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Preparation of CuO nanoparticles by laser ablation in liquid

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Abstract. Colloidal Cu nanoparticles (NPs) were synthesized by pulsed Nd:YAG laser ablation in acetone. Cu NPs were converted into CuO. The size and optical properties of these NPs were characterized using an UV/Vis spectrophotometer, transmission electron microscopy, and X-ray diffraction. Cu NPs were spherical, and their mean diameter in acetone was 8 nm–10 nm. Optical extinction immediately after the ablation showed surface Plasmon resonance peaks at 602 nm. The color of Cu NPs in acetone was green and stable even after a long time.

Keywords: CuO, nanoparticles, Colloidal processing, Oxidation, laser ablation.

INTRODUCTION

Metal nanoparticles (NPs) have been intensively studied over the past decade. Nanosized materials are an important subject in basic and applied sciences because of their application in different fields, including chemistry, physics, biology, material science, medicine, and catalysis [1, 2]. Metal NPs are prepared through numerous methods, such as laser ablation technique, chemical reduction method, photo-reduction, microorganism arc-discharge method, and bio surfactant. Laser ablation technique has attracted increasing interest and is extensively employed to synthesize new novel materials [3, 4]. Laser ablation plasma is formed above the surface of the solid target when an intense laser beam strikes the target. Laser ablation provides a simple and contaminant-free method, which can be used for a large number of materials. CuO is an excellent NPs system for investigating size-induced structured transformations and phase stability. Lasers have open new doors in the process of nanomaterials and their characterization. Pulsed-laser ablation process possesses several advantages compared with other conventional routs. These advantages include a large number of available ablation parameters for controlling size- and shape-inherent stochiometry as their mother targets and thus capabilities to produce nanomaterials of desired chemical composition and nanomaterials with chemical-free surfaces [5, 6]. Laser ablation technique is used to synthesize colloidal NPs of different metals and semiconductors. In this work, we performed laser ablation of Cu target in one type of solution to synthesize CuO NPs [7, 8]. The optical properties and morphology of Cu NPs were studied. We also demonstrated a method to generate stable CuO NPs from Cu metal by laser ablation technique under aerobic condition. In cases where metal plate is used as ablation target, the focus of laser light on the metal surface immersed in solvent is difficult to adjust. The turbulence of fluid generated by plume expansion can protect the subsequent laser pulse to arrive on the metal surface. The metal plate has to be continuously rotated to prevent irradiation of laser light on the same position of the metal plate. If the concentration of NPs increases as the ablation proceeds, the laser light becomes increasingly difficult to arrive on the metal surface by self absorption of NPs.

In this study we found the relationship between the Laser intensity and concentration Increased laser intensity concentration leads to an increased concentration.

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MATERIALS AND METHODOLOGY

CuO NPs were produced by laser ablation of high-purity Cu target immersed in acetone at room temperature. **FIGUER 1.** displays the schematic of the experimental set-up of the pulsed-laser ablation in liquid (PLAL) system. Cu target was placed at the bottom of a quartz vessel filled with 5 ml of liquid and irradiated with Q-switched Nd:YAG laser operated with emission wavelength at 1064 nm and a pulse duration of 7 ns with a repetition frequency of 5 Hz. The laser energies were used to ablate Cu target with 150 and 300mJ/pulse with 10 min ablation time. The laser beam was focused on the Cu target by using focusing lens with 100 mm focal length. After ablation, the Si substrate of the distillation of CuO solution was created to carry out X-ray diffraction (XRD) and ensure the presence of CuO nanoparticles. The structural and optical properties of the solution of synthesized and aged colloidal NPs were characterized using a transmission electron microscope (TEM, FEI CM 12) operated at 120 kV and an UV/Vis spectrophotometer (JAZ-ULM-200, Ocean Optics), respectively. The structural properties of CuO NPs on Si substrate were investigated using a high-resolution X-ray diffract meter system (PANalytical X'Pert PRO MRD PW3040).

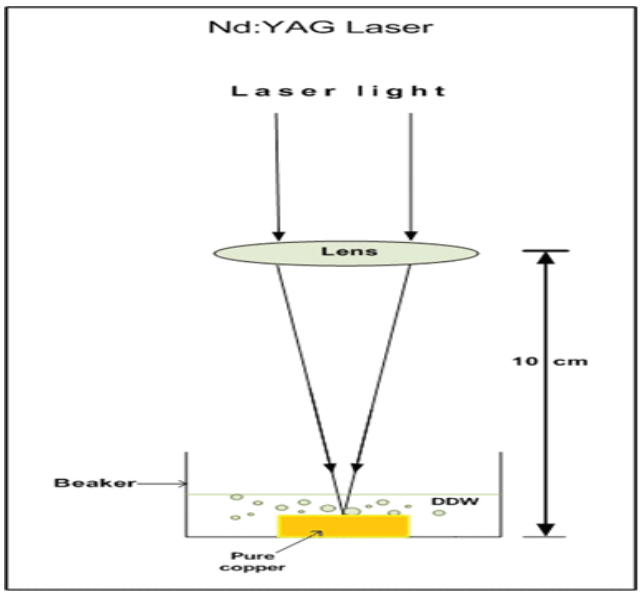

FIGURE 1. Schematic diagram of PLAL system.

