Study the Properties of Toxicity Gas Sensors Using Mixed Nano Oxide Thin Films by Pulsed Laser Deposition Method

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Abstract

A study of the properties of gas sensors was carried out using (CdS), as thin issues were deposited on silicon bases by pulsed laser (PLD) technology. X-ray diffraction (XRD) patterns showed that it has a polycrystalline structure and hexagonal structure. X-ray examination also showed an increase in the size of the nanoparticles with increasing energies used. Atomic force microscopy examination with dimensions (6µm × 6µm) showed a detailed and comprehensive description of the surface pattern of the prohibited films. Where the surface roughness was (24.16 _ 49.64 nm) for the wavelength (532) nm. Scanning electron microscope (SEM) examination showed the formation of the CdS film on a silicon base, in which the uniform distribution of quasi-spherical nanoparticles shows a compact and homogeneous distribution. The granular diameter of the prepared membrane granules was also calculated and was in the range (46.2 - 61.7 nm).

As for the wavelength (1064), the roughness was (23.39 _ 37.59 nm). The maximum height was calculated according to the increase in energies (we note that the height increased with the increase in energies). The energy gap for the issues prepared on silicon substrates was calculated by the photoluminescence test and was as follows (2.85 ev, 2.78 ev, 2.78 ev), since a decrease in the energy gap was observed with an increase in energies.

Keywords: *Silico N-type; Thin Films; XRD; CO2Gas Sensor; Pulsed Laser Deposition.*

INTRODUCTION

Cadmium sulphide (CdS) is attracted to semiconductor compounds due to its efficiency in optoelectronic device applications [1-2]. When it comes to different electronics Photovoltaics, such as solar cells, sensors, photodetectors, light-emitting diodes, and nuclear detectors, (CdS) compounds—one of the members of the (II-VI) group of semiconductors—have been acknowledged as an essential material [3–4].

At ambient temperature, CdS films exhibit a large bandgap (2.42 eV). They are also utilised in thin-film sensors as a window layer. In light of this, n-type CdS/Si is ideal for various applications [6-5]. Recent research on this intriguing substance suggests that CdS may make an appealing choice for printed electronics [7-8], the production of different display devices [9], and as an antibacterial agent in the medical industry. The utility of CdS thin films in possible new technological applications has drawn attention to their qualities in recent decades. These properties include low cost, good chemical stability, facile growth, and optical conductivity [10-11].

Practical Part

The researcher used the pulsed laser deposition (PLD) system, which is located in the Materials Research Laboratory in the Department of Physics in the College of Science - University of Anbar. In this study, a hydraulic press was used to prepare a target made of cadmium sulphide (CdS) powder by pressing 3 g of the substance under 3 tonnes of pressure for a certain amount of time. CdS films were made utilising various laser energies (220, 180, and 140 mJ) with 200 pulses for each energy under pressure ((2-10×5.2 mbar) using pulsed laser deposition (PLD) technology. The source for the (PLD) was a Nd: YAG laser with two wavelengths (532–1064 nm) and a frequency (6Hz). For the purpose of depositing the material on the bases that were positioned (2.5 cm) away from the target, as indicated in Figure (1), the laser was pointed towards the target at an angle of 450.

Fig. (1) shows the working method of the pulsed laser deposition system in a vacuum (Vacuum).

X-ray diffraction (XRD) was used to calculate the crystal structure and particle size of the films prepared by the PLD technique. The particle size (D) was calculated using Scherer's Formula [12].

