International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST229622

Synthesis of Colloidal Copper (Cu) Nanoparticles by Pulse Laser Ablation Method (Nd:YAG 1064 nm) in Deionized Water

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Article Info
Volume 9, Issue 6
Page Number : 147-150

Publication Issue
November-December-2022

Article History
Accepted : 05 Nov 2022
Published : 18 Nov 2022

ABSTRACT

Copper nanoparticles are usually used for various fields, such as medical, energy, environmental, and others. Copper nanoparticles were successfully synthesized in deionized water (DIW) using the 1064 nm ND:YAG pulse laser ablation method at 85 mJ energy. The resulting colloidal nanoparticles are greenish in color. This study investigates the use of DIW liquid medium that can survive one day after being synthesized or changed. The result is that there is a change in the colloidal photo of copper (Cu) nanoparticles shortly after being synthesized and one day after being synthesized. There is a change in color to become clearer after the colloid is left alone for one day. Not only did the colloid photo change, but the absorbance of the UV-Vis testing of the Cu nanoparticle colloid also changed. Changes in UV-Vis absorption in colloids immediately after being synthesized and after colloids were left standing for one day decreased from 1.175 to 0.561, and experienced a shift in wavelength from 222.96 nm to 223.07 nm. The morphology of Cu nanoparticles was seen using FESEM with a spherical shape. The average size distribution of Cu nanoparticles is about 56.7 nm.

Keywords: Colloidal Copper Nanoparticles, Pulsed Laser Ablation, Deionized Water Solution

I. INTRODUCTION

Nanoparticles (NP) are particles with dimensions in the nanometer range, which are important nanomaterials that are useful in a number of applications in physics, chemistry, engineering, and biology [1]. The synthesis of nanoparticles most often uses chemical, biological, and physical methods. Examples of chemical methods such as chemical reduction, polyols, hydrothermal, and others [2-3].

Biological methods usually use green synthesis [4]. The advantage of chemical and biological methods is that they can produce nanoparticles in large quantities and at high concentrations in a relatively short time. But the weakness in chemical and biological methods, they produce nanoparticles with low purity because they use chemical additives. Requires complicated treatment to purify nanoparticles, so to apply nanoparticles to the medical field that can be inserted into the body requires careful treatment. While using the physical method usually uses the pulse laser ablation method. The pulse laser ablation method can produce high purity colloidal nanoparticles [5]. With high purity and no added chemicals, making nanoparticles more effective and with appropriate doses will be suitable for application in the medical field.

The pulse laser ablation method can usually produce colloidal nanoparticles from metal plates, one of which is copper. Copper has been successfully synthesized using the pulse laser ablation method as in the following studies [6-7]. In Tilaki and Begildayeva's research, colloidal copper nanoparticles were produced in deionized water (DIW) liquid medium, but they only compared DIW with other solvents [8-9]. Copper synthesis in DIW was also carried out by Khalid and Fernández-Arias but only discussed the effect of Cu nanoparticles on bacteria [10-11].

In this study, the synthesis of colloidal Cu nanoparticles in DIW medium was carried out by looking at the optical characteristics of colloidal Cu nanoparticles after they were synthesized and one day after they were synthesized. This research is to find out whether colloidal Cu nanoparticles can be stable in DIW medium.

II. METHODS AND MATERIAL

Preparation of colloidal copper (Cu) nanoparticle synthesis by preparing metal copper plates, petri dishes, and deionized water (DIW) liquid medium. First prepare metal Cu plates with a size of 1.5 x 1.5 cm, then put the Cu plates into a petri dish, and after that put DIW into a petri dish that already has Cu plates in it. Figure 1 is a sample preparation scheme for the synthesis of colloidal Cu nanoparticles.

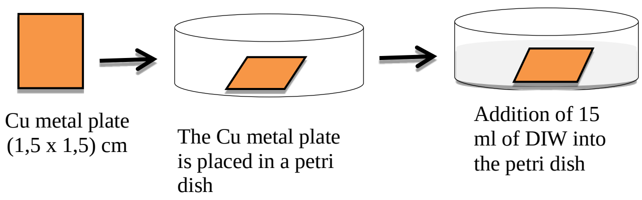


Figure 1: Schematic of sample preparation for the manufacture of colloidal Cu nanoparticles

The petri dish that has been filled with Cu and DIW plates is then placed under the focusing lens on the laser device used. The laser is turned on, reflected by the mirror, then focused by the lens towards the target Cu plate sample which is in the DIW liquid medium, then nanoparticles are formed in the liquid. The pulse laser ablation (PLA) method in this study used a 1064 nm Nd:YAG laser, a pulse width of 7 ns, with an output energy of 85 mJ. The set-up of Cu nanoparticle colloid synthesis experiments can be seen in Figure 2.

