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Synthesis Nanoparticles of Copper and Dicopper Oxide via Change Atmosphere of Copper Ablation

Ahmed Hussein Mohammed Al-Antaki*

Department of Chemistry, Faculty of Science, University of Kufa, Najaf – Iraq

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ABSTRACT

The fabrication technique to synthesis dicopper oxide nanoparticles (Cu_2ONPs) and copper nanoparticles (CuNPs) is laser ablation by a pure copper rod. To save the environmental system, we converted setup of device to develop the clean technology. In addition, the solvent using in both systems is water (green chemistry) without agent or surfactant. The average size of Cu_2ONPs is 20 nm via enclosed platform of air under 600 mJ of laser power for 1h. However, the average size is 12 nm to generate CuNPs under N_2 gas and 600 mJ of laser power for 1h. The morphology and the shape of the particles explain by Scanning Electron Microscope (SEM) images and Transmission Electron Microscopy (TEM) images. Also, the average size of the nanoparticles proved by measuring of 100 particles by using TEM image. In addition, The High-Resolution Transmission Electron Microscopy (HRTEM) image explains the distance between the layers in CuNPs which is 0.21 nm. The X-ray diffraction (XRD) and Attenuated Total Reflection-Fourier Transform Infrared (ATR-FTIR) of the product show the type of nanoparticles' structure.

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1. Introduction

Various methods to create of dicopper oxide nanoparticles (cuprous oxide nanoparticles (Cu_2ONPs)) and copper nanoparticles employing chemical, physical and biological techniques considering top-down methods synthesis have been studied. The properties of dicopper oxide nanoparticles and copper nanoparticles depend largely on their synthesis procedures. The product from many investigations outright by different scientists using these experiments have been summarized (Umer et al., 2012). They used many characterization techniques to mention the advantage and disadvantages to use each synthesis method with some applications on the other via discussion. Batch processing is one of methods used in the fabrication of dicopper oxide nanoparticles and copper nanoparticles. The one of study details to product is the Pulsed laser ablation methods which is more suitable to synthesis dicopper oxide nanoparticles and copper nanoparticles (Sadrolhosseini et al., 2016). Pulsed laser ablation (PLA) involves ablating a pure metal target in a liquid phase or in gas phase, which has several advantages such as no high vacuum, high yielding, high purity, and avoiding harsh chemicals to be high impact for sustainable processing for the future as green chemistry. Furthermore, the experimental parameters could control the types and size of the nanoparticles (Haram & Ahmad, 2013).

The metal surface will absorption the laser radiation to make interaction zone which will transform of kinetic energy into thermal energy. Also, when the laser power is sufficiently high, a local plasma plume with high temperatures and pressures is formed (Vitta et al., 2011), and this can lead to synthesis of metal oxide particles under presence of oxygen or metal particles under Nobel gas

***Corresponding author:** Ahmed Hussein Mohammed Al-Antaki, Department of Chemistry, Faculty of Science, University of Kufa, Najaf – Iraq

E-mail: **ahmed.alantaki@uokufa.edu.iq**

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or N_2 gas (Al-Antaki et al., 2019). These types of nanoparticles have many applications such as catalytic organic, electrocatalysis, and photocatalysis (Allen et al., 2013; Poreddy et al., 2015; Yin et al., 2015). Moreover, copper nanoparticles are good applications with sensitivity to oxygen, water, and different reagents (Gawande et al., 2016).

The research uses a simple setup of pure copper rod as a target in the conical flask and the pulsed laser hits it under air or N_2 gas and a magnetic bar to stir water on the wall of a conical flask with avoid touching the pure copper rod, Figure 1. The experiment with air could synthesise dicopper oxide nanoparticles (Cu_2ONPs). On the other hand, using N_2 gas to collect copper nanoparticles (CuNPs). We used 600 mJ of laser energy to ablation the nanoparticles from pure copper rod during 15 mins. The lower power of the laser is not enough to ablate nanoparticles from the surface of pure copper rod. In contrast, the high yield of the nanoparticles during the same time is high power of the laser. Thus, the 600 mJ is the best power of the laser to collect high yield from nanoparticles. To determine the end of the experiment as other conditions, we used high power laser (600 mJ) with 15min, 30min, 45min, 1h, and 1.5h. we found 1h is enough time to end the experiment with a high yield and less agglomeration of nanoparticles. In addition that, the concentration of the yield in the solvent (water) will reduce the effect of the laser power on the surface of the pure copper rod to ablate nanoparticles.