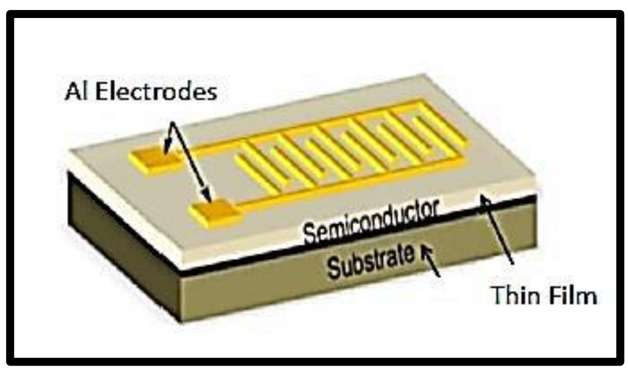
$$D = \frac{K\lambda}{\beta \cos\theta}$$

where k is a constant of 0.94, λ is the wavelength of 0.0154Å x-ray, β is the full width at half maximum (FWHM), θ is the Bragg angle [13]. The optical absorption properties of SCd films were investigated within the range nm (900 to 200), and they increased with increasing energies used for both wavelengths (532,1064 nm).

Configure the sensor electrodes

Gas sensing electrodes were deposited on the films prepared on silicon substrates to test the sensitivity of the gas sensor by connecting these electrodes to the sensor circuit. This requires making electrodes of thin aluminum and placing them on silicon bases (CdS) on which the thin film is deposited, as in Figure (2). For the purpose of measuring (sensitivity, response time, and recovery time), the principle of measuring the difference in resistance was relied upon when the surface of the thin film was exposed to carbon dioxide (CO2) at a certain temperature.

Fig. (2) A model of an electrode installed on a thin film.



Results and Discussion

• Figure (3) showed the results of X-ray diffraction, three main peaks representing the crystal levels (002), (100) and (103), which correspond to the angles θ2 (28.3610, 26, 9620, 44.1840), all of which are related to the composition of (CdS) films of the wavelength (532nm). Figure (4) showed the results of X-ray diffraction with three main peaks representing the crystal levels (002), (100) and (103), which correspond to the angles θ2 (.28.3630, 9630, 26, 44.1850) for the wavelength (1064nm). The diffraction patterns shown in the figure for both wavelengths are that the largest intensity (peak) appeared at θ2 = 28.3610 and this peak represents the dominant direction of growth (002) and according to the numbered card (JCPDS No.41-1049), as it showed a high degree of crystallization with a change in crystal size by increasing the laser power as shown in Table (1).

Fig. (3) Shows the The deposited films' X-ray diffraction (XRD) patterns with a wavelength of (532nm).

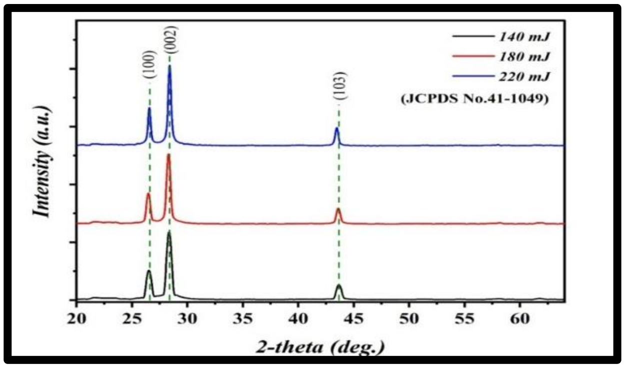


Fig. (4) Shows the The deposited films' X-ray diffraction (XRD) patterns with a wavelength of (1064nm).