RESULTS AND DISCUSSION

After laser ablation of Cu target, the suspension color changed from colorless to transparent green (acetone suspension), which indicates the production of CuO colloidal NPs. Laser energy was absorbed in the liquid to the target, resulting in the removal of material by reactive sputtering rather than direct laser ablation. Owing to the laser intensity in the presence of ablated material in the acetone, the amount of light reaching to the target approached zero. Plasma formation in the acetone created cavitations bubbles that expanded and then collapsed, thereby driving highly energetic species into the target. Absorbance showed an increase in the Plasmon peak with increasing laser energy, which indicates the increase in the concentration of CuO NPs.

As the energy increased, the peak became narrow, a blue shift occurred in the Plasmon peak, and the size of CuO NPs increased. The shape and size distribution of colloidal particles in acetone were characterized by TEM. The specimens for TEM experiments were prepared by depositing a drop of solution containing colloidal Cu particles onto sions of plume species or nucleation of small clusters from free atoms [9, 10]. Figure 2. shows the UV/Vis spectra of the colloidal dispersion containing particles synthesized by laser ablation of Cu target. These spectra were

directly measured after ablation. Figure 2. indicates significant absorption peaks at 598 nm, which are related to the surface Plasmon resonance (SPR) of CuO [11]. This result agrees with other data reported by other workers. The SPR was equal to 589 nm. TEM images show that NPs are spherical in shape, with an average diameter of 3.5 nm in 150mJ dispersion and 5nm 300 mJ dispersion, as shown in **FIGURE 3.** (a) and (b), respectively. The XRD pattern **FIGURE 4.** of the obtained product was identical to the single-phase CuO with a monoclinic structure. The pattern shows two peaks at 2theta = 55.945,and 80.207 for 150mJ/pulse, and, which corresponded to (021)and(-204), respectively. and planes of cubical CuO, The pattern shows three peaks at 2theta = 52.660, 61.406 and 65.145 for 300mJ/pulse, and, which corresponded to (026).(-113) and(022) , respectively. and planes of cubical CuO, [12]. The XRD result confirms the presence of CuO.

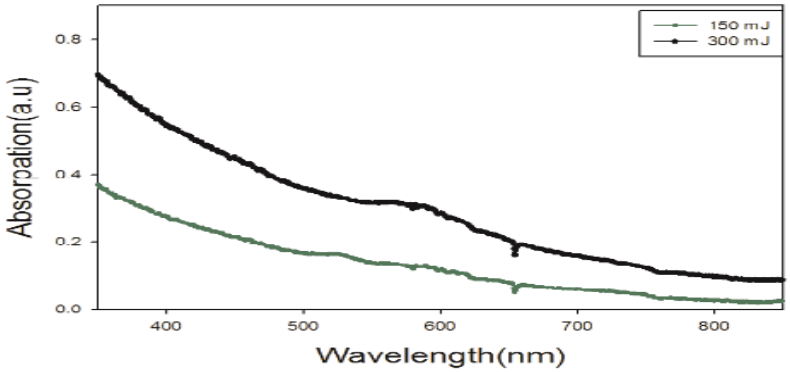

FIGURE 2. UV/Vis spectra of the colloidal dispersion containing particles synthesized by laser ablation of Cu target at 150mJ/puls and 300mJ/puls