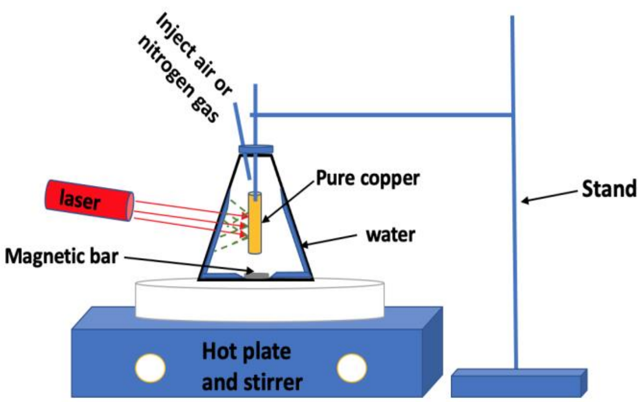

Fig. 1. *The Experiments under Air or Nitrogen Gas with High Speed of Starrier*

2. Materials and Methods

Materials

Milli-Q water was used. A high purity (>99.998%) of copper metal rod of 8 mm in diameter (Colnbrook Bucks, England) was used for all the processing.

Synthesis of Cu_2ONPs and CuNPs

The power laser used to synthesis dicopper oxide nanoparticles (Cu_2ONPs) and copper nanoparticles (CuNPs) was 600 mJ/pulse by 1064 nm as a wavelength of the source operating which was generated from a Nd:YAG source , and the solvent of both the experiments was Milli-Q water. The Cu_2ONPs are synthesised by the flowing of air inside the conical flask when the magnetic bar stirrer water for 1h. On the other hand, to synthesis CuNPs are by the flowing of N_2 gas inside a conical flask to avoid oxidation of copper when the magnetic bar stirrer water for 1h.

Characterization

To character the dicopper oxide nanoparticles and copper nanoparticles used scanning electron microscopy (SEM, Inspect FEI F50), XRD (Bruker D8 ADVANCE ECO, Co Kα, λ = 1.7889 A), ATR-FTIR (Perkin Elmer Frontier), and HR-TEM (Tecnai_G2_Spirit).

3. Results and Discussion

The method to synthesis Cu_2ONPs or CuNPs by using simple setup of the pure copper rod inside the conical flask under air or N_2 gas respectively, which is useful to collect nanosize structure of the copper. Furthermore, the solvent is water without using an agent or surfactant to stabilize the particles as nanosize is a big deal for green chemistry and clean technology. The SEM images of our results show the morphology and the shape of nanoparticles, figure 2. The images(a-c) of Cu_2ONPs explain the size of the particles after the experiment which are nanosize and less agglomeration of the nanoparticles. In contrast, the images (d-f) show the morphology and nanosize of copper with some agglomeration as spherical shape.

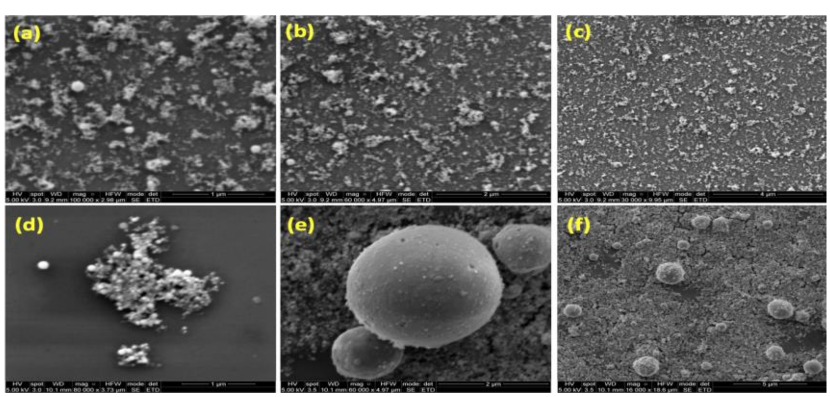

Fig. 2. SEM images for nanoparticles via 600 mJ of laser power for 1h (a-c) dicopper oxide nanoparticles (Cu_2ONPs) under air, (d-f) copper nanoparticles (CuNPs) under N_2 *gas*