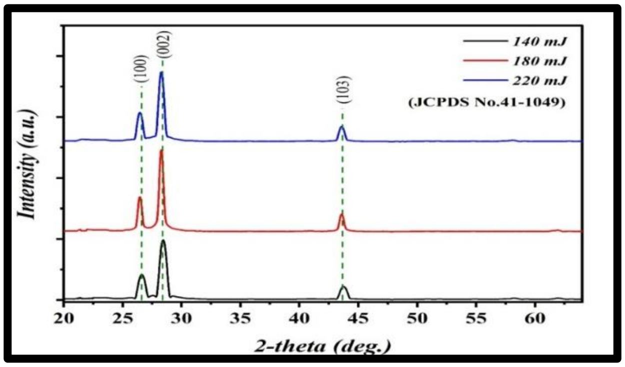


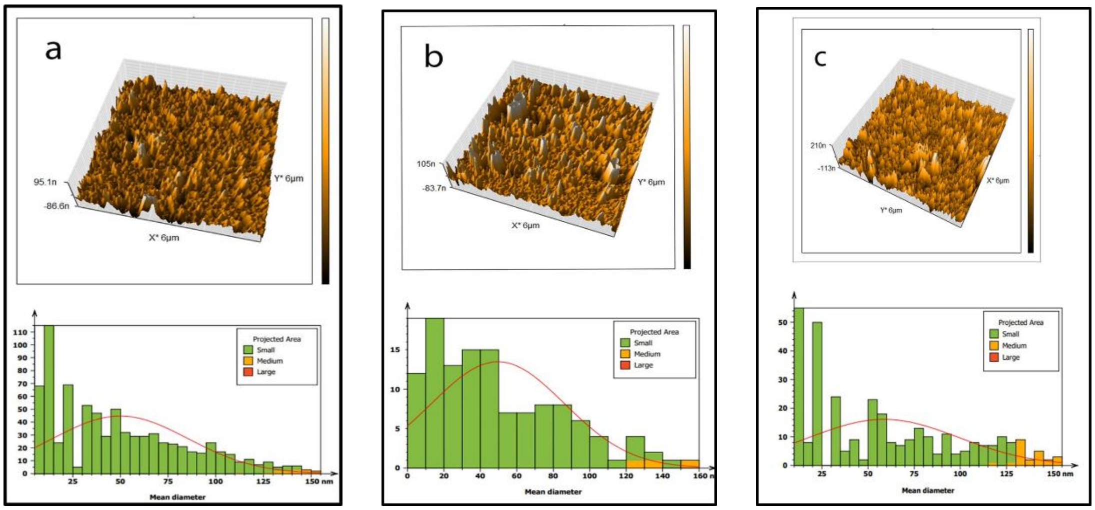
Table (1). X-ray diffraction (XRD) data for CdS films prepared on quartz substrates for both wavelengths (532-1064nm).

Wavelength Laser (λ)	Energy Laser (mJ)	2θ (Deg.)	d_{hkl} Std.(Å)	FWHM (Deg.)	G.S (nm)	hkl
532nm	140	28.335	3.146	0.866	12.595	(0 0 2)
	180	28.356	3.258	0.692	11.866	(0 0 2)
	220	28.361	3.263	0.652	9.482	(0 0 2)
1064nm	140	28.341	3.224	0.572	15.825	(0 0 2)
	180	28.359	3.231	0.551	14.900	(0 0 2)
	220	28.363	3.276	0.519	12.971	(0 0 2)

Results of Atomic Force Microscopy (AFM).

Atomic force microscopy gives a comprehensive description of the surface topography of thin films prepared on silicon bases. The dimensions were described from the two-dimensional images of the surface topography as in Figure (3c,b,a)

Fig(5).(5-a),(5-b),(5-c)Three-dimensional images of thin films prepared on silicon substrates for (140, 180,220)mJ different energy

