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PHOTOCHEMISTRY
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Influence of Laser Irradiation on the Optical Properties of Nano-Sized Powder of Metal Oxide[1]

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Abstract—ZnO Nano powders were prepared by co-precipitation method which includes post-oxidation and annealing in air. Influence of laser irradiation was carried out using 355 nm laser on the physical properties of ZnO nanoparticles. SEM studies reveal agglomeration of grains resulting into enlargement and deformation of the nanoparticles. XRD pattern exhibited decrease in FWHM which is a clear evidence of the increase in crystallite size due to laser irradiation. Optical properties showed decrease in the band gap of the laser irradiated Nano powders. The observed results indicated the UV laser irradiation increases the ZnO nanoparticles crystallinity that affects the optical properties of the ZnO.

Keywords: nanoparticles, laser irradiation, co-precipitation, post-oxidation.

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1. INTRODUCTION

Nanoparticles have wide range of applications in many fields of science and technology because of tremendous increase in the surface area to volume ratio [1–3]. Large surface area is an important factor in chemical reactions. In the nano scale materials, interaction on atomic scale dominates and exhibits quantum mechanical behavior as compared to bulk materials. Behavior of light interaction with materials also changes drastically as we go down to the nano size of the materials. This is due to decrease in the dimensions below the critical wavelength of light [4]. There are many methods for nanoparticle generation [5–8]. In the recent past, several preparation methods comprising ZnO quantum dots were used to develop nano size optical devices identified as nanophotonic devices [9, 10]. With the use of nanophotonic devices, one can reduce the device size away from the diffraction limit of light and attain unusual functionality unattainable by means of conventional photonic devices. Moreover, nanophotonic devices lessen power consumption and accomplish energy savings. In the literature, several researchers have demonstrated AND gate [11–13], NOT gate [14], nanoscale optical energy transfer devices [15], and nanoscale light-harvesting nanofountains [16] as nanophotonic devices. Numerous semiconductor materials which include CuCl [9, 11, 16], InAs [13, 14], and CdCe [15, 17], have been used for nanophotonic devices. Especially, ZnO is a promising material because of its large exciton binding energy and good optical properties at room temperature [18, 19]. Liu et al. reported Controlling the size of ZnO quantum dots using the dressed photon–phonon-assisted sol–gel method. Size distribution of ZnO QDs grown without light irradiation and with 325 nm laser irradiation has been studied [20]. In order to obtain high-performance nanophotonic devices, the size of ZnO nanoparticles must be tailored to reduce the size difference and resonate the discrete exciton energy level of nanoparticles.

We have synthesized the ZnO nanoparticles with co-precipitation technique and studied the effect of laser irradiation on the structural morphology at the wavelength of 355 nm from Nd: YAG laser system.

2. SYNTHESIS AND IRRADIATION OF ZnO NANOPARTICLES

ZnO nanoparticles were prepared by the co-precipitation technique with the post-oxidation annealing in air atmosphere. The process is explained below.

Zinc Chloride and NaOH powders of analytical grade purity were used as chemical reagents in the preparation of ZnO nanoparticles. Zinc chloride solution (0.2 M) was prepared in 20 mL ethanol by constantly stirring at 60°C for about half an hour. Then a separately heated 0.4 M NaOH solution at 60°C was slowly added to the above solution in order to initiate the chemical reaction. The following chemical reac-

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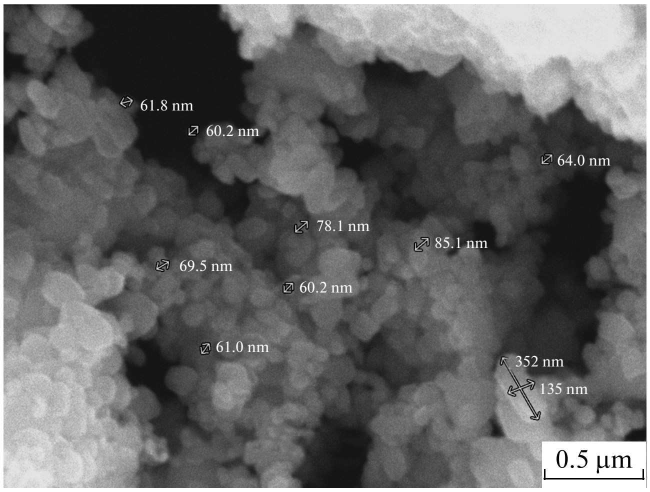

Fig. 1. SEM image of ZnO before laser shot.

