [6, 7]. The films formed in this way (PLD) can control their thickness and have high quality special II–VI compound semiconductors with thickness as thin as one nanometer [5].

The aim of this work is to study the properties (optical and structural) of CdS films and to prove that Ar gas will affect these properties.

2. MATERIAL AND METHODS

Pulsed first harmonic Nd:YAG laser with wavelength of 1064 nm, laser pulse repetition rate of 10 Hz , laser energy (130 mJ) with pulse duration of 10 ns and laser ablation was used to target CdS. The laser spot area was 1 mm^2. Firstly, the cadmium sulfide powder was pressed into a tablet, then pressed into granules and heated to 150°C in air. A vacuum chamber with a pressure of up to 10^{-3} tor was used to conduct the deposition process for these films. The target is about 10 cm away from the laser beam. The laser beam is tilted at an angle of 35^{o} degrees from the target. The effect of gas pressure inside the vacuum chamber on the ablation process within the range (5-15) torr was studied.

In order to obtain the growth rates, we measured the thickness of the films using a surface profile. Using optical transmittance analysis, the optical characteristics of formed films were studied by using a UV/Vis spectrophotometer (PerkinElmer Lambda 950). The optical power bandwidth was calculated for the samples from the optical transmission spectra. The surface shape was examined by AFM, atomic force microscopy. Digital Instruments NanoScope Italy operates in eavesdropping mode. The crystalline structure study of thin films was used, an X-Ray Diffraction measurement, with wavelength=1.5418 Å and Cu Ka radiation.

3. RESULTS AND DISCUSSION

In order to use the CdS films in one of the important applications such as sensing and photovoltaic applications, the optical properties must be studied. Therefore, the samples were labeled with a UV/VIS spectrophotometer. The optical properties of these samples were studied through spectroscopic and absorbance optical transmittance analysis. Figure 1 shows the optical transmittance of these films of the same films thickness of 100 nm deposited on glass substrate at 200^{o}C. Note that transmittance is a function of wavelength as it increases with increasing wavelength. The highest value of transmittance of precipitated films was obtained at a gas pressure of 5, and it reached 72%. This can be used in many applications, such as for solar cells.

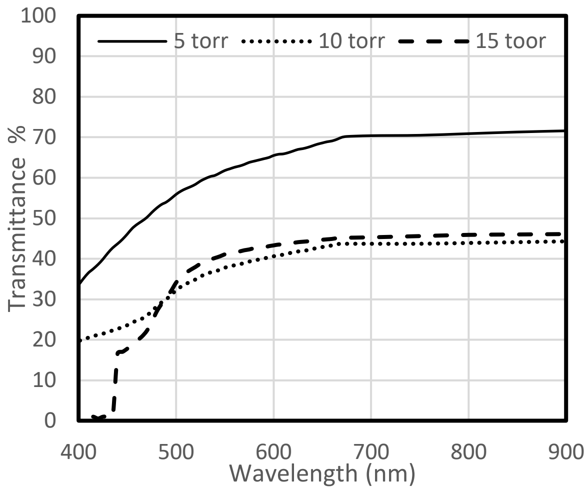


Figure 1. Transmittance spectra of CdS thin films with different Ar gas pressures (5, 10 and 15 torr)

Figure 2 shows the absorbance change as a function of the wavelength of the range from 400 to 900. From this figure, it is shown that the change in the ratio of Ar gas has a strong effect on the value of the absorbance. So, when the gas pressure is 5 torr, the deposition rate of cadmium atoms will increase. However, if the pressure of the Ar gas is 10 torr, the collision probability in CdS particles increased from the target substance, and the amount of CdS particles that reached the substrate decreases. Moreover, after a lot of energy collisions, the CdS molecules that reached the substrate are lower. If the deposed pressure is 15 torr, the deposition rate decreases, and this can determine many surface properties, including more uniform grain sizes and reduced crater density, which makes us get the lowest absorbance values at 15 tor gas pressure [7, 8].

