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Study the Influence of number of laser pulses on Optical Properties of CdS Thin Films Prepared by Laser Pulsed Deposition

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Abstract:

In this paper, we studied the effects of the number of laser pulses and optical properties, such as the UV-visible spectra of cadmium sulfide (CdS). The films were created using the pules laser deposition technique (PLD) in a vacuum at a pressure of 10-5 mbar at a wavelength of 1064 nm with various laser pulse numbers (50, 100, 150, and 200) and a frequency of 6 Hz, with a laser energy of 700 mJ. The optical properties of the films were studied, and the variables affecting them were investigated in relation to the number of laser pulses. In the visible region, the average transmittance of cadmium sulfide (CdS) thin film was found to be more than 70%. We discovered that as the number of laser pulses increases, so does the transmission of the film, and that all films have a value of absorption coefficient (> 104 cm1), which increases the probability of the occurrence of allowed direct transitions with band gap. The purpose of this work was to investigate the effect of the number of laser pulses on certain optical properties of pulsed laser deposition (PLD) techniques on 25- K deposited CdS films.

Keywords: Laser parameters, thin films, nanoparticles, cadmium sulfide, UV-VIS, pulsed laser deposition, and optical properties

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Introduction

Thin-film interference process used in reproduction and photography equipment, as well as used in lenses coating, mirrors and filters for some wavelengths with special specifications for use in photovoltaic cells and solar cells and detectors in general [1]. Ablation laser deposition is one of the development methods of thin-film and installation of various nan scale high connectivity with insulators, metals and various substances. This method need a high capacity somewhat up to (10 8W / cm2) pulse laser of the degree of vaporization temperature materials is high, this evaporation process occurs at high illumination of flames plasma away very quickly from the target material. The plasma formed may react with the latter part of the pulse and the result of this interaction leads to win high kinetic energy and an increase in the degree of ionization and this case fall within the deposition of film processes [2]. The cadmium sulfide (CdS) is a yellow solid, and prepared by adding H2S or sulfide ion to the acidic solution of cadmium salt. The presence of chloride ion (Cl−) can reduce the ion concentration (Cd + 2) to a sufficient degree even prevents the deposition process. The detection of the presence of cadmium the interaction of aqueous solution (Cd + 2) with sulfide ion, which gives (CdS) yellow [3]. The crystal structure of the material is of the hexagonal or cubic type (cubic) and the unit cell for this structure is fixed faces (fcc) and this is similar to the composition of diamond, sodium chloride and zinc sulfide [4]. Each ion is surrounded by four sulfur ions of cadmium associated with covalent bonds resulting from the participation of two electrons between two atoms of cadmium and sulfur [5]. Gap of energy is (2.42 eV). The main applications that have been used for this compound are in solar photovoltaic cells [6, 7].

The film growth process or deposition of ejected target material onto a growing film, can be described by the following sequence: Firstly, the arriving particles must be adsorbed on the surface, then they may diffuse some distance before they react with each other at the surface and start to nucleate. The way the particles nucleate may determine the structure or morphology of the growing film. Under certain circumstances (high substrate temperature), diffusional interactions within the film and with the substrate, beneath the growing film surface, may subsequently modify film composition and film properties.

Material and methods

To prepare a thin film of cadmium sulfide (CdS) using a pulsed laser deposition system consisting of two parts, the first being a vacuum chamber containing the target holder, the substrate holder, and a window for the passage of the laser light making the quartz beam light, as well as the thermal fuse discharging and the double, and the substrate heated up to 2500 °C, where the substrate subject is perpendicular to the target holder

The second component is a system of Nd:YAG lasers operating at 1064 nm with different laser pulse numbers (50, 100, 150, and 200) and a frequency of 6 Hz, with a laser energy of 700 mJ. A beam of laser is focused on the target using the focal lens dimension for distant subjects with a 30 cm inclination angle and a surface of almost 450 mm. The pure cadmium sulfide (CdS) powders were homogeneous for 36 minutes before being compressed using hydraulic pistons under 8 tons of pressure, resulting in tablets with a thickness of 4 mm and a diameter of 3 cm. It was placed inside the deposition chamber on the target holder, and the discs were ablated using an Nd:YAG laser and a 30 cm focal length lens. The thin films prepared were examined by a UV-Vis-NIR spectrophotometer.