To understand more details about the shape and the morphology of the nanoparticles we used HRTEM. The images (a, b) in figure 3 prove the nanosize of Cu_2ONPs and less aggregation. However, the images (c, d) from figure 3 show the nanosize of the CuNPs with some aggregation of nanoparticles as spherical shape. By using TEM images, the size estimations of hundred particles from Cu_2ONPs and CuNPs show high percent with average 20 nm and 12 nm respectively, figure 4. From that, we could prove the nanosize of both particle's structures which are prepared in the same conditions but different atmospheres. Furthermore, the figure 5 is HRTEM for CuNPs which shows the distance between the layers 0.21 nm by zoom in of HRTEM image (Cheng & Hight Walker, 2010; Zhang et al., 2015; Fernández-Arias et al., 2020).

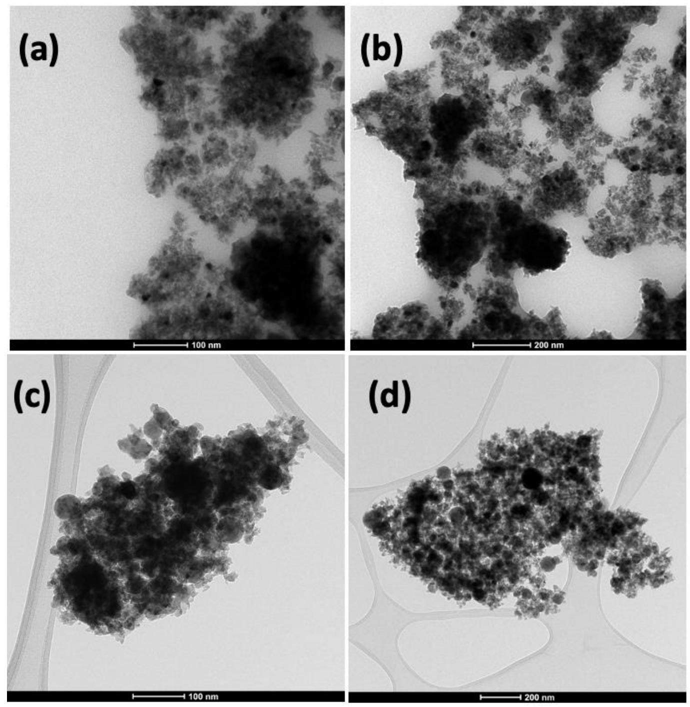

Fig. 3. TEM images for nanoparticles via 600 mJ of laser power for 1h (a, b) dicopper oxide nanoparticles (Cu_2ONPs) under air, (c, d) copper nanoparticles (CuNPs) under N_2 *gas*

