Journal of Engineering and Applied Sciences 14 (Special Issue 3): 6036-6041, 2019
ISSN: 1816-949X

Preparation and Study of $CdO/ZnO/Fe_2O_3$ Nanoparticles by Laser Ablation

Saif M. Alshrefi, Mohammed H.K. Al-Mamoori, Mohammed J. Jader,
Rafea Tuama Ahmed and Amer Al-Nafiey
Department of Laser Physics, College of Science for Women, University of Babylon, Hillah, Iraq

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 $CdO/ZnO/Fe_2O_3$ Nanoparticles (NPs). These colloidal nanoparticles were syntheses by laser ablation of a solid target (Cd/Zn/Fe) in DDW 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 $CdO/ZnO/Fe_2O_3$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 $CdO/ZnO/Fe_2O_3$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 Fe_2O_3 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-Nafiey *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 (Fe_2O_3), the most common oxide of iron has the important magnetically properties. The existence of amorphous Fe_2O_3 and four polymorphs (alpha, beta, gamma and epsilon) is well established (Lasemi *et al*., 2018). The most frequent polymorphs structure "alpha" (hematite) having a rhombohedral-hexagonal, prototype corundum structures and cubic spinel structure "gamma" (magnetite) have been found in nature (Maneeratanasarn *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 excitonbinding 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).

Cadmiumoxide (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).

Corresponding Author: Saif M. Alshrefi, Department of Laser Physics, College of Science for Women, University of Babylon, Hillah, Iraq

Here, this study focusedon the preparation of $CdO/ZnO/Fe_2O_3$ NPs by Plus 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: $CdO/ZnO/Fe_2O_3$ NPs were prepared by tow processes, the first process acheves by adding (4 g) of Zeto (3 g) of NaOH and adding it to (2 g) of $FeCl_3$ 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.

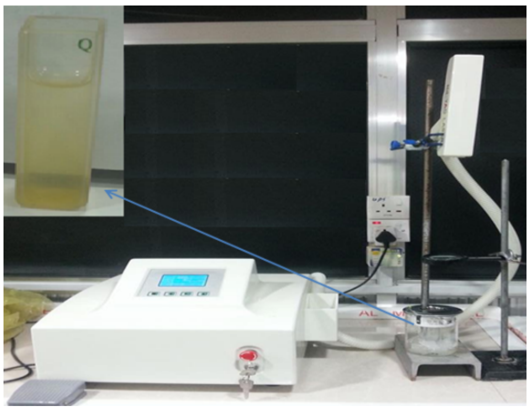

Fig. 1: Illustrated the Laser Ablation system in Liquid (PLAL-technique)

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 $CdO/ZnO/Fe_2O_3$ NPs at 200 and 1000 pulses. It illustrations that the prepared ZnO in the composite hasmulti-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) (Tarwal *et al*., 2011). The strong diffraction peaks in the XRD spectrum of CdO located at 33.04, 38.33 and