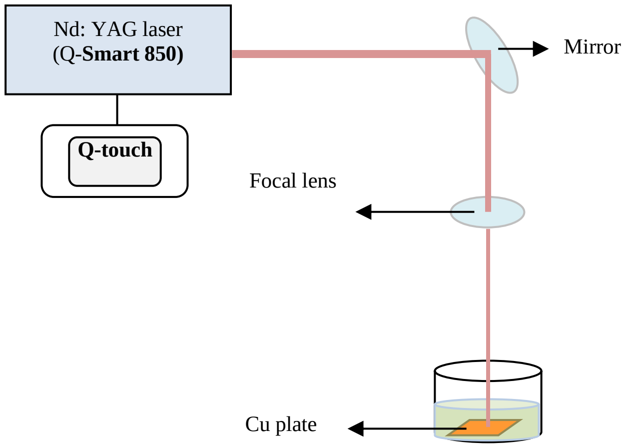


Figure 2: The experimental set-up for the synthesis of colloidal copper (Cu) nanoparticles

III. RESULTS AND DISCUSSION

Colloidal synthesis of copper (Cu) nanoparticles was carried out in this study and was successful. The results of colloidal Cu nanoparticles are shown in Figure 3. In Figure 3 it can be seen that the resulting colloidal nanoparticles are greenish in DIW liquid medium. Before being synthesized the transparent colored liquid, after being synthesized using pulse laser ablation, the DIW liquid turned green. This indicates that the Cu nanoparticles have been distributed in the liquid medium and change their color.

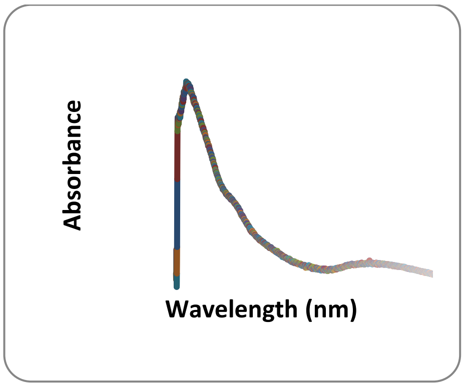
The mechanism for the formation of colloidal Cu nanoparticles starts from the laser beam hitting the target, namely the Cu plate which is submerged in DIW media, evaporation, excitation, and ionization occur sequentially to produce plasma on the surface of the Cu plate due to the laser. The resulting plasma contains many atoms, ions and electrons from Cu plates. This plasma from small and expands, then transfers heat energy to the liquid DIW which forms a layer of vapor that surrounds the surface of the plasma. The vapor layer expands to form cavitation bubbles and can suppress the plasma so that the plasma shrinks. The cavitation bubbles burst and release Cu nanoparticles in the DIW medium, and colloidal Cu nanoparticles are formed [12].

(a) (b)

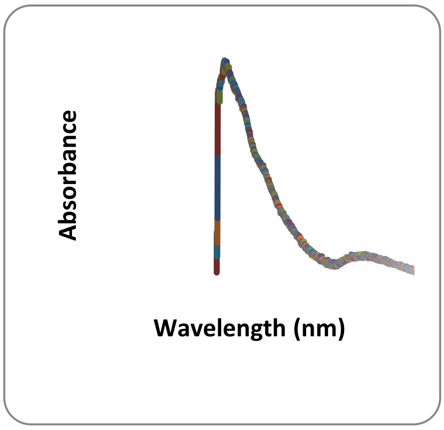
Figure 3: Colloidal Cu nanoparticles in DIW (a) days at the time of synthesis and (b) one day after synthesis.

Figure 3(a) is a photo of the colloidal Cu nanoparticles immediately after being synthesized using the PLA method, while Figure 3(b) is a photo of the colloidal Cu nanoparticles after being left for one day, or the next day. In Figure 3(a) it can be seen that the colloidal Cu nanoparticles are greener in color than in Figure 3(b). Figure 3(b) looks clearer, this indicates Cu nanoparticles are unstable in DIW media because they are pure water. Fedele in his research compared the stability of DIW media with other liquid media using chemical methods [13]. Obtained lower DIW stability, only lasted a few days. In our research using the PLA method, it turned out that Cu nanoparticles were unstable in DIW media.