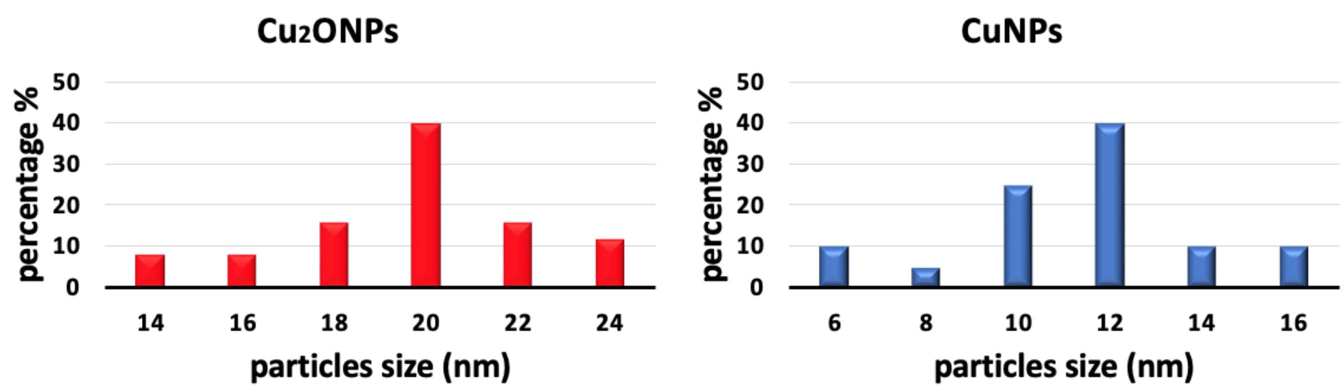

Fig. 4. Particles size of dicopper oxide nanoparticles and copper nanoparticles by using TEM images.

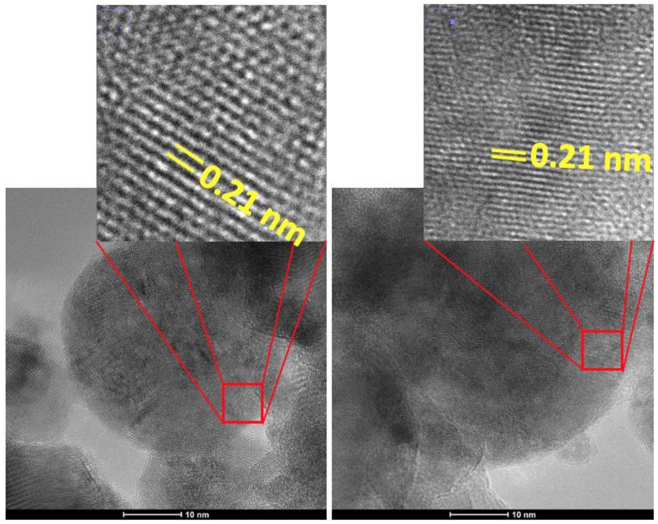

Fig. 5. HRTEM images with zoom in to measure the layers of copper nanoparticles (CuNPs) collected via 600 mJ of laser power for 1h under N_2 gas.

The X-ray diffraction (Co Kα, λ = 1.7889 A) of Cu_2ONPs shows 2θ peaks at 34.7°, 42.6°, 49.5°, 72.8° and 88.2° which are corresponding to (110), (111), (200), (220), and (311) for cubic cuprite, respectively (Salavati-Niasari & Davar, 2009; Gondal et al., 2013; Zhao et al., 2014; Bergum et al., 2018). Moreover, the diffraction pattern presents small peaks of some CuO by oxidation of Cu_2ONPs during the experiment (Lupan et al., 2020). On the other hand, the X-ray diffraction pattern of CuNPs shows 2θ peaks at 50.9°, 59.5° and 89.1° which correspond to a cubic crystal structure of (111), (200) and (220) respectively (Betancourt-Galindo et al., 2014; Ji et al., 2014; Fernández-Arias et al., 2020; Lupan et al., 2020), and small peaks of Cu_2ONPs by oxidation of CuNPs during the workup, Figure 6. The Scherrer equation via XRD presents the average nanosize 20 nm and 12 nm of Cu_2ONPs and CuNPs respectively which are match the result of TEM images in figure 4.