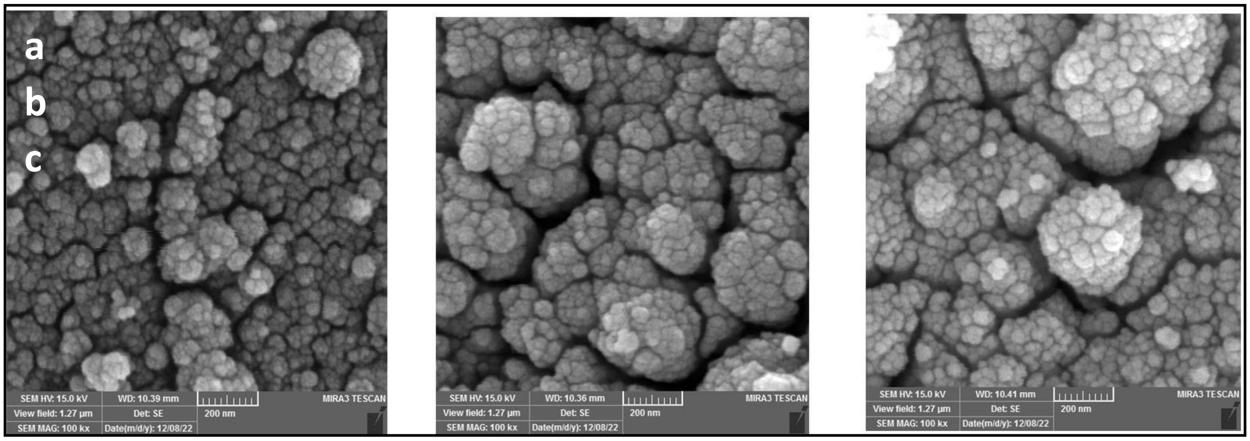


a b c

where it was found that the surface roughness factor is of great importance because it provides the idea of surface quality and grain growth, where the value of the mean square root represents the surface roughness ratio), which is (47.64nm, 35.76nm, 24.16nm) using different energies (140, 180, 220) mJ. The maximum height, which represents the amount of nanoparticle growth, was calculated, so the peak value was (30.99nm, 22.62nm, 17.97nm). As for the horizontal dimensions of the surface, they were determined from the 3D images.

Scanning electron microscopy (SEM) resultsA scanning electron microscope was used to examine the samples' surface morphology on silicon bases in a high-magnification scanning range (200 nm), where the microscopic images of the samples showed diffusion throughout the entire base. Using the Image j program, the particle diameters and the average particle diameter were found using the (ImageJ) program, and the particle diameters ranged between ((40-60nm). As for the average diameter of the nanoparticles, it was found equal to (52.9nm, 47.5nm, 46.2nm) according to the energies used, respectively. Figure (4-5 (c,b,a) also shows the regular distribution of the semi-spherical nanoparticles. “The morphology of the thin films plays an important ”role as a catalyst in increasing the electrochemical reactions when used as an electrode to increase the sensitivity of the gas sensor [14].

Fig (6)(a,b,c). Illustrating FE-SEM topography of the as-prepared films using a laser energy of a) 140 b) 180 c) 220 mJ



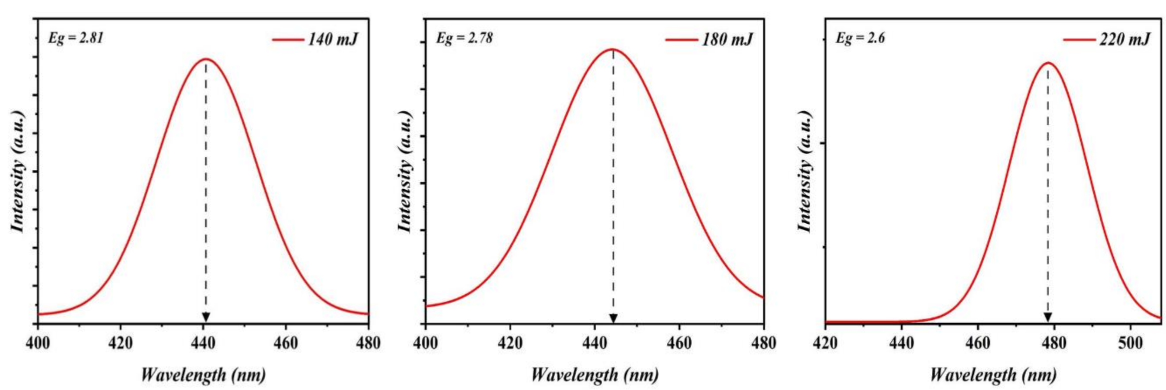
Photoluminescence (PL) Results

The energy gap was calculated by photoluminescence as in Figure (5), which shows the amount of energy gap for (CdS) membranes, where the values of the energy gap were (2.85 eV, 2.78, 2.78), using different energies (140,180,220) mJ, where we observe a reduction in the gap energy as the energies rise. As a function of the wavelengths at which the photoluminescence emission occurs, the energy gap of the photoluminescence spectrum of thin films was calculated [15].

$$E = \frac{hc}{\lambda} \qquad or \qquad E = \frac{1240}{\lambda}$$

Since photoluminescence is a technique for sensing the electronic structure by examining and analysing the light radiation produced by the fluorescence, it is applied to semiconductors to ascertain the purity of semiconductors. [16].

