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Indium Trioxide Preparation and Characterization using Pulsed Laser Deposition at Various Energies of Laser

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ABSTRACT

The impact of varying the pulsed laser intensity on the characteristics of the produced indium tri-oxide thin (In2O3) films was examined in this work. using silicon bases and the pulsed laser deposition (PLD) technique. utilizing a (Nd:YAG) laser with a wavelength of 1064 nm, In2O3 nanofilms were produced utilizing the pulsed laser deposition technique. X-ray diffraction (XRD), field emission scanning electron microscopy (FE-SEM), atomic force microscopy, and UV-visible spectroscopy were used to analyses the material. The morphological characteristics show the microscope image and polycrystalline nature. The (AFM) atomic force microscopy analysis revealed that a nono-films made using the technique of the deposition by pulsed laser, have a good and homogeneous crystal surface, while electron scanning demonstrated that the spherical of nanostructure formation with the changes in the optical results occurs as the energies of laser increases, and UV-visible spectroscopy were used to analyses the deposited Nano films.

Keywords: *Indium Trioxides, Nanostructure, Laser fluencies, PLD, FESEM*

1. INTRODUCTION

Metal-oxides doped are used to fabricate the optoelectronic devices such solar cells (including dye-sensitive solar cells and inorganic devices) and flat panel displays [1-4].

The goal of the current study is to enhance some TCOs' (transparent conductive oxides) electrical and optical characteristics [5-7]. By altering the conditions inside the volatile sedimentation machine, the researchers are enhancing materials like indium zinc oxide (IZO) and indium tin oxide (ITO) [8-10]. Researchers can attain varying with a carrier concentrations and sheet resistance within the device by adjusting its parameters [11-13]. This carrier concentrations have effect on the short circuit current. The investigators discovered combinations that increase the short-circuit current after adequately varying the parameters [14-17].

TCOs, or transparent conducting oxides, have Excellent electrical characteristics and a significant amount of visible optical transparency are crucial for semiconducting applications like liquid crystal displays and solar cells. In_2O_3 and another semiconductors oxide such (SnO ،ZnO, & CdO) are important for a realization of several optical and photonic devices and for fundamental research [18-24]. They possess outstanding substrate obedience, firmness, chemical subsidence, high brilliant transmittance, and superior electrical conductivity. Numerous researches have been conducted because of these qualities. [25-28]

In2O3 is one of the most important TCO materials because to its high electro-optical properties in the visible spectrum and large optical band gap [29-33]. Numerous applications, such as grating materials, electrochromic devices, organic/polymer light-emitting diodes, electrical switches and memory, optoelectronic devices, and ultrasensitive gas sensors, have made extensive use of this composite due to its band gap [33-38].

This study used a variety of intensities and used the pulsed laser approach to produce thin films. This work's main goals were to maximize the deposition of In2O3 thin films and investigate the resulting films' structural, optical, and morphological characteristics as well as how these characteristics relate to deposition parameters like power and working pressure.

2. EXPERIMENTAL

The PLD method, used to deposit undoped In_2O_3 thin films ans presented in fig 1, was created on a silicon substrate for all investigations except the UV-Vis deposited on quartz. The laser of Nd:YAG , wavelength (λ = 1.06 μm), 3 Hz frequency, and 7 nm pulse duration. The laser's specifications were displayed accurately. The laser beam was concentrated on the rotating target using a convergent lens with 250 pulses for each of the following pulsed energies: 900 mJ, and 700 mJ. The pure indium oxide target was supplied from China. The substrate temperature was maintained within 300°C, and the In2O3 target was set at a 45° incidence angle. Every film was made at a background oxygen pressure of 100 mbar. This method was used to deposit samples onto a silicon substrate. The substrate layer was heated to 300 ºC using a hotplate. The procedures took less than ten minutes to complete. Using a meter of stylus profile, the film thickness was determined to be between 71 and 243 nm. The sample of indium oxide thin film nanoparticles (In_2O_3) was examined using the FESEM, and AFM, The results and debates section that follows provides an analysis of every result.