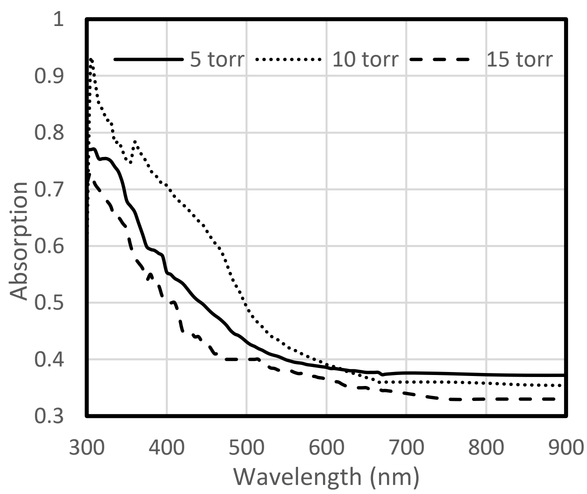


Figure 2. Absorbance of CdS films deposited at Ar gas pressures (5, 10 and 15) torr

The optical energy gap can be defined as the energy required to transfer an electron from the valence band to the condition band. Using the mathematical relation as shown in Equation (1):

$\alpha h\nu = A(h\nu\text{-}Eg)^{a}$,

where A is a constant deal with the energy band structure of the type of materials, $h\nu$ is the energy of incited photon energy, and Eg is the band gap. The energy gap is within the indirect band of CdS, a = 2. From the graph of $(\alpha h\nu)^2$ against $h\nu$, the band gap of the CdS films deposited at different Ar gas pressures is known from the initial absorption edge line when a = 0. Figure 3 shows the variance obtained energy gap values $(\alpha hv)^2$ against the energy of photon for the deposited films (CdS) under different value of Ar gas pressures [15, 16]. The value of Eg was 2.54, 2.16 and 2.72 eV for gas pressure 5, 10 and 15 respectively. A decrease in the values of Eg was recorded with high in Ar gas pressure due to an increase in the average grain size over time.

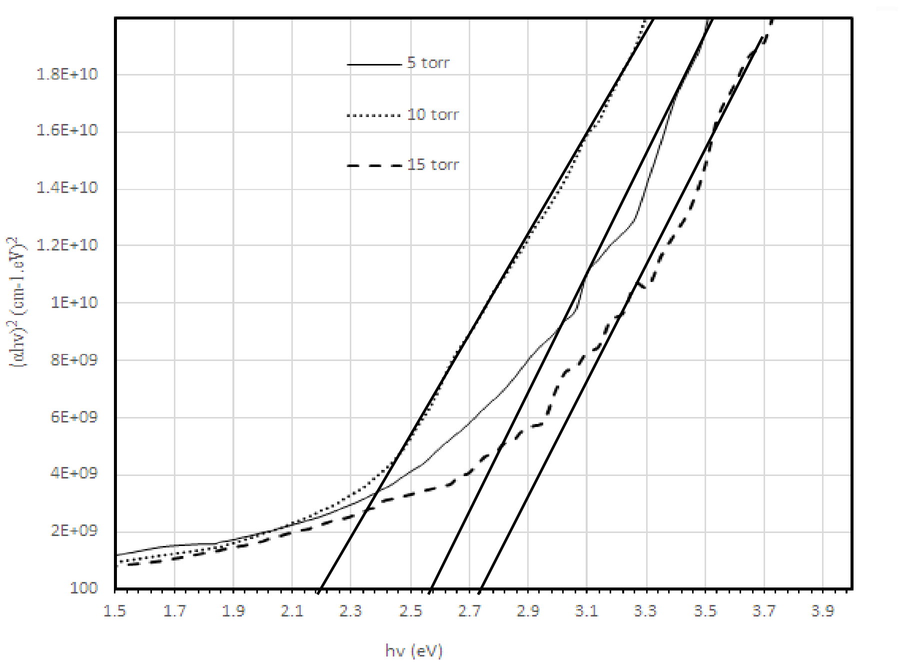
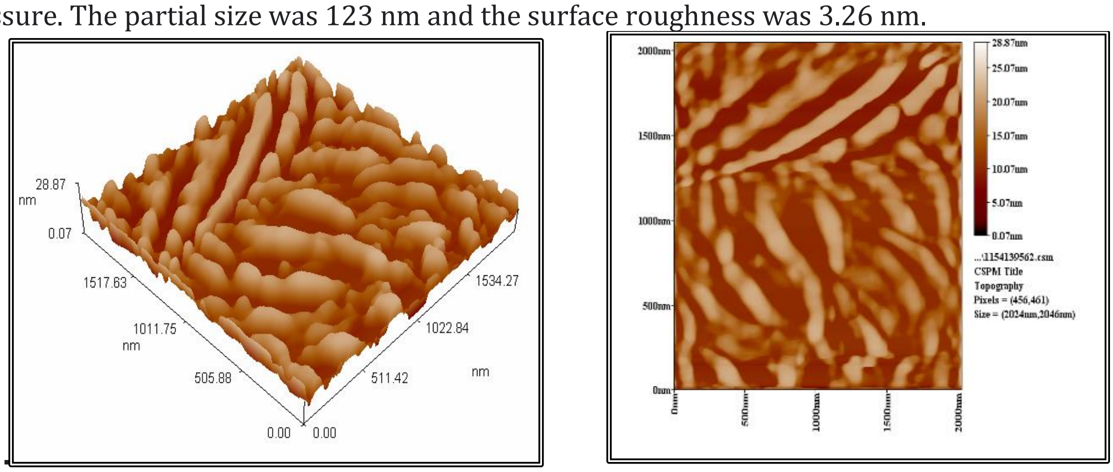