Results and discussion

Figure 1 shows the number of laser pulses' effect on the absorption spectra of the wavelength in the range 320–900 nm. The optical absorbance spectra of the film deposited on glass substrate were investigated at wavelengths ranging from 320 to 900 nm. The above film shows good absorption in the entire UV region and a part of the visible region. The absorption was uniform in the most visible region and lower in the infrared region. It has been discovered that the absorbance of film increases as the number of laser pulses increases.

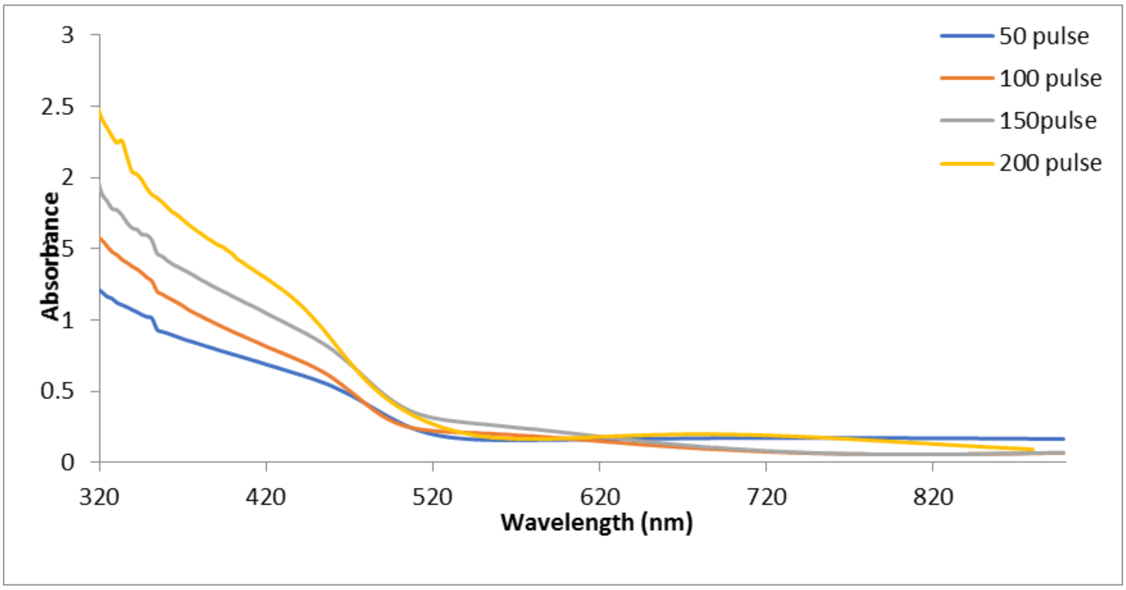

Figure 1: Absorbance spectrum of CdS films prepared by PLD at different the number of laser pulses [E=700mJ, λ Laser=1064 nm]

Figure 2 explains that the transmittance spectrum decreases exponentially with increasing the number of pulses for a specific wavelength. This may be due to an increase in the number of ejected particles reaching the substrate surface. This large amount of particles will increase the film thickness, lowering the transmittance. The sharp increase in the transmission spectrum varies from one film to another; this may be explained by the variation in the particle size distribution for the sample.