Not only from colloid photos, the instability of Cu nanoparticles can also be seen using the UV-Vis test. A decrease in the UV-Vis absorption level could indicate the instability of the colloidal Cu nanoparticles. The UV-Vis absorbance spectrum can be seen in Figure 4. Figure 4(a) is the UV-Vis spectrum immediately after synthesis (on the same day of synthesis), while Figure 4(b) is the UV-Vis spectrum one day after synthesis. As seen in Figure 4(b) there is a decrease in the absorption of the UV-Vis spectrum. Previously the absorption was 1.175 in Figure 4(a) to 0.561 in Figure 4(b).



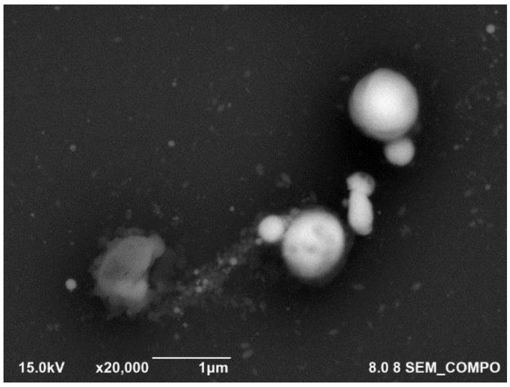
(b)



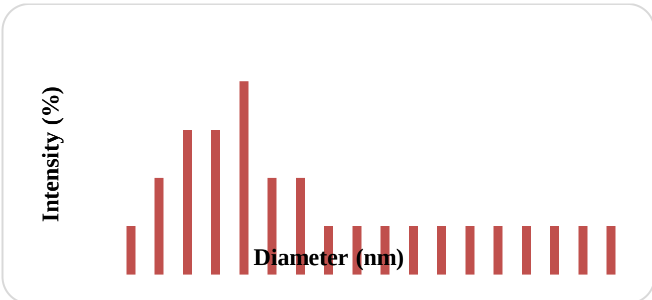
(b)

Figure 4. UV-Vis spectra of colloidal Cu nanoparticles at DIW (a) days during synthesis and (b) one day after synthesis.

The morphology of Cu nanoparticles is seen using field emission-scanning electron microscopy (FE-SEM) in Figure 5(a). Cu nanoparticles have a spherical shape, just like other studies [6, 11, 14-15]. Figure 5(b) is the average size distribution of Cu nanoparticles. Image-J was used to calculate the Cu nanoparticle size from the Cu nanoparticle morphology in Figure 5(a). Cu nanoparticles have an average size of about 56.7 nm. The size of Cu nanoparticles can be even smaller when using a stabilizing medium. The size of the nanoparticles can be related to the instability of colloidal nanoparticles in liquid media.



(a)



(b)

Figure 5. (a) Morphology of Cu nanoparticles in DIW as seen using FESEM and (b) mean size distribution of Cu nanoparticles.

The liquid media greatly affects the stability of the resulting Cu nanoparticle colloid. Hopefully, for future research, more stable colloidal Cu nanoparticles can be developed using appropriate stabilizing agents.

IV. CONCLUSION

Copper (Cu) nanoparticles in DIW medium were successfully synthesized using the pulse laser ablation method. The resulting Cu nanoparticle colloid is green in color. The Cu nanoparticle colloid in DIW one day after being synthesized, the color changed to become clearer and the absorbance of the UV-Vis spectrum decreased from 1.175 to 0.561. This shows that in liquid DIW medium, Cu nanoparticles are unstable. Cu nanoparticles are spherical in shape as seen from the morphology of the FESEM test, with an average nanoparticle diameter size of around 56.7 nm.

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Cite this Article : Ana Qona'ah, Maria Margaretha Suliyanti, Eko Hidayanto, Ali Khumaeni, "Synthesis of Colloidal Copper (Cu) Nanoparticles by Pulse Laser Ablation Method (Nd:YAG 1064 nm) in Deionized Water ", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 9 Issue 6, pp. 147-150, November-December 2022. Available at doi : https://doi.org/10.32628/IJSRST229622

Journal URL : https://ijsrst.com/IJSRST229622