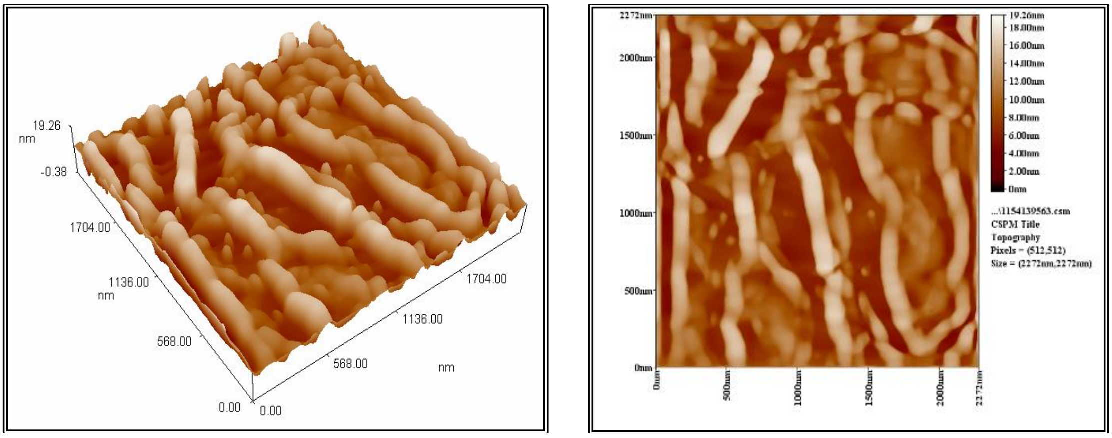
Figure 3. Optical band gap of CdS films at Ar gas pressures (5,10 and 15) torr

Figure 4 shows AFM images in 3D (left) and 2D (right)for all films obtained under different gas pressures (5, 10 and 15) torr. From here, CdS thin film deposited at 5 torr gives uniformly distributed grain size and the boundaries of weaken grain disappears. The deposited film is compact with less pore density, and particles of different sizes will be unevenly distributed on the surface with average partial size of 90 nm with roughness reaching to 3.49 nm. Particle aggregation also occurs and the grain boundaries cannot be found clearly. This is due to the reconstitution of CdS particles from the substrate surface.