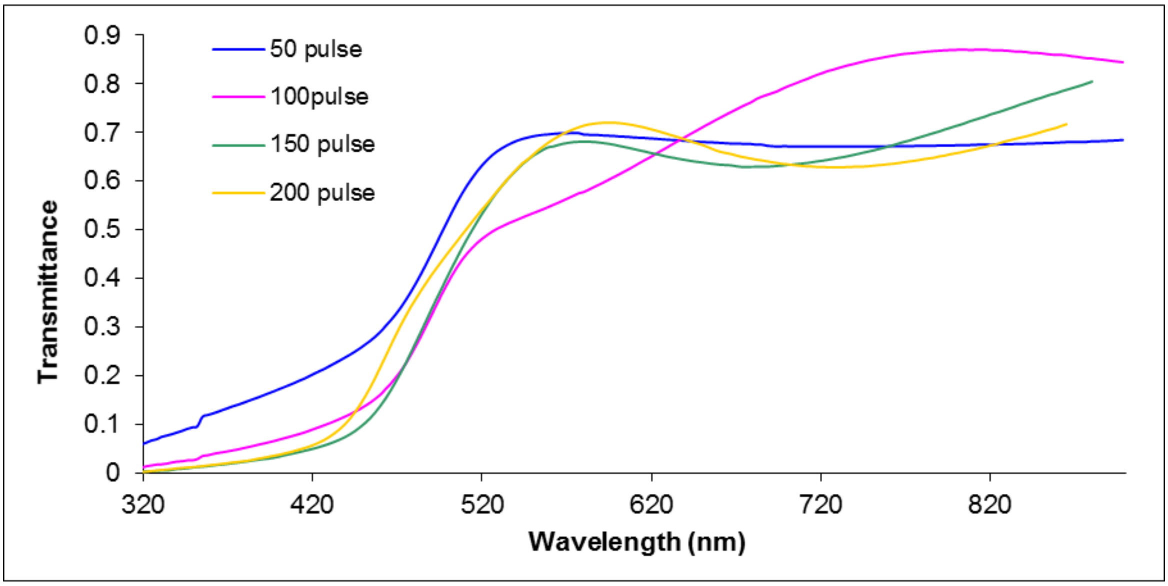

Figure 2: Optical transmission spectra of CdS thin films at different values of laser pulses.

Figure 3 shown the optical absorption coefficient as a function of incident wave length on CdS at different the number of laser pulses (50,100,150, and 200) pulse onto cleaned glass substrate at 250 Co and the thickness was about 320,332,346 and 362 nm respectively. We can evidently see that all films have a value of absorption coefficient (α >104 cm-1) which causes the increase of the probability of the occurrence direct transitions. The absorption coefficient value depends on absorptivity and theoretically its relation is reversed with the film thickness.

Thus, the absorption coefficient α corresponding to any wavelength λ can be calculated by applying the relation:

$$\alpha = 2.303\ A/t \qquad (1)$$

Where it is the thickness.

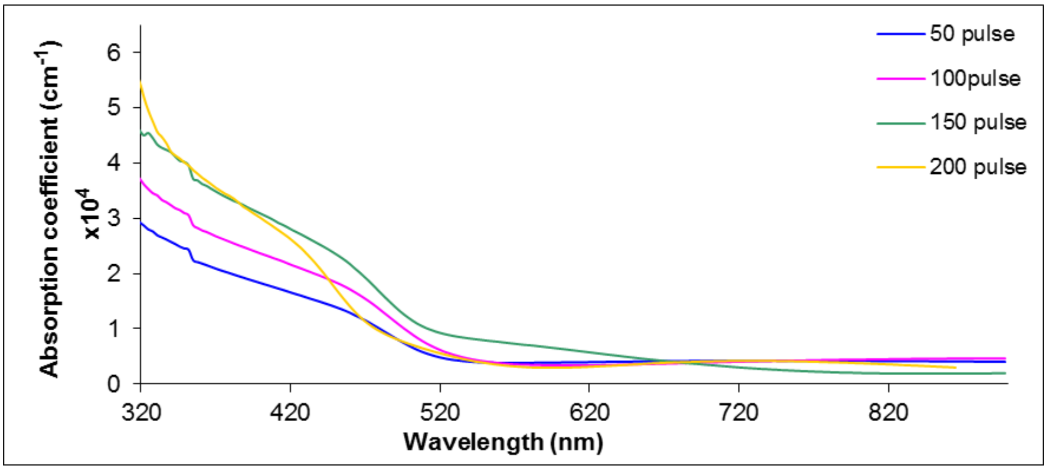

Figure 3: The absorption coefficient as a function of wave length of CdS thin film at different of laser pulses [E=700mJ, λ Laser=1064 nm]

Figure 4 is the variation of extinction coefficient of the CdS film against wavelength. The extinction coefficient is high in the wavelength range of 350-450nm and low in the wavelength range of 450-1000nm.

