Preparation and Study of CdO/ZnO/Fe₂O₃ Nanoparticles by Laser Ablation

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Abstract: This study involves the preparation of colloidal nanoparticles by laser ablation of the solid target immersed in water. Also, it discusses the effect of the number of laser pulses on the structural and optical properties of the prepared CdO/ZnO/Fe₂O₃ Nanoparticles (NPs). These colloidal nanoparticles were synthesized by laser ablation of a solid target (Cd/Zn/Fe) in DW solution by using Nd: YAG (λ = 1064 nm, energy = 200 mJ and number of pulses 200 and 1000). Structure, topography and optical properties of the CdO/ZnO/Fe₂O₃ NPs have been studied using X-Ray Diffraction (XRD), Field Emission Scanning Electron Microscopes (FE-SEM) and the UV-Vis absorption spectroscopy, respectively.

Key words: Nanocomposites materials CdO/ZnO/Fe₂O₃ NPs, Pulses Laser Ablation in Liquid (PLAL), optical properties, FE-SEM, XRD, Nanoparticles (NPs)

INTRODUCTION

Nanoparticles (NPs) are significant nanomaterials suitable in a number of applications in Physics, Chemistry, Engineering and Biology because of having a large surface-to-volume ratio (Semaltianos, 2010). There are several techniques for the preparation of CdO, ZnO and Fe₂O₃ nanoparticles such as sol-gel method (Kaur et al., 2006; Zhang et al., 2006), microemulsion method (Dong and Zhu, 2003; Sarkar et al., 2011), precipitation method, thermal decomposition (Ristic et al., 2004), hydrothermal method (Zhang et al., 2008; Wang and Li, 2006), chemical coprecipitation method (Al-Nafey et al., 2016) and thermal evaporation (Waghulade et al., 2007).

Also, nanoparticles can be synthesized by Laser Ablation (PLA) which involves a solid target that found in a liquid environment and assembly of the NPs in the form of a colloidal solution. It’s a simple, fast, direct, purity and sustainability of the colloidal solution for nanoparticles synthesis as compared to other methods, this is according to the choice of solutions for the medium (distilled water, ethanol, etc.) (Semaltianos, 2010). This technique can be produce different types of nanoparticles depends on the laser parameters (wavelength, energy, frequency and the number of pulses).

Laser Ablation in Liquids (PLAL) is a simple process of a reaction of the laser beam to the surface of the solid target that reasons vaporization of the target and a slight quantity of liquid surrounding it (Riabinina et al., 2012). Nanoparticles made up of target atoms can be produced by the chemical reactions between the removed portions and molecules in the liquid surrounding forming suspending particles (collides) in the liquid (Ratti et al., 2017). As a result, these collides interactions with the laser beam leads to extra modifications in the composition, size and shape of nanoparticles.

The iron oxide (Fe₃O₄), the most common oxide of iron has the important magnetically properties. The existence of amorphous Fe₃O₄, and four polymorphs (alpha, beta, gamma and epsilon) is well established (Lasemi et al., 2018). The most frequent polymorphs structure “alpha” (hematite) having a rhombic-hexagonal, prototype corundum structures and cubic spinel structure “gamma” (magnete) have been found in nature (Maneratana et al., 2013).

Zinc Oxide (ZnO) return to 2-6 group semiconductor material and has wide band gap (~3.3 eV at room temperature) and large exciton binding energy of 60 meV. ZnO thin films are extensively used in various applications due to have optical, electrical and semiconducting properties (Riabinina et al., 2012).

Cadmium oxide (CdO) is an 2-6 composite semiconductor made up of cadmium (group 2) and oxygen (group 6) from the periodic table of naturally occurring elements. The 2-6 semiconductor CdO has a face center cubic (fcc) ionic crystal structure (Li et al., 2008). Metal oxides such as CdO play a very important role in many areas of Chemistry, Physics and materials science. CdO (2.3. eV) makes it desirable for the applications relating to piezoelectric transducers, light-emitting devices, photonic crystals, nanoelectronics, transparent UV protection, chemical sensors (Mostafa et al., 2017; Heidari and Brown, 2015).

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Here, this study focused on the preparation of CdO/ZnO/Fe2O3 NPs by Plasma Laser Ablation Liquid (PLAL) and their structural, morphological and optical properties. Also, they study the effect of the number laser pulses on the target.

**MATERIALS AND METHODS**

**Experimental details:** CdO/ZnO/Fe2O3 NPs were prepared by two processes, the first process achieves by adding (4 g) of Zeto (3 g) of NaOH and adding it to (2 g) of FeCl3 and (2 g) of Cd, each of these materials dissolves in (100 mL) purified water with continuous stirring for 24 h, then treat it thermally to create the blend. The second process was achieved by Laser Ablation in Liquids (PLAL) as in Fig. 1.

The morphological characteristics of manufactured nano-oxides materials are scanned by Field Emission Scanning Electron Microscope (FE-SEM) system. The structural properties were scanned by X-Ray Diffraction (XRD) in a range of 20-80°.

