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PREPARATION AND CHARACTERIZATION OF CDO-NIO NANOCOMPOSITES USING LASER PULSE DEPOSITION APPROACH

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Abstract

In this manuscript, CdO-NiO nanocomposites (in the form of thin film) with particular concentrations are paper using laser pulse deposition technique under the effect of different laser energies (300, 400, 500, and 600 mJ). Furthermore, the structural, morphological, and optical analyses are thoroughly investigated. In particular, well-oriented deposited films are observed by using X-ray diffraction technique, while the morphological properties are investigated using two different techniques namely field emission scanning electron microscopy and atomic force microscopy which have revealed small nanoparticles with approximate diameter of 50 nm and average surface roughness ranging between 6.5 and 20.3 nm for laser energies of 400 and 600 mJ, respectively. Continuously, the optical technique applied which used UV-Vis analysis has showed cut-off phenomenon at around 339 nm. In the meanwhile, the energy band gap for the deposited films was found to be within the range of 2.2 and 2.4 eV, as a result of different laser energies.

Keywords: Pulsed Laser Deposition, Cdo:Nio Composite, Structural, Optical.

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1. Introduction

Reduction in the sources of fossil fuels and a significant development in environmental consciousness within the new world has raised the scientific research attempts to Find out an applicable alternative energy sources, especially photovoltaic technology [1, 2].Metal oxide semiconductors are being widely applied in optoelectronic applications; for example, light emitting diodes, flat panel display, smart windows, photodetectors, solar cells, etc.[3-8].Recently, transition conducting metal oxide (TCMO) nano materials are considered to be of precise attraction because of their exceptional microstructure, catalytic, magnetic electrical, and optical features [4, 9]. Continuously, transparent conducting oxide (TCO) thin film has pronounced significance in electronic device applications, particularly in solar cell applications [10].But, metal oxide especially on its own on its own may suffer from certain issues for instance, high recombination rate, visible light low harvesting, and low selective absorption which in turn affects negatively the catalytic, electrical and optical properties. Hence, mixing dissimilar semiconductor nanoparticles can be proposed in order to solve the addressed issue. So, through the combination of mixed metal oxides semiconductor, one may generate a mutual charge that carriers transfer from a semiconductor to another through which could enhance the physical properties [10].Nickel oxide (NiO, 3.5 eV) as a p-type semiconductor has revealed large Potential applications in electrochemical capacitors, lithium-ion battery, gas sensing, and solar cells. In the meanwhile, cadmium oxide, an n-type semiconductor (2.5 eV),has showed wide range of applications in gas sensors, optoelectronic devices, light emitting diodes, and solar cells. The aforementioned applications of the both addressed semiconductors could be mainly attributed to the high electrical conductivity, superior chemical features, and optical properties[11-13]. Therefore, this paper attempts to investigate the structural, morphological, and optical properties of CdO-NiO nanocomposite.

2. Methodology

2.1 Thin Film Deposition

In this study, the fabricated thin films are prepared by using laser pulsed deposition technique. In a typical procedure, a mixture of 0.7and 1.264gm of NiO and CdO, respectively, are mixed and then pressed under 5 tons to attain a desired NiO-CdO pellet (1×0.3 cm as diameter and thickness, respectively). Later on, the acquired pellet is usedas the pulsed laser deposition target. Here in after, the obtained target is positioned in an evacuated chamber (10^{-3}Torr) where the glass substrate is placed in a parallel position to the target with a distance of 2 cm. The delete
laser (Q-switched Nd-YAG, 500 mJ) with laser pulse width of 10 ns and repetition frequency of 6 Hz with wavelength of 1064 nm is applied. It worth mentioning that the obtained NiO-CdO target underwent multiple pulse energy is (300, 400, 500, and 600 mJ).

2.2 Characterization techniques

The structural properties of the deposited films are studied by using X-ray diffraction (XRD-6000, Shimadzu) technique. While, the morphological features are recorded by using two different approaches; namely, field emission scanning electron microscopy (FESEM, Hitachi-SU8030) and atomic force microscopy (AFM, SPM AA3000). The optical analysis of the prepared films is recorded ultra-violate visible light spectroscopy (UV-Vis, Shimadzu UV-1800). Furthermore, the electrical properties are investigated by using Hall effect technique.