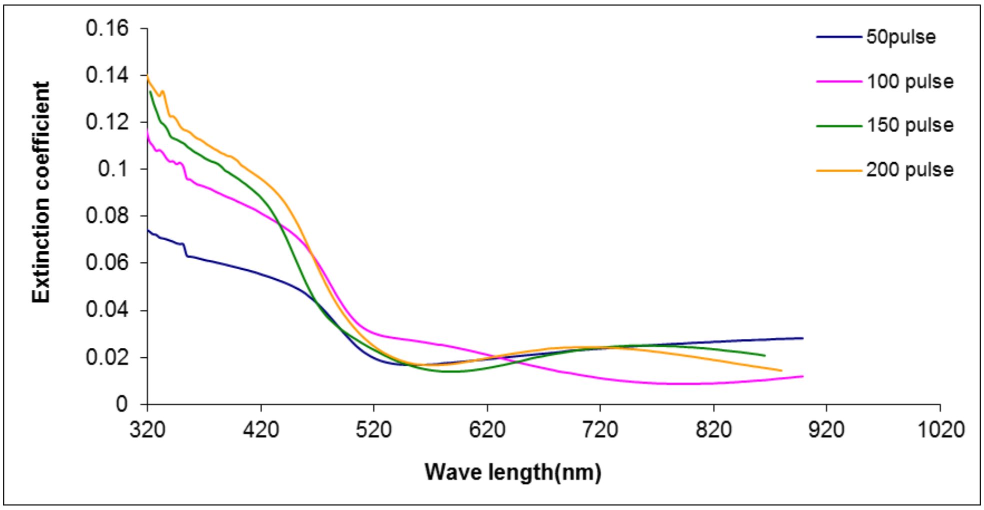

Figure 4: The variation of extinction coefficient a function of wave length of CdS thin film at different the number of laser pulses [E=700mJ, λ Laser=1064 nm].

Figure 5 depicts the variation of optical conductivity with wavelength for as-prepared films. The change in nanocrystal size of CdS films could explain the increase in refractive index.

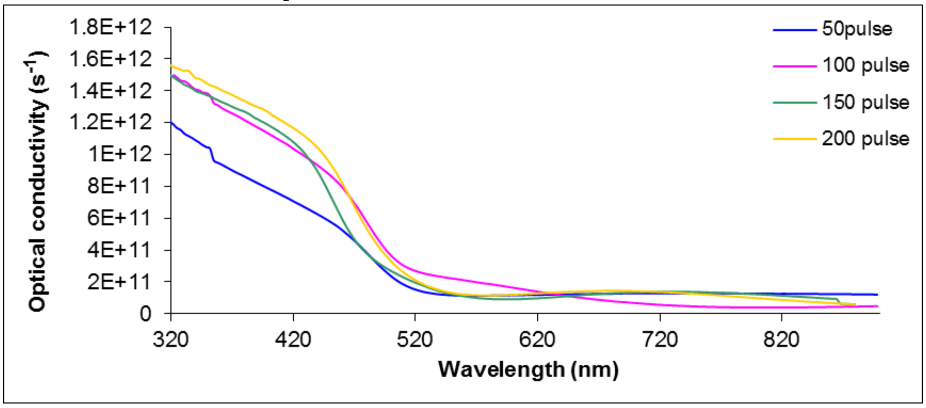

Figure 5: optical conductivity a function of wave length of CdS thin film at different the number of laser pulses [E=700mJ, λ Laser=1064 nm]

Figures 6 and 7 show the energy gap of CdS thin films deposited by PLD. From these figures, it can be observed that the energy gap value decreased with increasing laser energies. The effect of temperature change was evident in two cases where the energy gap values were increased by increasing temperatures, as shown in Table 1.