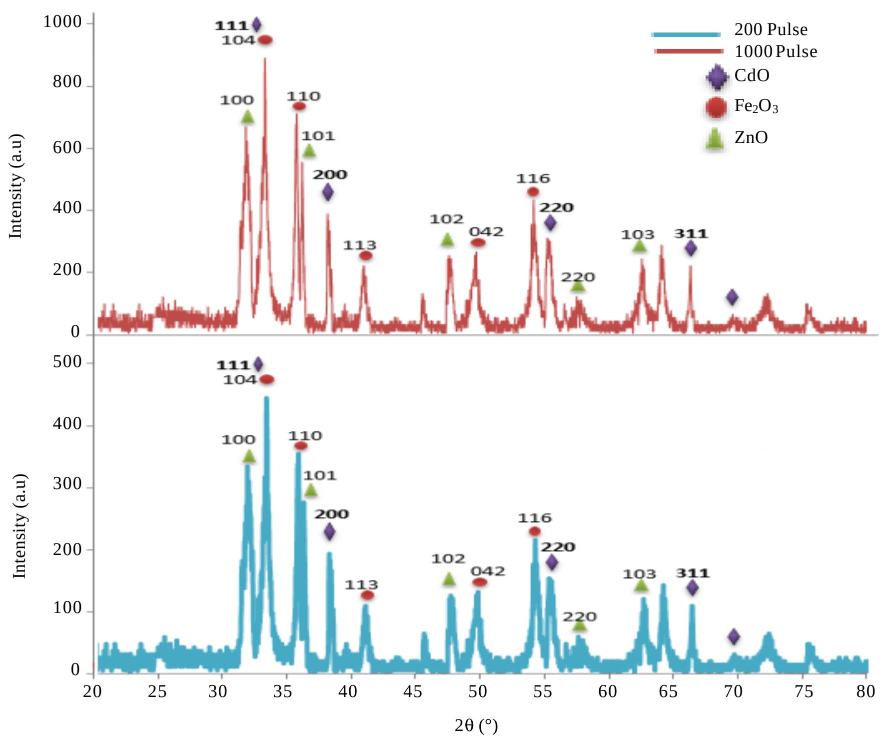

Fig. 2: XRD diffraction pattern of the prepared $CdO/ZnO/Fe_2O_3$ nanoparticles ablated with 200 and 1000 pulses at 1064 nm

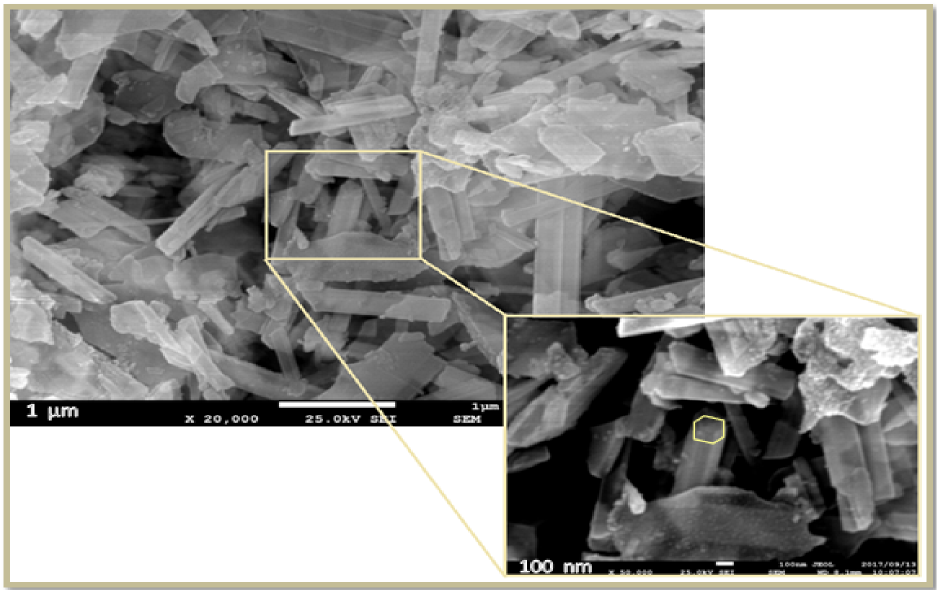

Fig. 3: FE-SEM for the prepared of $CdO/ZnO/Fe_2O_3$NPs ablated with 200 pulses

55.33° 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_2O_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) (Maneeratanasarn *et al*., 2013).

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

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

Where:

(B) = The full width at half maximum (in radians) of the peak

(θ) = Te Bragg angle

(λ) = The wavelength of X-ray (λ = 1.54)⁰A

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 peaksare observed indicating to the formation of high purity phase.

Figure 3 was illustrated the FE-SEM of the prepared $CdO/ZnO/Fe_2O_3$NPs ablated with 200 pulsesat λ = 1064 nm. It's indicated to 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 $CdO/ZnO/Fe_2O_3$ NPs ablated with 1000 pulses at λ = 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 duoto the increase in the number of laser plusses. Figure 5 was illustrated the UV-Vis.spectra of DDW solution $CdO/ZnO/Fe_2O_3$ NPs.

A red shift of absorption edge (λ = 670 nm at 1000 pulses) compared withabsorption edge (λ = 570 nm at 200 pulses) because of the quantum confinements was observed with an increase in the number of pulses and this leads to an increase in the particle sizedue to aggregation of particles with an increase in the number of pulses and this corresponds tothe measurement of XRD (Liu *et al*., 2015).