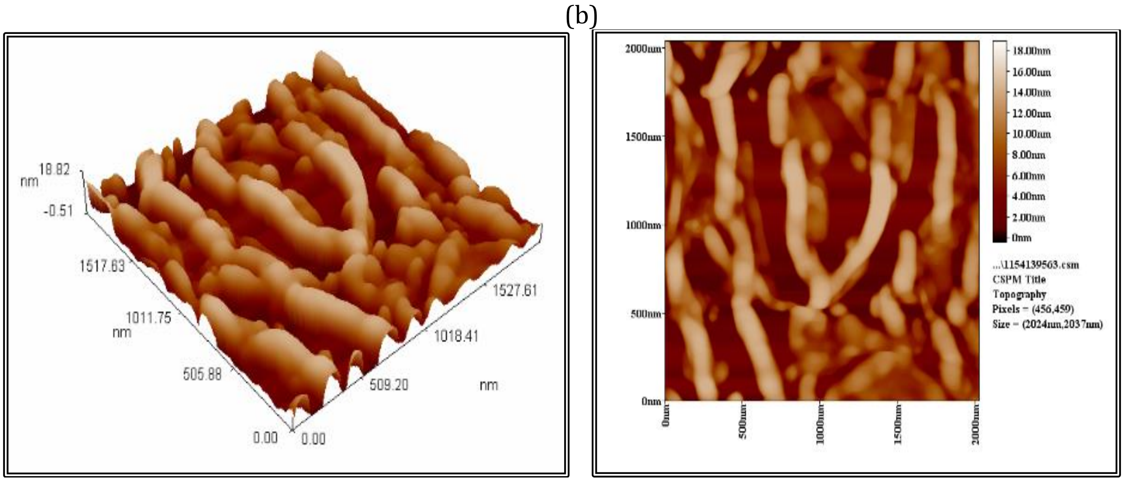
At the pressure of the argon gas reaches 10 torr, the energy delivered to the particles at the substrates is insufficient and uneven, and the migration of particles on the substrates is not sufficient. The film formed with 10 torr pressure has an average gain of 108 nm and a roughness of 2.27 nm. In Figure 3(c) where the pressure at 15 torr, resulted a strong damping at high pressure. The partial size was 123 nm and the surface roughness was 3.26 nm.



(a)



(b)



(c)

Figure 4. AFM images for CdS films deposited at different gas pressures: (a) 5 torr, (b) 10 torr and (c) 15 torr

X-ray diffraction (XRD) technology allows the exact crystal structure of materials to be determined. It has been reported that the predominant orientation of the thin film deposited on the glass substrate is affected by Ar gas pressure change. Figure 5 shows the CdS source diffractograms for films, prepared using PLD technique at different Ar gas pressure. XRD analysis of the prepared CdS thin films observed that they have a polycrystalline and hexagonal structure (JCPDS 96-900-8863) and have different orientations. The cubic structure of CdS was revealed in these films (JCPDS card 96-900-8840). The peaks will vary in intensity with different films deposited at different Ar gas pressures.

XRD analysis of the deposited films found that they contain highly oriented crystals with hexagonal structures at $2\theta=26.6^{o}$ and preferential orientation at the c-((002) axis) perpendicular to the substrate plane and for all samples prepared at different pressures. A very weak peak at 2θ = (47° and 51.4^{o}), corresponding to the (103) and (112) plane. From this figure, it can be found that increasing the pressure to 10 torr will show in the formed films polycrystalline structures (consisting of a hexagonal phase and a cubic style), and the basic phase was hexagonal phase. At a pressure of 15 torr, three major diffraction peaks for CdS thin films appear at 2θ = 34.1° and 43.3° which correspond to (110) and (200) of the hexagonal phase. This agreement with many researches [13, 15]. Using Scherer's equation shown in Equation (2), the average crystal size was calculated where the constant K is a form factor of 0.94, β FWHM in radians, with wavelength (0.15418 nm) and θ is the angle of Bragg. We use standard H reflection (0 0 2) at 2θ = 26.66°. It has been shown that the particle size of the thin film increases with increasing gas pressure with a value of (42, 80 and 130) nm for gas pressure 5, 10 and 15, respectively [6, 16].