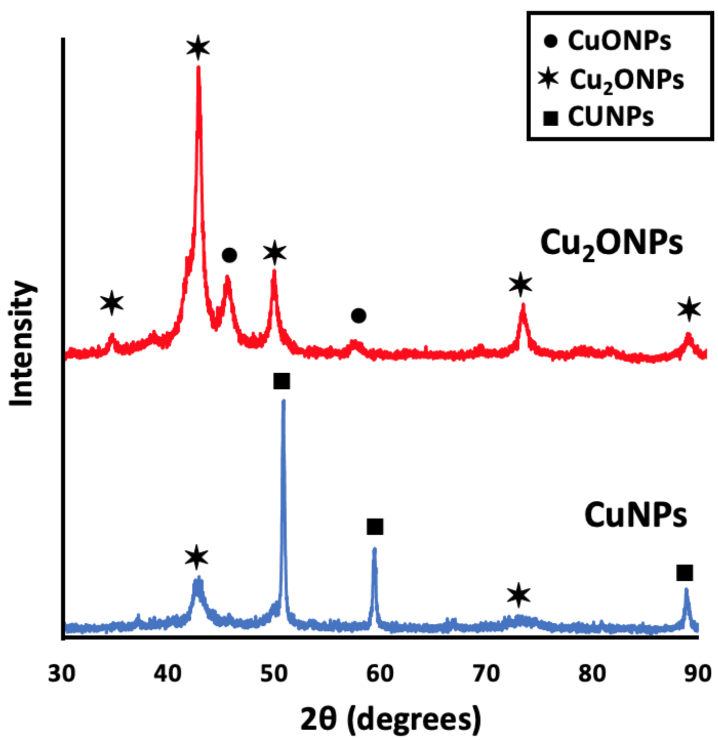

Fig. 6. X-ray diffraction (XRD) for dicopper oxide nanoparticles (Cu_2ONPs) under air and copper nanoparticles (CuNPs) under N_2 gas v*ia 600 mJ of laser power for 1h*

The Figure 7 is ATR-FTIR spectra to present of Cu_2ONPs and CuNPs, with a broad peak at 3389 cm^{-1} corresponding to H-O-H stretching vibration band and two peaks in the fingerprint region for surface-bound hydroxyl of water at 1460 cm^{-1} and 1375 cm^{-1} (Zhang et al., 2013; Tadjarodi & Roshani, 2014; Ullah et al., 2020). The peak at 597 cm^{-1} is corresponded to Cu–O vibrations in dicopper oxide nanoparticles (Zhang et al., 2006; Basu et al., 2012; Guo et al., 2015). However, the main stretch peak of copper nanoparticles is at 621 cm^{-1} (Ullah et al., 2020).

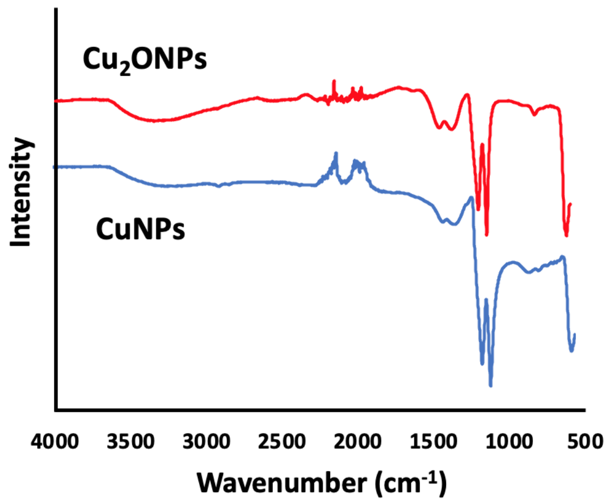

Fig. 7. ATR-FTIR for dicopper oxide nanoparticles (Cu_2ONPs) under air and copper nanoparticles (CuNPs) under N_2 gas v*ia 600 mJ of laser power for 1h*

4. CONCLUSION

In the present study, we could synthesis dicopper oxide nanoparticles (Cu_2ONPs) and copper nanoparticles (CuNPs) by laser ablation technique. To develop the clean technology and green chemistry, we used water as solvent and 600 mJ laser power for 1 h under air to collect Cu_2ONPs or N_2 gas to create CuNPs without agent or surfactant. Because of the setup of device, the average size of Cu_2ONPs and CuNPs are 20 nm and 12 nm respectively. The characterisations used to evident the size and the morphology of the two types of nanoparticles are SEM images and TEM images. Also, HRTEM use to measure the distains between the layers in CuNPs which is 0.21 nm. Moreover, the XRD and ATR-FTIR prove the structure of nanoparticles.

Competing Interests

The authors had no competing interests.

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