Figure 6 was described the transmittance of the prepared $CdO//ZnO/Fe_2O_3$ NPs. The absorption curve decreases sharply after 570 and 670 nm for 200 and 1000 pulses, respectively and up. The $CdO/ZnO/Fe_2O_3$ 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

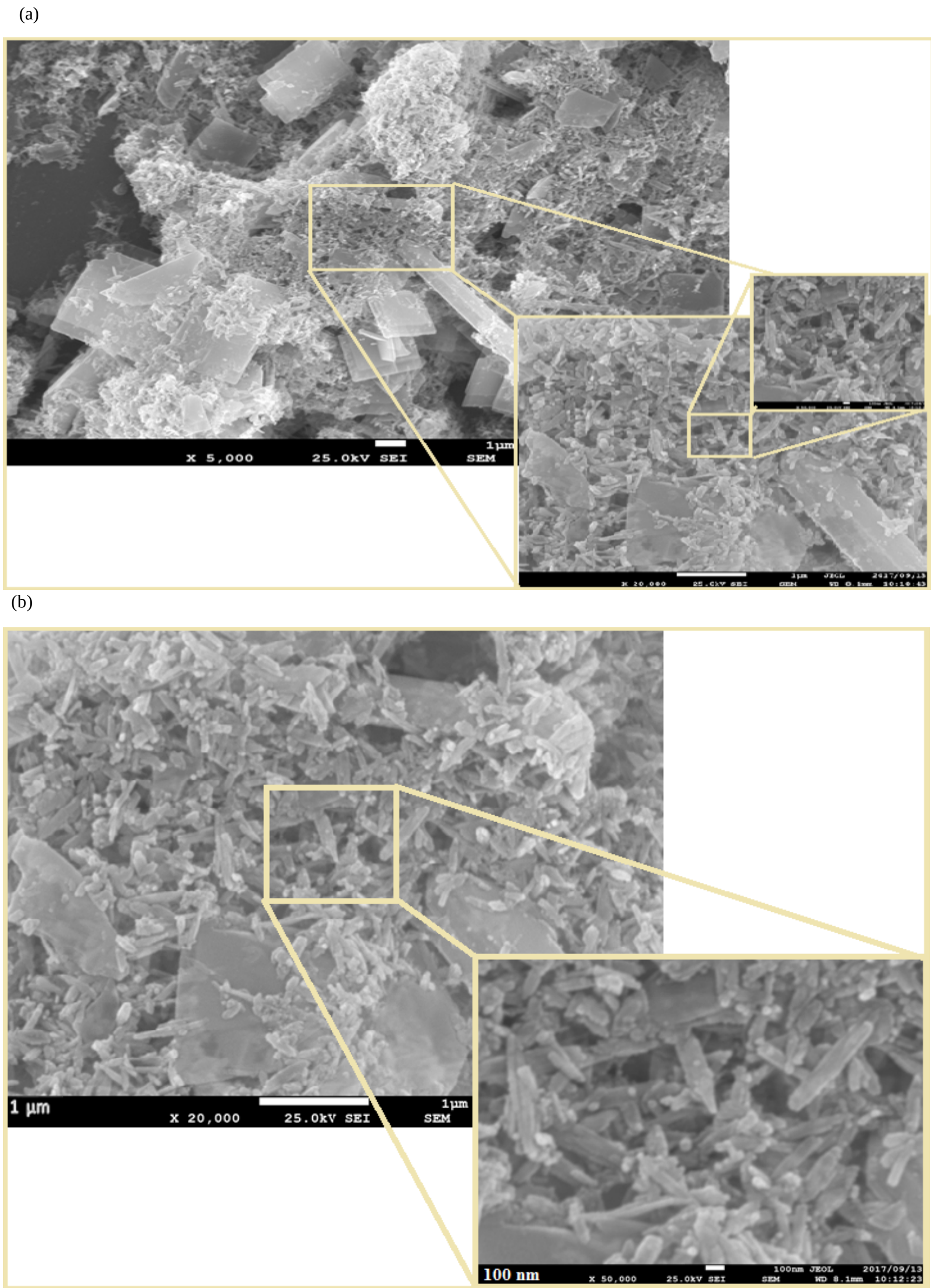

Fig. 4: a) FE-SEM of CdO/ZnO/Fe_2O_3NPs ablated with 1000 pulse at 1064 nm and b) FE-SEM of CdO/ZnO/Fe_2O_3NPs ablated with 1000 pulse at 1064 nm

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 hυ against $(\alpha h\upsilon)^{1/2}$ 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. Thismean 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.