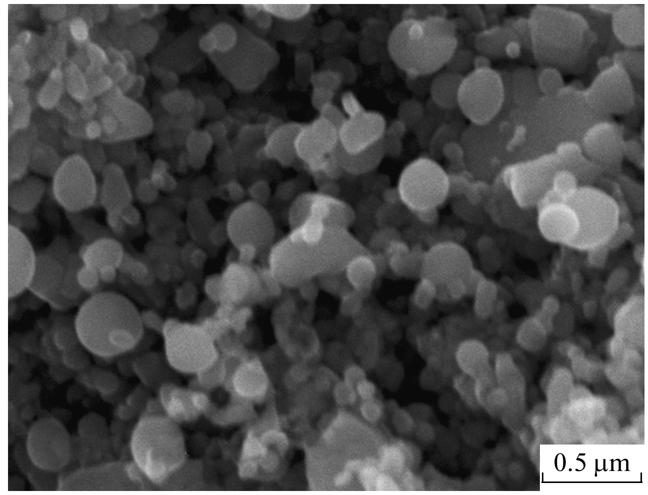

Fig. 2. SEM image of ZnO after laser shot.

tion took place in the process of fabrication of ZnO nano particles.

$$ZnCl_2 + 2NaOH \longrightarrow Zn(OH)_2 + 2NaCl.$$

Zinc Hydroxide is insoluble, it would most likely form some sort of precipitate (ppt). Sodium chloride is soluble. After 1hr of constant stirring at 60°C, the product was allowed to come to room temperature. It was then centrifuged and washed 10 times with deionized water and two times with ethanol to remove the by-products. The final filtered product was then dried into solid powder at low temperature, grinded and finally annealed at 450°C to get ZnO nanoparticles. The reaction after drying is;

$$Zn(OH)_2 \longrightarrow ZnO + H_2O.$$

The ZnO nanoparticles were irradiated with one shot of laser beam of 6 ns pulse and 25 mJ energy from third harmonic of Nd: YAG laser system at wavelength of 355 nm.

3. RESULTS AND DISCUSSIONS

SEM images of the synthesized ZnO nanoparticles before and after laser irradiation are depicted in Figs. 1 and 2, respectively. The images reveal that after laser irradiation, the size of the particles are increased and agglomerated in different shapes. The XRD pattern shown in Fig. 3 suggests that the ZnO nanoparticles crystallize in Wurtzite structure (Hexogonal phase) and all the peaks match well with JCPDF file no. 36-1451, $a = 0.3249$ nm, $c = 0.5206$ nm. Increase in size of the particles is also observed as calculated from Scherrer relation before and after laser irradiation. Usually, the crystallite size calculated through Scherrer formula is smaller than the actual value as seen in SEM images. This is attributed to the widening of the XRD peak due to internal stress and defects [21]. The intensities of first three characteristic peaks (100), (002), and (101) almost reduced to half with substantial decrease in the broadening (FWHM) after irradiation of samples with laser beam at 355 nm. These effects are shown in Fig. 4. These effects indicate the improvement in the crystallinity or crystallite size of the samples after laser irradiation. Similar observation of improvement in crystallite size has been reported in literature when the ZnO nanoparticles were thermally annealed [22] as well as at 325 nm laser irradiated [20] ZnO QDs. The expansion and deformation of the

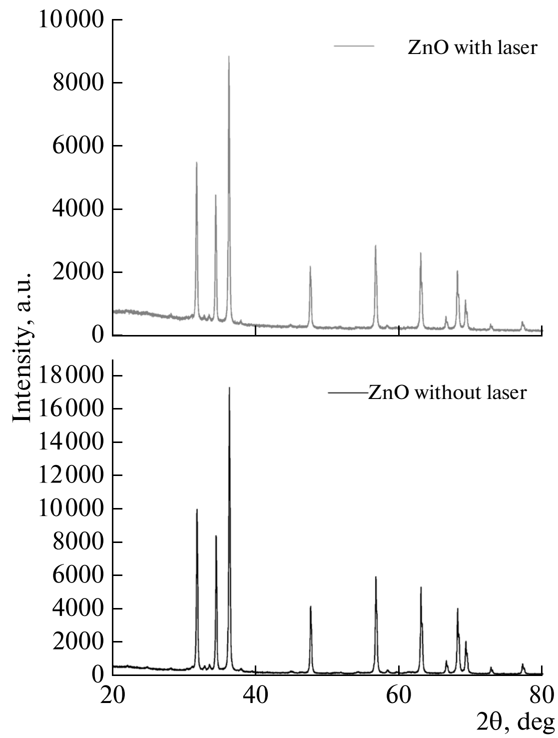

Fig. 3. XRD before and after laser shot.