3. Results and Discussion

The XRD patterns of the deposited films (300, 400, 500, and 600 mJ) are illustrated in Figure (1).The attained XRD diffraction peaks in accordance with planes (111), (200), (220), (311), and (222) which can be indexed to the CdO-NiO nanocomposite structure (JCPDS card No. 65-2908)in since both CdO and NiO phases are acquired. The obtained results are in good agreement with previously published data [14]. Furthermore, figure (1) also shows that different laser energies (300, 400, 500, and 600 mJ) do not reveal clear effect on the CdO-NiO nanocomposite. This indicates the purity of the prepared materials in our framework. It is worth mentioning that the resultant film (CdO-NiO) was found to be highly pure as there was not additional revealed peaks delete it; this in turn indicates the final composite which is a combination of both utilized materials (CdO and NiO). In similar geometry, the obtained XRD results were found to be in a good agreement with previously published data[15,16]. Furthermore, the crystallite size is calculated by using the well-known Scherrer's equation[17, 18]; the corresponding results are tabulated in Table (1). The crystallite size is indicated that higher laser energy is resulted in higher crystallite size; this in turn indicates higher purity at higher energies utilized.

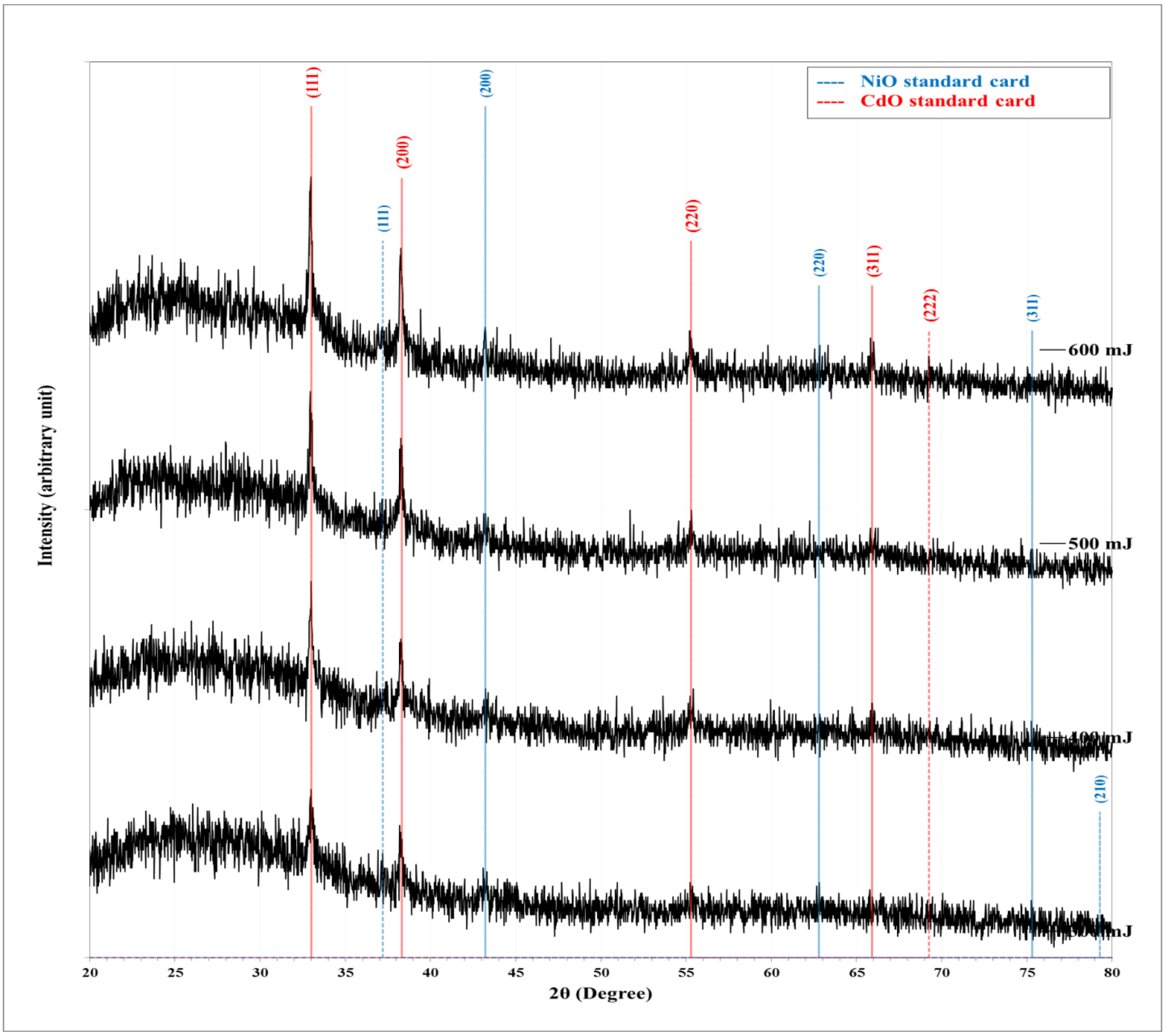

Figure (1)X-ray diffraction patterns for CdO:NiO composite thin films prepared by different laser energies.