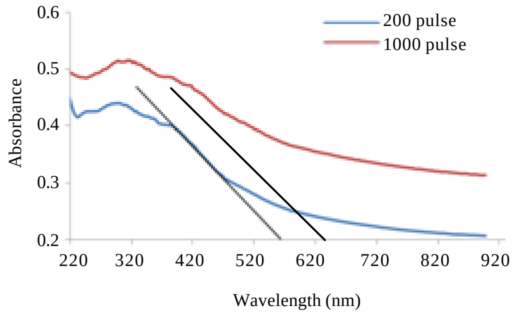

Fig. 5: Absorption spectra of the prepared CdO//ZnO/Fe_2O_3 NPs ablated with 200 and 1000 pulse at 1064 nm

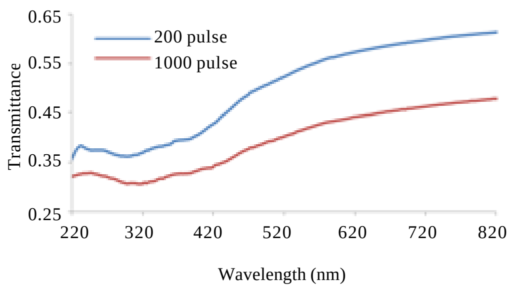

Fig. 6: Transmittance of nanoparticles colloid fabricated CdO/ZnO/Fe_2O_3 NPs ablated with 200 and 1000 pulse at wavelength 1064nm

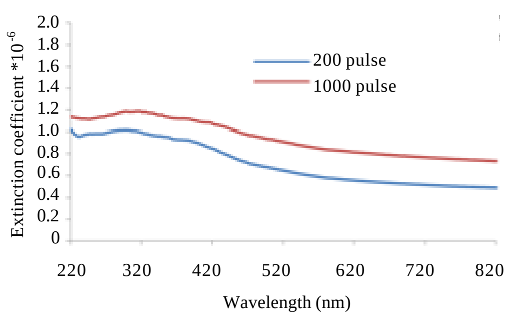

Fig. 7: Extinction coefficient versus wavelength of prepared CdO/ZnO/Fe_2O_3 NPs ablated with 200 and 1000 pulses at wavelength 1064 nm

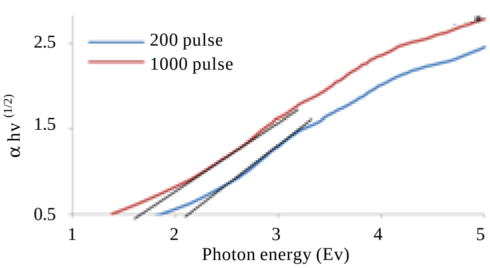

Fig. 8: Photon energy as a function of $(\alpha h\lambda)^{1/2}$ for the prepared CdO/ZnO/Fe_2O_3 NPs ablated with 200 and 1000 pulses at wavelength 1064 nm

CONCLUSION

Pulse Laser Ablation in Liquid (water) (PLAL) is an easy, purity and environmentally friendly technique to get on several oxide ofnanoparticles, cubic andnanorods. 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 indications to an increase in the particle size due to aggregation of particles. The prepared CdO/ZnO/Fe_2O_3 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

Al-Nafiey, A., B. Sieber, B. Gelloz, A. Addad and M. Moreau *et al*., 2016. Enhanced ultraviolet luminescence of ZnO nanorods treated by high-pressure water vapor annealing (HWA). J. Phys. Chem. C., 120: 4571-4580.

Alyamani, A. and O.M. Lemine, 2012. FE-SEM Characterization of Some Nanomaterial. In: Scanning Electron Microscopy, Kazmiruk, V. (Ed.). IntechOpen Publisher, New York, USA., ISBN:978-953-51-0092-8, pp: 464-472.

Dong, W. and C. Zhu, 2003. Optical properties of surface-modified CdO nanoparticles. Opt. Mater., 22: 227-233.

Heidari, A. and C. Brown, 2015. Study of composition and morphology of Cadmium Oxide (CdO) nanoparticles for eliminating cancer cells. J. Nanomed. Res., 2: 1-20.

Heidari, A., 2016. Novel and stable modifications of intelligent Cadmium Oxide (CdO)nanoparticles as anti-cancer drug in formation of nucleic acids complexes for human cancer cells treatment. Biochem. Pharmacol, 5: 1-2.