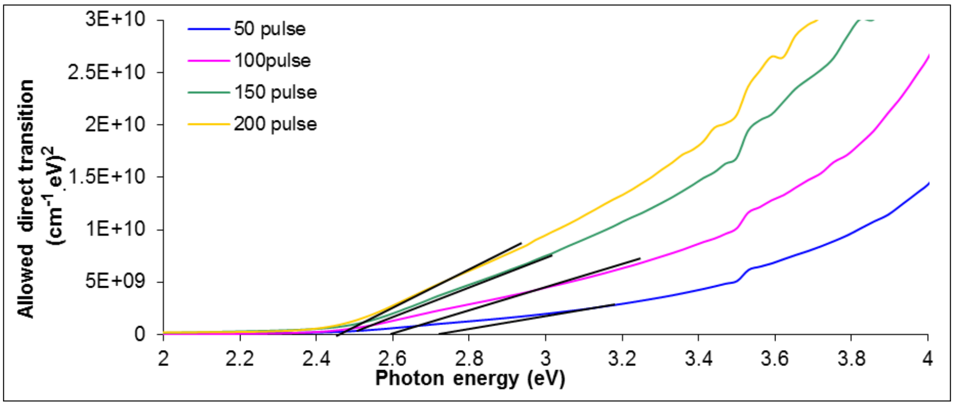

Figure 6: CdS direct transition prepared on a PLD at various laser pulses count [E = 700 mJ, , λ Laser = 1064 nm]

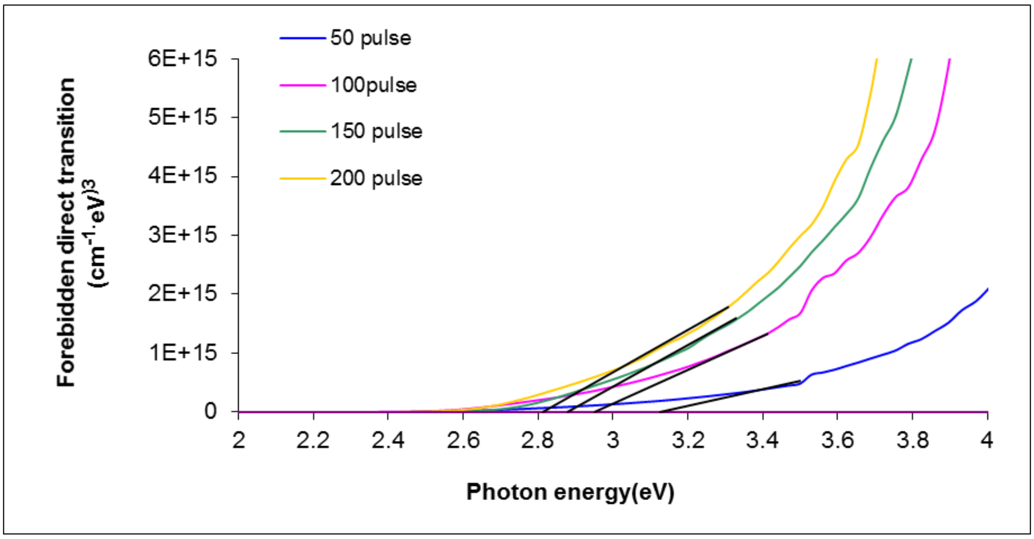

Figure 7: In direct transition of CdS prepared by PLD at different numbers of laser pulses [E=700mJ, λ Laser=1064 nm].

Forbidden Energy Gap (eV)	Allowed Energy Gap (eV)	Thickness (nm)	Number of laser pulse Pulse
3.16	3.04	320	50
2.99	2.98	332	100
2.91	2.83	346	150
2.82	2.81	362	200

Table 1: The values of energy gap of CdS thin films

Conclusion

As a result of the images and the diagrams of pure and doped CdS with Mg, it was concluded as follows:

1. From the optical properties of the cadmium sulfide thin films using pulsed laser deposition, film absorbance increases with increasing the number of laser pulses.
2. The optical spectra (transmittance) showed systematic changes that corresponded to their nanostructures.
3. We can clearly see that all films have an absorption coefficient greater than 104 cm1, which increases the likelihood of direct transitions.
4. The energy-dependent absorption coefficient was calculated from the optical spectra to determine the band gap.
5. The value of the allowed direct band gap is lower than the forbidden direct band gap.

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