Table (1): In-depth structural parameters of the prepared materials.

Energy (mJ)	2θ (Deg.)	FWHM (Deg.)	Crystallite size (nm)
300	33.0280	0.5120	16.2
	38.2888	0.6106	13.8
	43.2561	0.5598	15.3
	55.3181	0.5597	16.0
400	32.9771	0.3563	23.3
	38.2697	0.4545	18.5
	43.2520	0.5088	16.8
	55.2672	0.5088	17.6
500	32.9262	0.4072	20.3
	38.2677	0.3053	27.5
	43.1952	0.4071	21.0
	55.2672	0.4579	19.6

	65.9033	0.4580	20.7
600	32.8753	0.3054	27.1
	37.2010	0.4589	18.3
	38.2667	0.2572	32.7
	43.1861	0.2545	33.6
	55.2163	0.4071	22.0
	65.9033	0.3562	26.6

Figure (2) illustrates the topographic information obtained by using FESEM technique for the deposited CdO-NiO films at different laser pulse energies (300, 400, 500, and 600 mJ).

The images are shown in two different magnifications both 1 μm and 100 nm. In general observation of all samples, the attained surfaces are composed of consistently distributed spherical nanoparticles. In the meanwhile, it can be clearly noticed that some nanoparticles agglomeration is confirmed. The deposited CdO-NiO films are exhibited an average diameter of approximately of 55 nm. In the evaluation of laser energies, it can be noticed that the deposited films have demonstrated lower nanoparticle diameter at higher laser energy which evidences higher crystallinity at higher laser energies. The outcomes of the FESEM analysis are in good agreement with those obtained through the XRD investigation.