Ismail, M., S. Gul, M.A. Khan and M.I. Khan, 2016. Plant mediated green synthesis of anti-microbial silver nanoparticles-A review on recent trends. Rev. Nanosci. Nanotechnol., 5: 119-135.

Kaur, R., A.V. Singh and R.M. Mehra, 2006. Sol-gel derived highly transparent and conducting yttrium doped ZnO films. J. Non-Cryst. Solids, 352: 2335-2338.

Lasemi, N., U. Pacher, L.V. Zhigilei, O. Bomati-Miguel and R. Lahoz *et al*., 2018. Pulsed laser ablation and incubation of nickel, iron and tungsten in liquids and air. Appl. Surf. Sci., 433: 772-779.

Li, J.C., H.B. Lu, L. Liao, H. Li and Y. Tian *et al*., 2008. Fabrication of CdO nanotubes via simple thermal evaporation. Mater. Lett., 62: 3928-3930.

Liu, Y., Z. Xu, M. Yin, H. Fan and W. Cheng *et al*., 2015. Enhanced photoelectrocatalytic performance of a-Fe_2O_3 thin films by surface plasmon resonance of Au nanoparticles coupled with surface passivation by atom layer deposition of Al_2O_3. Nanoscale Res. Lett., 10: 1-8.

Luo, Z., S. Zhu, Z. Liu, J. Liu, M. Huo and W. Yang, 2015. Study of phosphate removal from aqueous solution by zinc oxide. J. Water Health, 13: 704-713.

Maneeratanasarn, P., T.V. Khai, S.Y. Kim, B.G. Choi and K.B. Shim, 2013. Synthesis of phase-controlled iron oxide nanoparticles by pulsed laser ablation in different liquid media. Phys. Status Solidi., 210: 563-569.

Mostafa, A.M., S.A. Yousef, W.H. Eisa, M.A. Ewaida and E.A. Al-Ashkar, 2017. Au@ CdO core/shell nanoparticles synthesized by pulsed laser ablation in Au precursor solution. Appl. Phys. A., 123: 1-9.

Ratti, M., J.J. Naddeo, J.C. Griepenburg, S.M. O'Malley and D.M. Bubb *et al*., 2017. Production of metal nanoparticles by pulsed laser-ablation in liquids: A tool for studying the antibacterial properties of nanoparticles.Production of metal nanoparticles by pulsed laser-ablation in liquids: A tool for studying the antibacterial properties of nanoparticles. J. Visualized Exp., 1: 1-2.

Riabinina, D., J. Zhang, M. Chaker, J. Margot and D. Ma, 2012. Size control of gold nanoparticles synthesized by laser ablation in liquid media. ISRN. Nanotechnol., 2012: 1-5.

Ristic, M., S. Popovic and S. Music, 2004. Formation and properties of $Cd(OH)_2$ and CdO particles. Mater. Lett., 58: 2494-2499.

Sarkar, D., S. Tikku, V. Thapar, R.S. Srinivasa and K.C. Khilar, 2011. Formation of zinc oxide nanoparticles of different shapes in water-in-oil microemulsion. Colloids Surf. A. Physicochem. Eng. Aspects, 381: 123-129.

Sawada, H., R. Wang and A.W. Sleight, 1996. An electron density residual study of Zinc oxide. J. Solid State Chem., 122: 148-150.

Semaltianos, N.G., 2010. Nanoparticles by laser ablation. Crit. Rev. Solid State Mater. Sci., 35: 105-124.

Tarwal, N.L., P.R. Jadhav, S.A. Vanalakar, S.S. Kalagi and R.C. Pawar *et al*., 2011. Photoluminescence of zinc oxide nanopowder synthesized by a combustion method. Powder Technol., 208: 185-188.

Waghulade, R.B., P.P. Patil and R. Pasricha, 2007. Synthesis and LPG sensing properties of nano-sized cadmium oxide. Talanta, 72: 594-599.

Wang, Y. and M. Li, 2006. Hydrothermal synthesis of single-crystalline hexagonal prism ZnO nanorods. Mater. Lett., 60: 266-269.

Zhang, F., F.L. Bei, J.M. Cao and X. Wang, 2008. The preparation of CdO nanowires from solid-state transformation of a layered metal-organic framework. J. Solid State Chem., 181: 143-149.

Zhang, J., H. Feng, W. Hao and T. Wang, 2006. Blue-emitting ZnO sol and film obtained by sol-gel process. J. Sol Gel Sci. Technol., 39: 37-39.