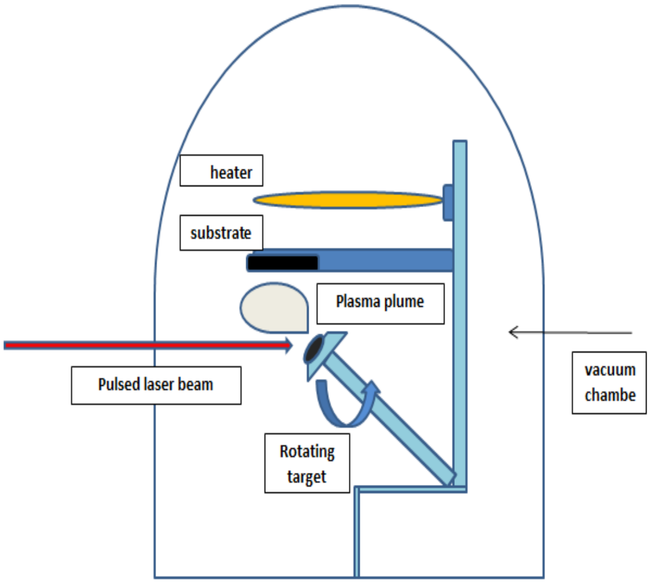


Figure 1. The technique method of pulsed laser deposition.

3. RESULTS AND DISCUSSION

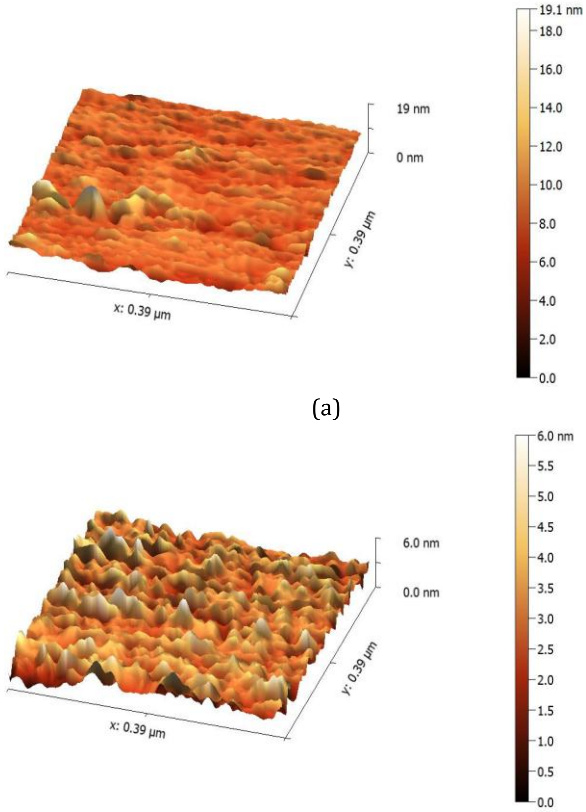
3.1. Morphological Properties

3.1.1 AFM Results

The morphological characterization used to investigate the variations in roughness among In_2O_3 thin films is vividly displayed by AFM analysis. The 3-D morphological images of the deposited nano-In_2O_3 films deposited at energies of 900 mJ and 700 mJ, respectively, are displayed in Figures 2(a) and 1(b), respectively. Table 1 contains a tabulation of the deposited thin film RMS values. Around 32.87 nm of RMS surface roughness with granular structure was visible in In2O3 film at 700 mj (Figure 2(a)). At 700 mj, the grain sizes of the In2O3 thin film are evenly spaced across the surface of the deposited films. As the energy increased to 900 mJ, it showed an additional uniform structure, with the largest value of the RMS occurring to be 16.17 nm (Figure 2(b)). It's observed that the structure became more uniform, ordered, and granule-rich as the mj increased to 000. In contrast to low-energy In_2O_3 films, AFM research indicated that nano In_2O_3 films produced at energy of high energy displayed an additional uniform structure with higher surface roughness as a result of increased dislocation of nanoparticles and their installation on silicon substrates [39-43].