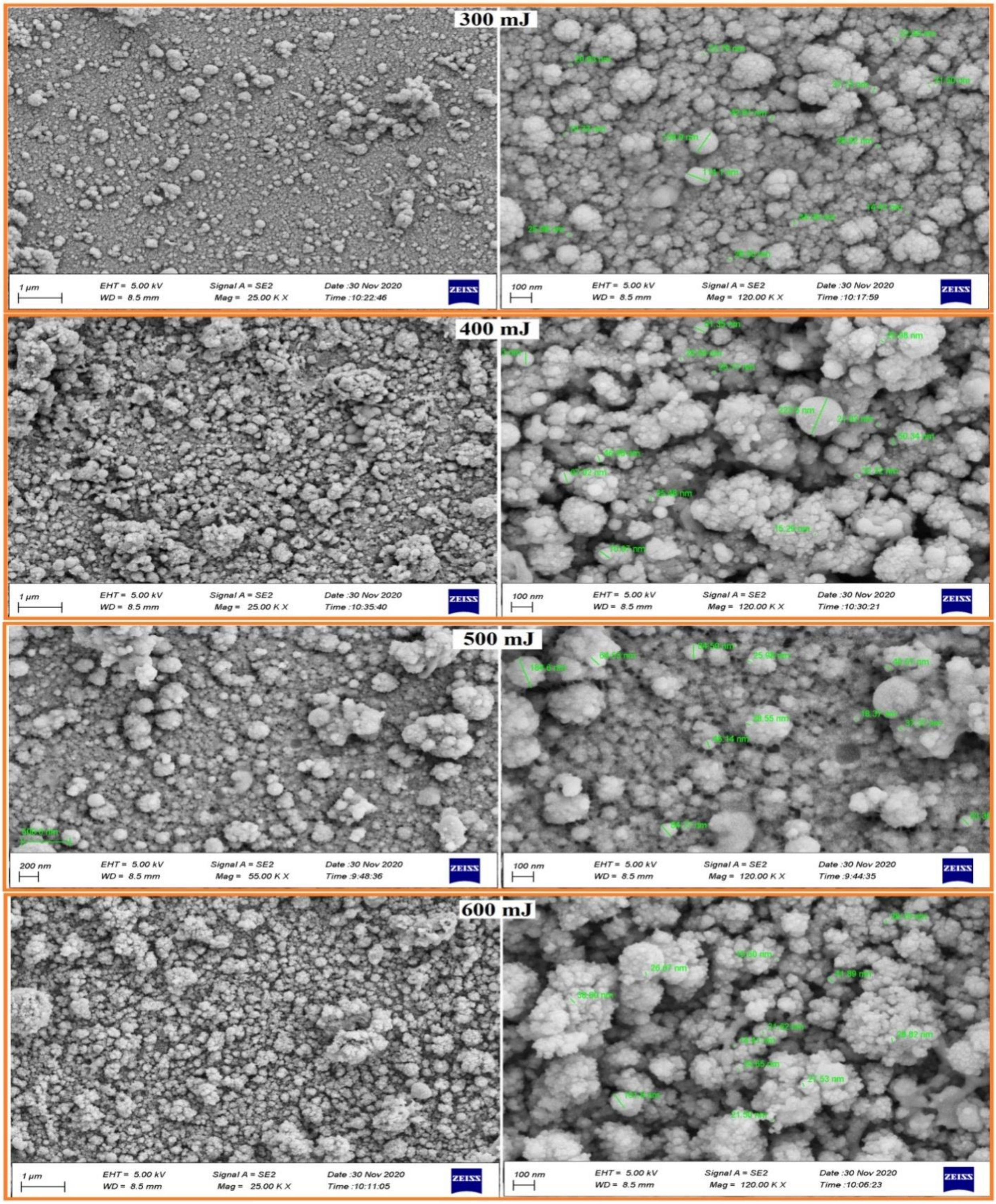

Figure (2): FESEM images at two magnification powers for CdO:NiO composite thin films Which are prepared by different laser energies.

The surface roughness as well as the morphology of the deposited CdO-NiO nanocomposite films at different laser energies (300, 400, 500, and 600 mJ) are investigated by using atomic force microscopy technique (Figure 3). The deposited films at different energies have revealed a well-uniformed distribution of the prepared nanoparticles with upfront alignment grans and spherical shape particles. Additionally, a non-compact CdO-NiO morphology is observed at different energies. In particular, the average diameter for the laser energies of (300,400,500,and 600 mJ)are found to be (62.29,70.54,76.54, 110.58nm), respectively, this shows that higher laser energies deliver higher nanoparticles diameter. In the meanwhile, the RMS roughness for the mentioned energies are found to be (5.25,12.2,15, and 17.6 nm), respectively. Finally, the average surface roughness was found to be (6.5,14.4,17.3, and 20.3 nm), respectively. It is widely known that particles with rough feature of surface delivers a main part in electrochemical activity in comparison to that of smooth surface[19]. It should be mentioned that the obtained results of the average diameter are in good accordance with those obtained for the RMS roughness and average surface roughness.