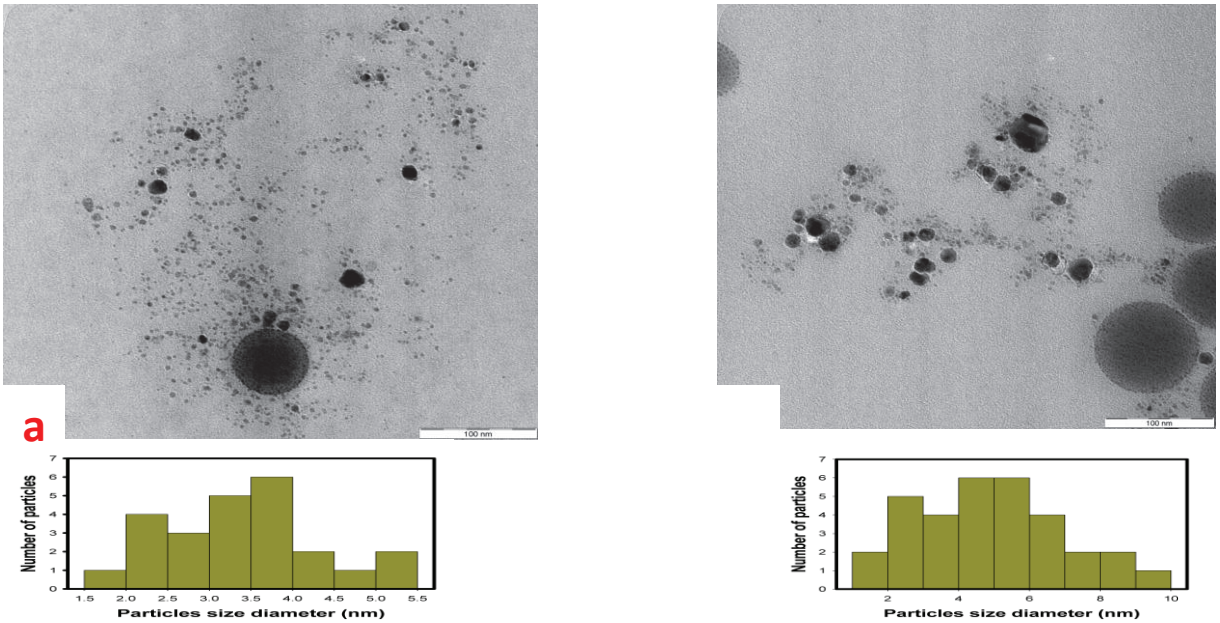

FIGURE 3. TEM images and sizes distribution of the CuO nanoparticles produced by laser energy at (a) 150 mJ/puls and (b) 300 mJ/puls.

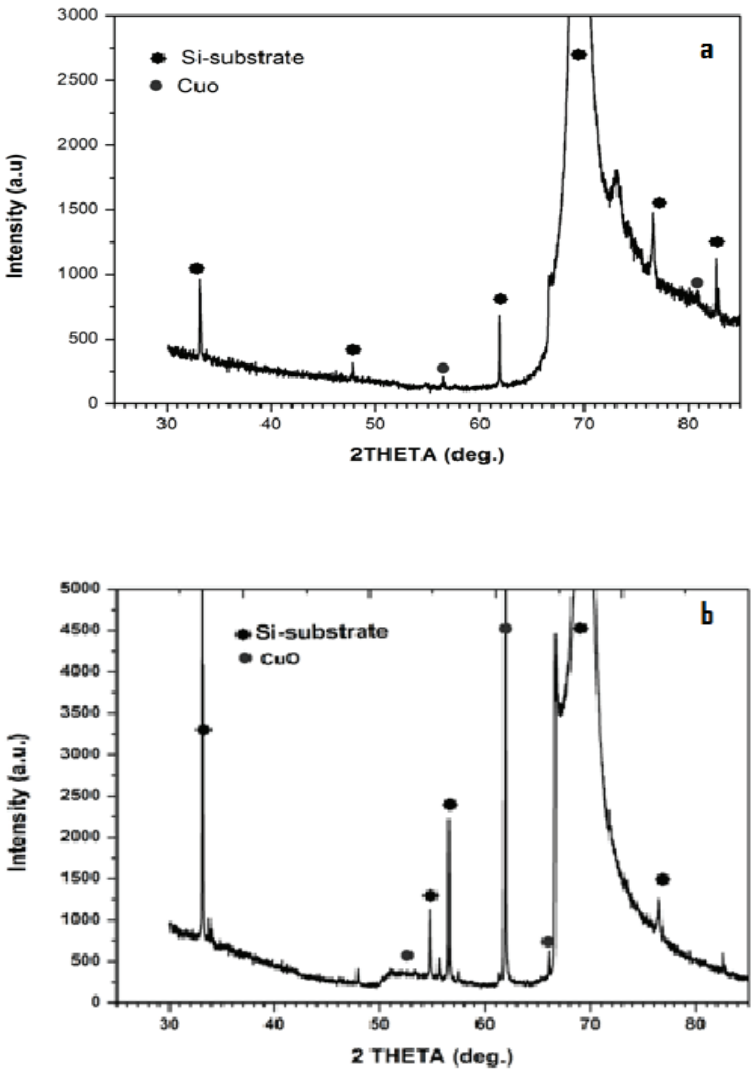

FIGURE 4. XRD spectrum of nanoparticles CuO/Si synthesized by laser ablation at (a) 150 mJ/puls and (b) 300 mJ/puls.

CONCLUSIONS

In this work, colloidal Cu NPs were successfully synthesized by pulsed Nd:YAG laser ablation of pure Cu target in acetone. Cu NPs were oxidized and converted from Cu to CuO nanostructure. Absorbance showed an increase in the Plasmon peak with increasing laser energy, which indicates the increase in the concentration of CuO NPs. As the energy increased, the peak became narrow, a blue shift occurred in the Plasmon peak, and CuO NPs increased. TEM was employed to characterize the size and shape of the particles in acetone. The particles were spherical. The average diameter of Cu NPs was 4 nm. In acetone, colloidal Cu changed into oxidized particles. Cu oxidation was caused by the reaction of dissolved oxygen in water with the colloidal particles. The oxidation of Cu NPs into CuO with the passage of time was confirmed by XRD.

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