Table 1 Surface roughness (RMS) of the produced thin film at different energies (600,700,800,900,1000) mJ

Pulsed laser Energy (mJ)	Average roughness (nm)	RMS
700	23.22 nm	32.87 nm
900	13.64	16.17



(a)

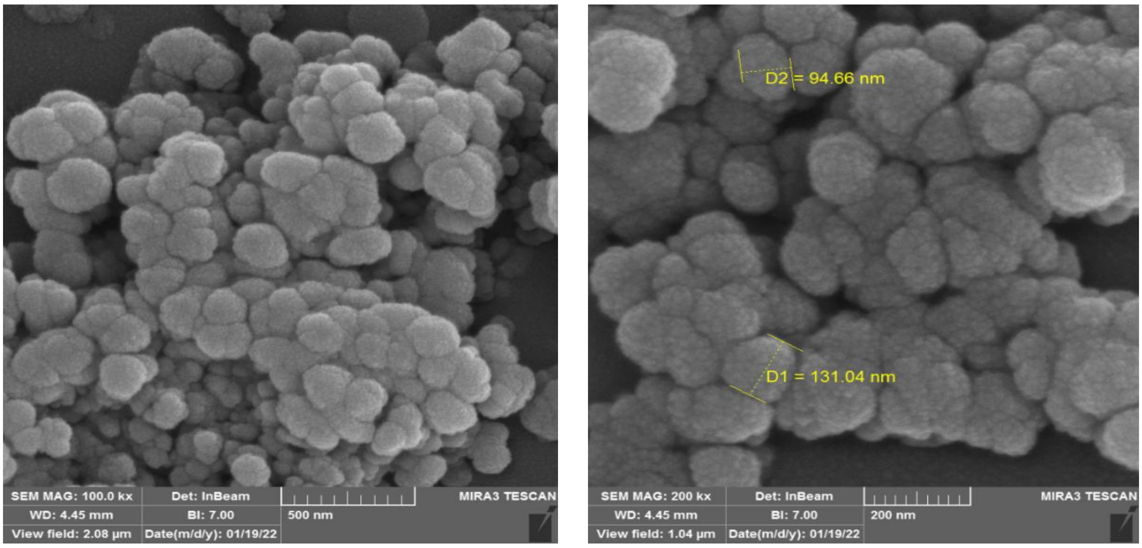
(b)

Figure 2. AFM images for pure nano In2O3 film via different laser energies (a) 700 mJ, and (b) 900 mJ