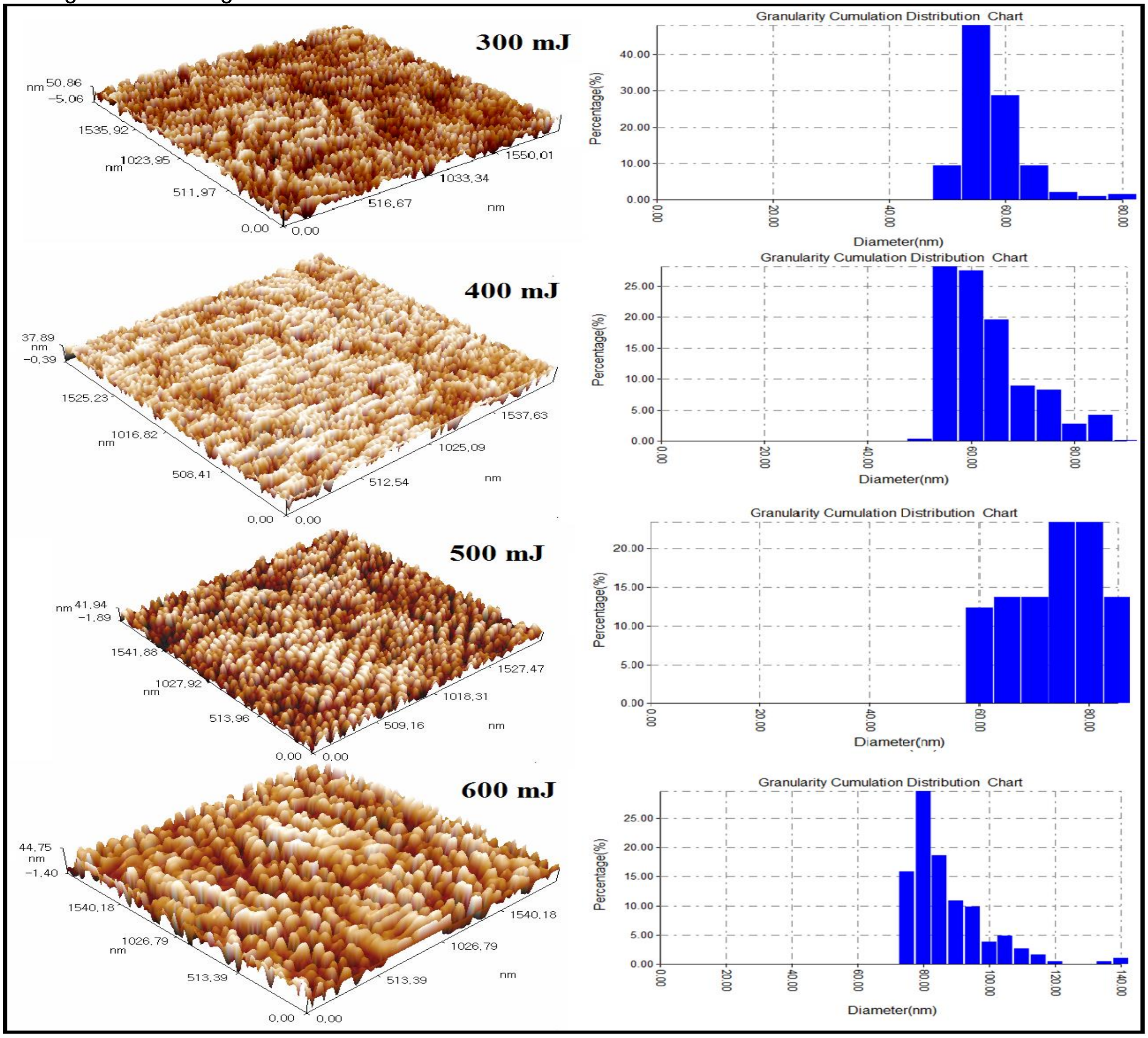

Figure (3): AFM images for CdO-NiO thin films and their granularity cumulating distribution.