**RESULTS AND DISCUSSION**

Figure 2 shows XRD for synthesized CdO/ZnO/Fe2O3 NPs at 200 and 1000 pulses. It illustrates that the prepared ZnO in the composite has multi-crystal line with characteristic peaks at 31.82, 36.28 and 34.40° which can be indexed to the (100), (101) and (102), respectively, planes of a hexagonal pattern of ZnO (wurtzite phase) and it’s in agreement with that reported in (JCPDS card No. 89-0510) (Sawada et al., 1996). The measured value of 1.60 is close to the value 1.633 and this is close to the formation of ideally close packed hexagonal structure (hcp) (Tarwol et al., 2011). The strong diffraction peaks in the XRD spectrum of CdO located at 33.04, 38.33 and
55.3° corresponding to the (111), (200) and (220) planes and its can be indexed to a cubic pattern of CdO (JCPDS card No. 65-2908) (Li et al., 2008). The strong diffraction peaks in the XRD spectrum of Fe$_2$O$_3$ located at 33.25, 35.33 and 44.58° corresponding to the (104), (110) and (116) planes can be indexed to a cubic pattern and it’s in agreement with that reported in (JCPDS card No. 033-0664) (Maneeratasararn et al., 2013).

The average particle size was calculated using Debye-Scherrer equation:

$$D = \frac{0.9\lambda}{B \cos \theta}$$

Where:

- $\lambda$ = The full width at half maximum (in radians) of the peak
- $\theta$ = The Bragg angle
- $\lambda$ = The wavelength of X-ray ($\lambda = 1.54\AA$)

Particle size for both zinc oxide and cadmium oxide nanoparticles approximate value from (13-30 nm) for 200 pulse and (20-50 nm) for (1000) pulse. No other reflection peaks are observed indicating to the formation of high purity phase.

Figure 3 was illustrated the FE-SEM of the prepared CdO/ZnO/Fe$_2$O$_3$ NPs ablated with 200 pulses at $\lambda = 1064$ nm. It’s indicated the presence of polymorphism in crystallization as well as the formation of nanoparticles in the form cubic, monoclinic and nanorods distributed on different nanosheets within the sample surface (Alyamani and Lemine, 2012; Heidari, 2016; Luo et al., 2015) and it’s in agreement with results of XRD. Particles distribution varies from one region to another causing simple spatial defects. Figure 4a, b was illustrated the FE-SEM of the prepared CdO/ZnO/Fe$_2$O$_3$ NPs ablated with 1000 pulses at $\lambda = 1064$ nm. It’s indicated the existence of several shapes and similar to what is in the previous figure at 200 pulses and an increase in the number of nanoparticles due to the increase in the number of laser pulses. Figure 5 was illustrated the UV-Vis spectra of DDW solution CdO/ZnO/Fe$_2$O$_3$ NPs.

A red shift of absorption edge ($\lambda = 670$ nm at 1000 pulses) compared with absorption edge ($\lambda = 570$ nm at 200 pulses) because of the quantum confinement was observed with an increase in the number of pulses and this leads to an increase in the particle size due to aggregation of particles with an increase in the number of pulses and this corresponds to the measurement of XRD (Liu et al., 2015).

Figure 6 was described the transmittance of the prepared CdO/ZnO/Fe$_2$O$_3$ NPs. The absorption curve decreases sharply after 570 and 670 nm for 200 and 1000 pulses, respectively and up. The CdO/ZnO/Fe$_2$O$_3$ NPs have a good transmittance after 570 and 670 nm for 200 and 1000 pulses, respectively.

Figure 7 shows the relation between wavelengths versus extinction coefficient (k). The extinction coefficient decrease with increased wavelength. The extinction coefficient represents the amount of attenuation in the intensity of the electromagnetic radiation due to the interaction of this radiation and the particles in the
solution of the two samples. Observing that the value of attenuation obtained is few and within the hierarchy of the microwaves.

Figure 8 was displayed the variant of $h\nu$ against $(zhu)^{12}$ for Indirect band gap which have been calculated by the extrapolation of linear portion versus the photon energy axis. It can be seen that the value of the energy gap is about (1.7, 2.1) eV for a first sample (1000 pulses) and the second sample (200 pulses), respectively. This mean that the greater the number of pulses, the lower of the energy gap due to the quantum size effect. The small energy gap at the first sample (1000 pulses) indicates an increase in the size of nanoparticles (aggregation) and this corresponds to results of XRD.
CONCLUSION

Pulse Laser Ablation in Liquid (water) (PLAL) is an easy, purity and environmentally friendly technique to get on several oxide of nanoparticles, cubic ananorods. Increasing the number of pulses has a clear effect on optical and structure properties. Any increase in the number of pulses leading to a decrease in the energy gap and appearance the red shift and this indicates to an increase in the particle size due to aggregation of particles. The prepared CdO/ZnO/Fe$_3$O$_4$ NPs have a good transmittance at the wavelength 570 and 670 nm for 200 and 1000 pulses, respectively and up which can be used in solar cell and a smart window (Ismail et al., 2016).

REFERENCES