Figure (7): shows the photoluminescence (PL) spectra of (CdS) thin films



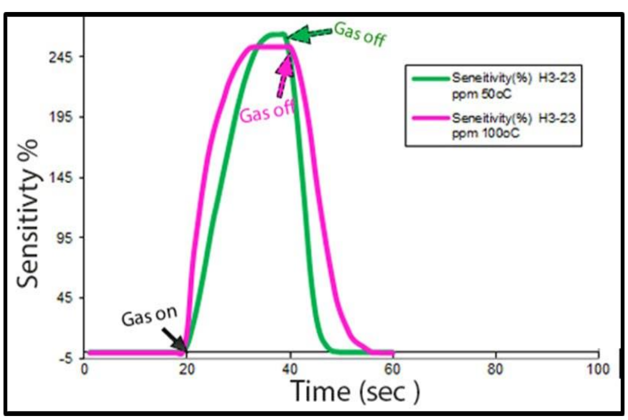
High sensitivity and the use of the oxidising gas (CO2) were two features that semiconductor-based gas sensors were often known for [17]. The characteristics of the CdS film-based gas sensor were investigated, the basic gas sensor properties of (CdS) films were examined as a function of operating temperature and concentration gas test. This study characterized the film by factors such as sensitivity, response and recovery time. The figure shows the sensitivity to CO2 gas as a function of the operating temperature of the thin film.

Where the results showed that the best sensitivity was (S = 263.6%) for the gas sensor made of (CdS\Si) prepared with an energy of (220) millijoules of wavelength ((532nm) at a temperature (50°C) with a short response time of (10.2sec) “and a shorter recovery of (5.1sec) This is due to the fact that one of the methods used to increase the sensitivity of the gas sensor is (PLD), which results in an increase in the surface area of the prepared thin film, which causes a regulation in pore sizes as a result of an increase in the surface area to volume ratio”. This directly affects the deposition of the semiconductor on the surface of the silicon substrate with different energies and wavelength of the laser used, which in turn is reflected on the characteristics of the gas sensor, including increased sensitivity [18]. The level of sensitivity is also significantly influenced by the roughness factor; more specifically, the interaction between the target gas and the membrane surface rises as the membrane's surface roughness increases.

Table (4-7): Shows allergic values and response and recovery times at temperatures (50,100 ° C).

Wavelength Laser (λ)	Energy Laser (mJ)	Temperature (ºC)	Sensitivity %	Response Time(s)	Recovery Time(s)
532nm	140	50	102	6.4	5.7
		100	139.3	8.8	7
	220	50	263.6	10.2	5.1
		100	253.4	8.6	10.3

Fig(8). provides the optimum response to a gaseous allergen by demonstrating the change in sensitivity with temperature.



Conclusions

The impact of operating temperature and concentration on the CdS gas sensing characteristics of thin films was investigated in this article. The resulting films were polycrystalline with a hexagonal structure, according to an XRD analysis, and the crystal size grew as the energy input increased. Morphology showed membranes (CdS) on silicon substrates showed the regular distribution of semi-spherical nanoscale granules in different sizes depending on the impact of laser intensity distributed on the surface of the membrane with no cracks caused by defect;ll;l;;l[.The photoluminescence results showed that the thin films have an energy gap of 2.6 eV, which confirms that these films are good semiconductors. These sensors have been studied for CO2 gas sensing and have shown high sensitivity, response speed and recovery times.

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