prepared by different laser energies. Figure(4) presents the UV-Vis results in which the absorption phenomenon of the prepared materials is illustrated at different laser energies (300, 400, 500, and 600 mJ). It can be clearly observed from the figure that the cut-off phenomenon of the deposited films is noticed at around (~339 nm), with respect the laser energies applied. Furthermore, a slight bath ochromic shift is noticed at higher laser energies. Ahmed A. et al. (2021) revealed some similar behavior of the exhibited UV-Vis analysis at around 335 nm cut-off phenomenon[20]. Additionally, the energy band gap of the deposited films are calculated in accordance with Tauc relation as previously elaborated (Figure 5)[3, 19]. In this investigation, it is noticed that lower laser energies have demonstrated higher energy band gap. Specifically, laser energies of(300)and (400)mJ have revealed energy band gap of (2.4 eV), while laser energies of(500) and (600)mJ have exhibited energy band gaps of (2.3)and (2.2)eV, respectively.K. Karthik et al. (2018)

reported similar energy band gaps at different conditions which in turn support the obtained results in this study[3, 4].

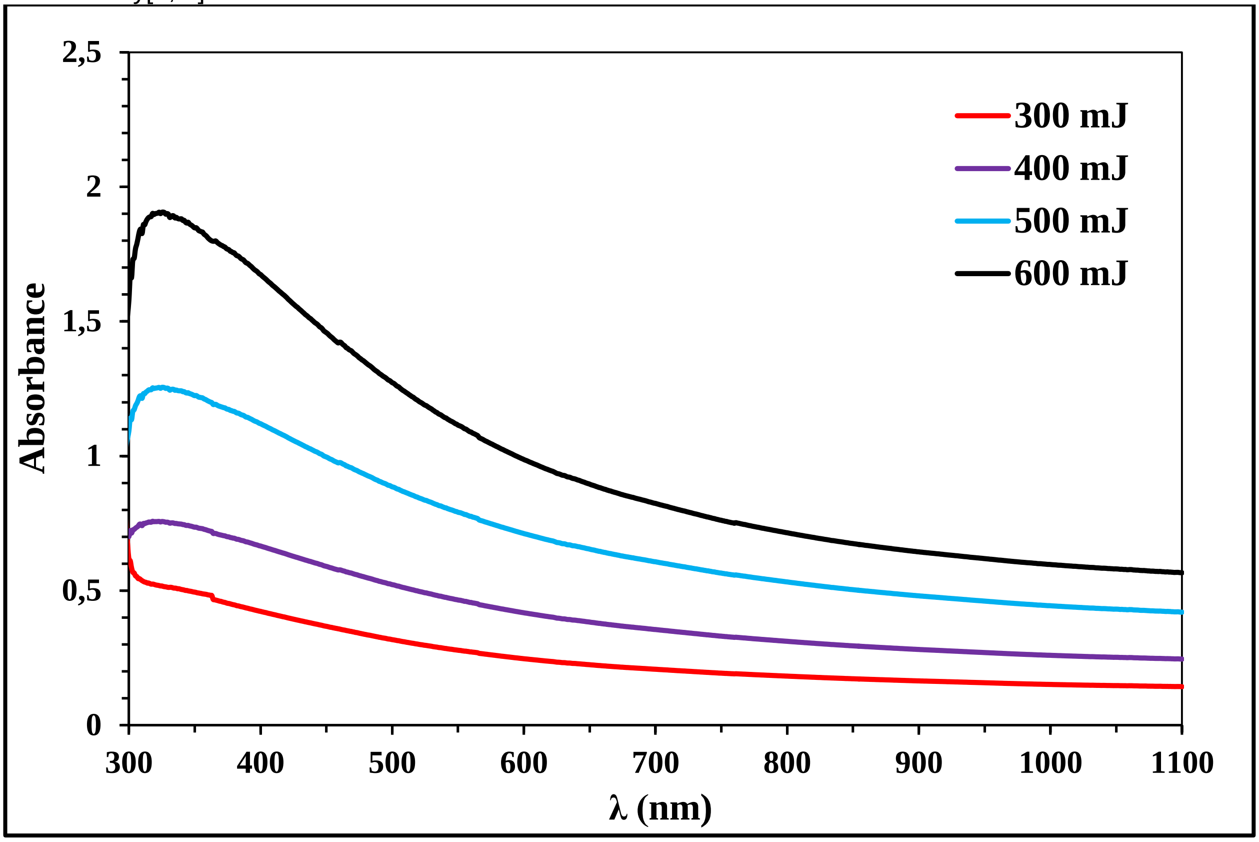

Figure (4): UV-visible absorbance spectra for CdO:NiO thin films are prepared by different laser energies.