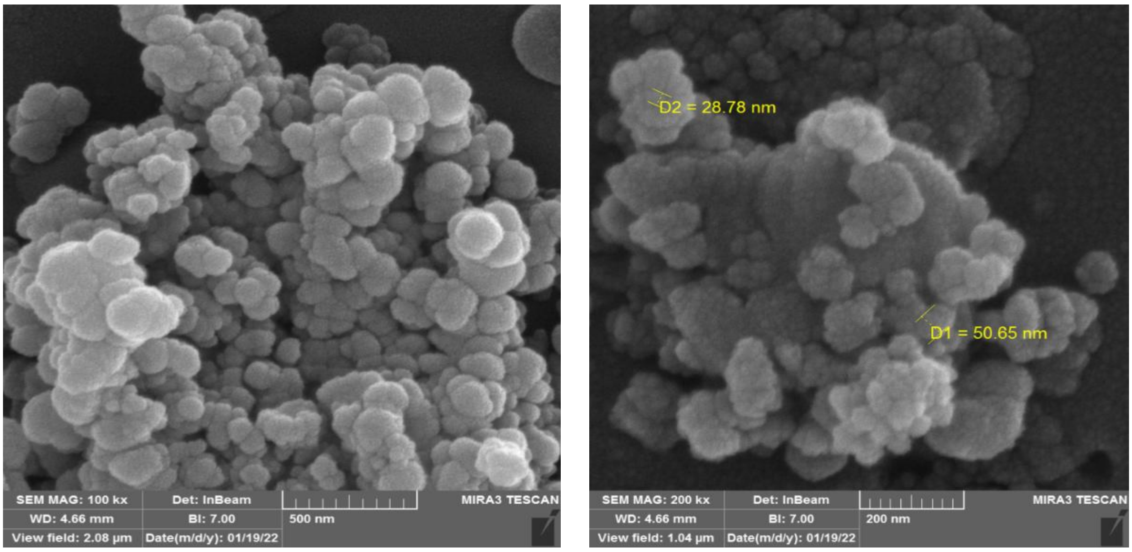
3.1.2 FESEM Results

FESEM images of In_2O_3 thin layers prepared by different pulsed energies for 700 and 900mJ were presented in Figure 3. According to the findings, the nano-crystalline spherical circle with a diameter of 135-221 nm is one of the structures that make up the particle structure of the In2O3 thin layer. Figure 3 reports the In_2O_3 thin layer (700 and 900 mJ) FESEM images. Every In_2O_3 thin layer displayed the existence of uniformly distributed small particles, which led to the formation of small particles that are evenly distributed across the surface and resemble spherical circles. It is important to observe that when high energy is continuously introduced, compact aggregates with a spherical structure are formed and dispersed like thin particles on the spherical surface.

The In_2O_3 particle size distribution in Figure demonstrated that the participation energy had a considerable impact on the diameter of spherical, circle-like particles. A decrease in particle diameter, with the majority being less than 135 nm, has been noted in conjunction with an increase in energy from 700 mJ to 900 mJ. Furthermore, as the energy increases above 900 mJ, the spherical particles attributable to In_2O_3 species get bigger. For 700 mJ, the spherical particles are the largest [44-48]



(a)



(b)

Figure 3. FESEM photos of In2O3 produced at 300°C via: (a)700 mJ, and (b)900 mJ, energies.

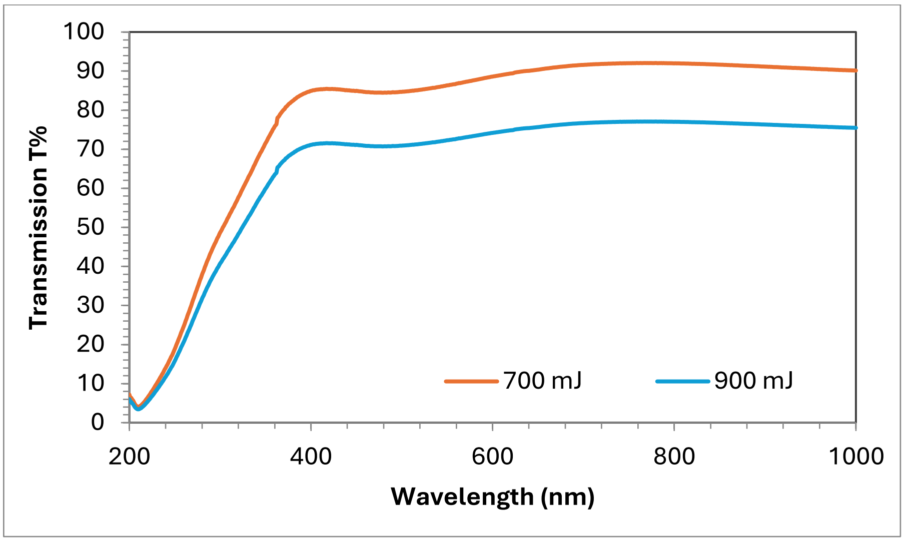
3.2. Optical Properties

In Figure 4a, it was discovered that the transmission decreased as the pulsed laser energy increased because the deposition efficiency increased and the In_2O_3 Nano-films, and also the thickness of the deposited nano structure, decreased [49-51].

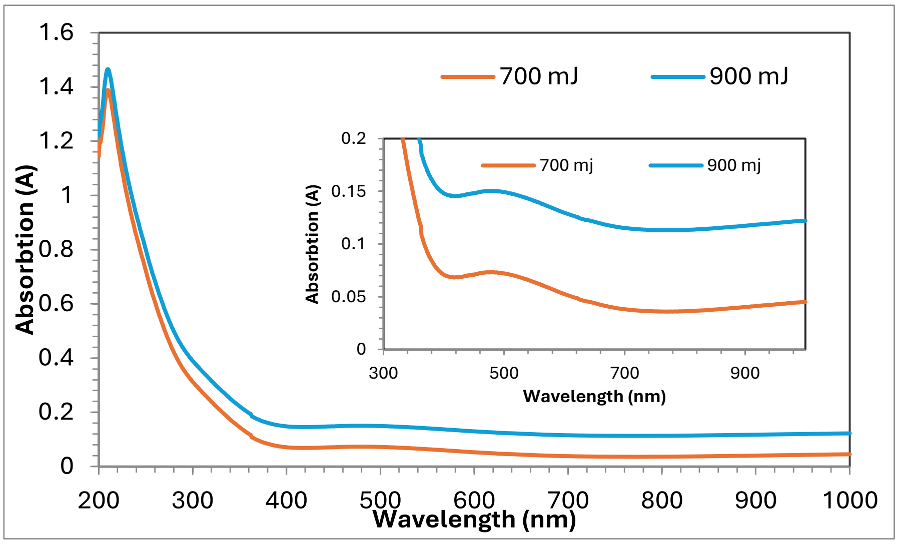
The optical absorption edges in Fig. 4b exhibit a slight blue shift as laser power increases because of the smaller particle size [52-54]. The absorbance increases with wavelength up to 220 nm, after which it decreases with wavelength, as seen in the figure below.