$$D = \frac{K\lambda}{\mathcal{B}\cos\theta} \quad (2)$$

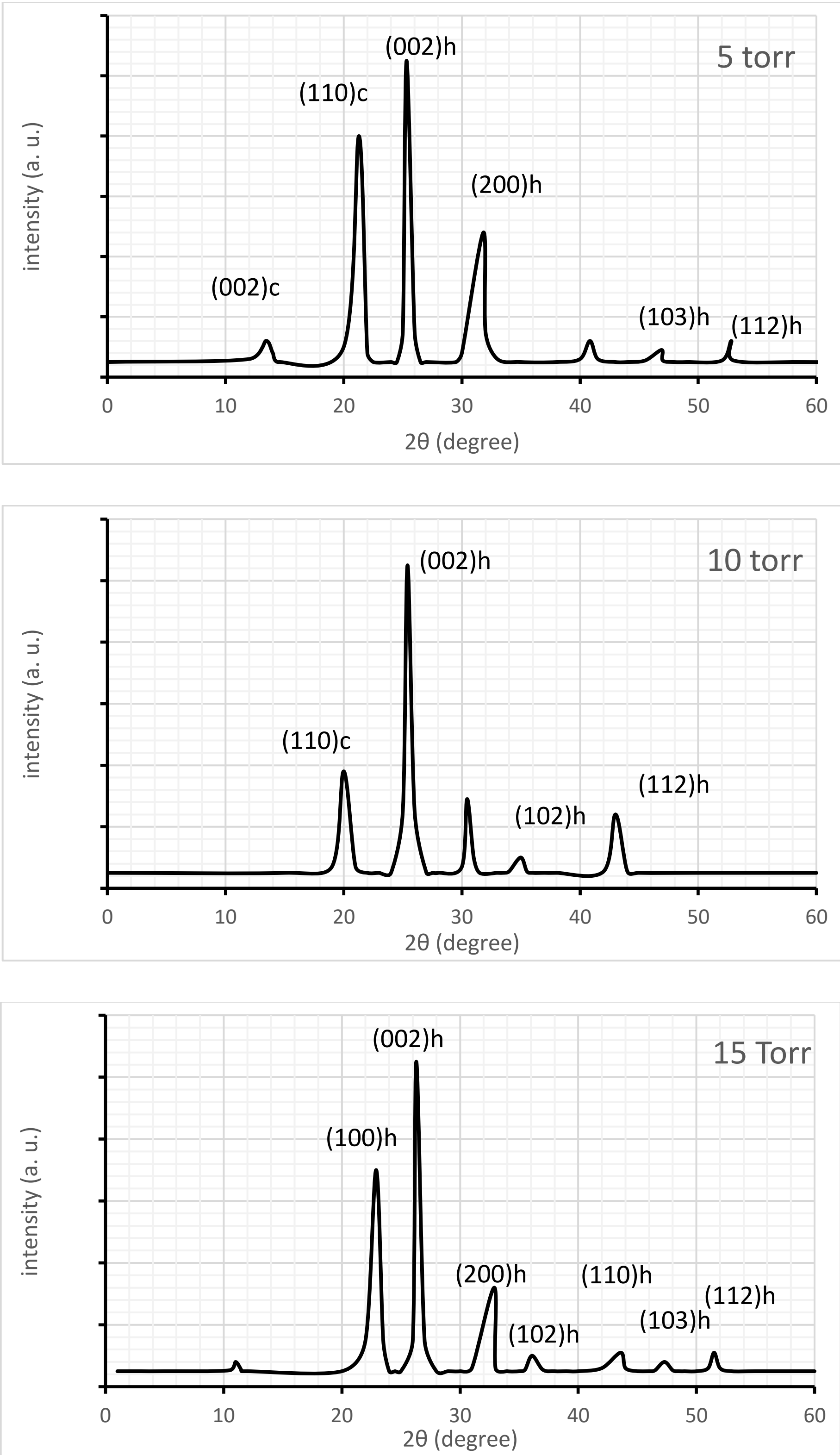


Figure 5. The XRD pattern of thin films (CdS) deposited at different pressures

4. CONCLUSION

In this paper, CdS films were deposited by PLD at different deposition pressures of (5, 10, and 15) torr for Ar gas. The properties of these films were shown depending on the gas pressure during the deposition process. Film formation rate is highly dependent on gas pressures. All films have polycrystalline structurer. The films which deposited at 5 torr of pressure were mainly hexagonal, and when pressure reach to 10 torr, the cubic phase will appear. AFM morphology image shows that CdS thin films prepared at 5 torr gas pressures were crystalline and have uniformity film surface with low grain sizes. The optical bandgaps (Eg) of the CdS films have values of 2.1, 2.54 and 2.3 eV at a deposition gas pressure of 5, 10 and 15 torr, respectively.

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