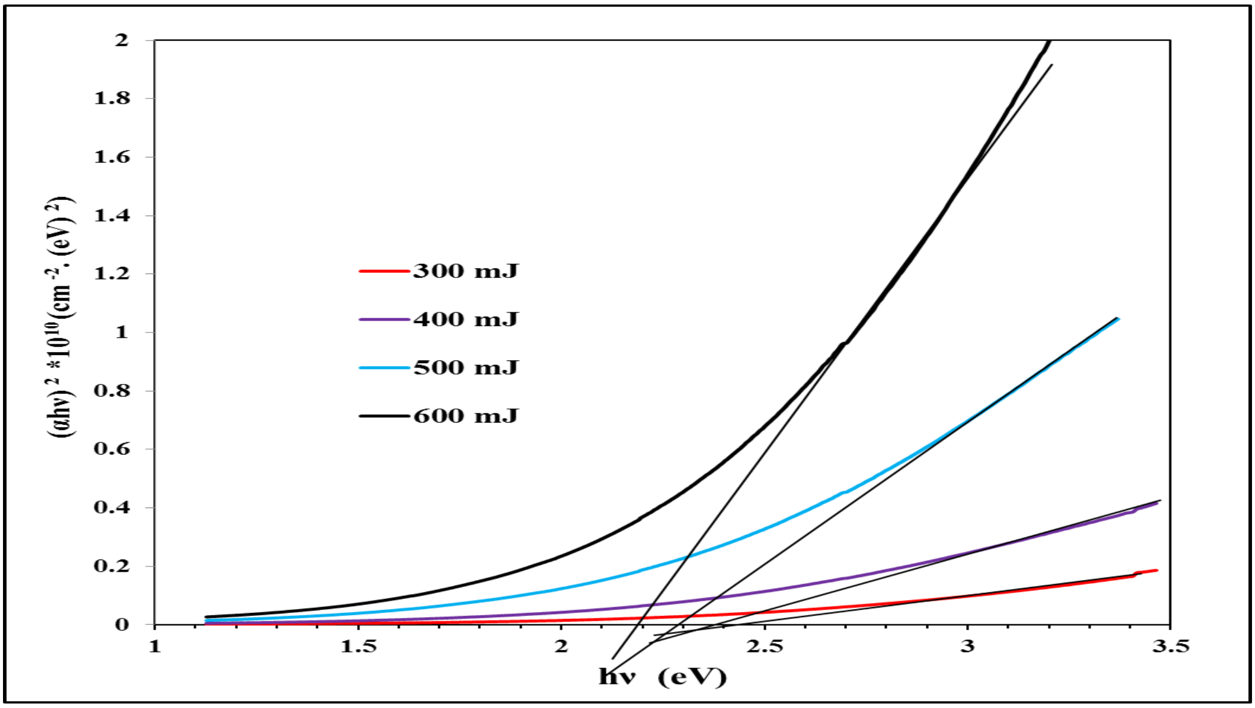

Figure (5): Energy gap for CdO:NiO thin films are prepared by different laser energies.

Conclusion

The CdO-NiO thin films are successfully deposited on quartz substrate by using laser pulse deposition method with dissimilar laser energies (300, 400, 500, and 600 mJ).Additionally, a thorough investigation of the structural, morphological, and optical properties for the prepared samples are presented. Subsequently, the XRD outcomes have indicated the occurrence of highly crystallite structure of the prepared samples. In the meanwhile, both FESEM and AFM analysis have since revealed a compact surface with well-distributed nanoparticles, the average diameter of the deposited nanoparticles was found to be (~50)nm. The optical analysis, on the other hand, has showed a cut-off phenomenon at around (339)nm with a slight red shift at higher laser energies.

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