Additionally, the energy absorption rises with increasing energy up to 900 mj, with the maximum absorption taking place at that point.

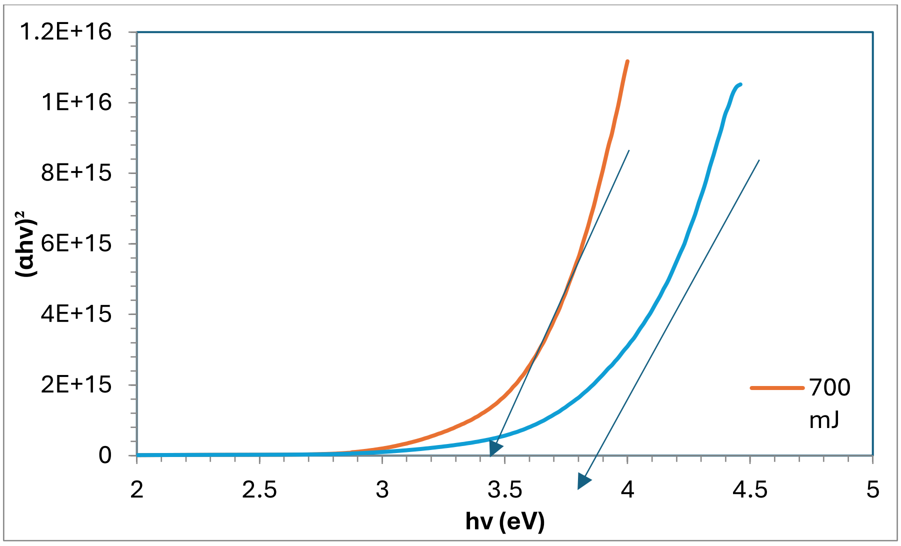
Plotting (αhv)2 vs. hν yields the band gap energy Eg, as illustrated in Figure 4c. As particle sizes grow because of the quantum confinement phenomenon and the surface/volume ratio, the predicted band gap energy falls between 3.42 and 3.74, which corresponds to 700 and 900 mJ. These band gap energies are greater than the bulk [55-58]. Band gap energies rise because of the surface atom's reduced coordination number and atomic contact, which change the valence band's energy and the vacant conduction band [59-63].



(a)



(b)



(c)

Figure 4. (a) Wavelength-dependent optical transmission for In2O3 at various laser energies, (b) Optical absorption as a function of wavelength for In2O3 at various laser energies. (c) A plot of (αhν) 2 verses photon energy (hν) of the in2O3 thin films at different laser energies.

4. CONCLUSION

The production of indium oxide thin films (In2O3) nanostructures via five distinct energies utilizing the pulsed laser deposition method is presented in this study. AFM and FESEM tests were used to investigate In_2O_3 that was placed on the silicon substrate. The means of AFM findings. It was discovered that the volume ratio granularity increased with laser power. According to (FESEM) images, the granules are spherical and get bigger as the laser pulse energy increases. These results give an indication to used it in photonic and optoelectronics devices. The optimum result is obtained at 900 mJ, and the in2O3 absorption peaks are (402, 0.15). This laser energy is regarded as the ideal energy employed in this work since the films formed at an oxygen pressure of 100 mbar exhibit rising band gap energy at this energy, which has the greatest value (3.8), but it also yields the best results in the majority of measurements.

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