

# Copper Nanoparticles Synthesis via Chemical Reduction method with De-Ionized Water

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**Abstract:** Copper nanoparticles were produced through the utilization of a chemical reduction technique, employing de-ionized water as the solvent. The Atomic Force Microscope (AFM) was employed to observe the surface morphology. The confirmation of copper nanoparticle formation was achieved through the utilization of various analytical techniques, including UV-Visible spectrophotometer (UV-Vis), X-ray diffraction (XRD), and fourier transform infrared spectroscopy (FTIR). The diameter of the copper nanoparticles, fabricated via the chemical reduction method, ranged from 12 nm to 56 nm. Structural analysis further revealed the presence of a face-centered cubic (fcc) crystal structure in the copper nanoparticles.

**Keywords:** copper NPs, chemical reduction,  $\text{Cu}^{2+}$  ion, reduction method

## 1. Introduction

Copper nanoparticles (Cu NPs) with a high fraction of surface atoms and specific surface area have been extensively researched due to their unique physical and chemical properties, including catalytic, optical, antimicrobial, and electronic characteristics. Various physical and chemical techniques, such as chemical reduction, laser ablation, electrochemical methods, thermal decomposition, and the polyol method, can be employed to fabricate Cu NPs. Among these techniques, chemical reduction is a convenient method for nanoparticle fabrication, offering high yields, cost-effectiveness, simplicity, speed, and better size distribution control by adjusting experimental parameters. While noble metal nanoparticles like silver and gold are commonly used for synthesis despite their high cost, copper presents a more economical alternative. Recent studies have focused on the synthesis of copper nanoparticles, with reports of chemically synthesized Cu NPs with a diameter of 25 nm. The current research emphasizes the fabrication of Cu NPs using the chemical reduction method, with characterization performed using techniques such as UV-Visible spectroscopy, Atomic force microscopy, X-ray diffractometer (XRD) and Fourier transform infrared spectra (FTIR).

### Preparation method and apparatus

The chemicals employed in the experiment are of analytical grade and utilized without undergoing any purification process. Copper sulfate pentahydrate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ), with a purity level of 98%, is utilized. De-ionized water is employed as the solvent. Sodium borohydride ( $\text{NaBH}_4$ ) serves as the reducing agent, whereas sodium hydroxide ( $\text{NaOH}$ ) is utilized to regulate the pH. Ascorbic acid is employed as the antioxidant for colloidal Cu NPs.

## 2. Method

The experimental procedure flowchart is illustrated in figure 1. A solution of ascorbic acid (0.02 M) was prepared using deionized water. Separately, a solution of copper sulfate pentahydrate ( $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ ) with a concentration of 0.01 M was also prepared in deionized water, and this was subsequently added to the ascorbic acid solution while being continuously stirred using a magnetic stirrer. To adjust the

pH, a 1 M solution of  $\text{NaOH}$  in deionized water was introduced. Following 30 minutes of stirring at room temperature, a 0.1 M solution of  $\text{NaBH}_4$  in deionized water was added under continuous stirring. The stirring process was sustained for an additional 15 minutes in ambient conditions to allow the reaction to reach completion. The initial blue color of the reaction mixture transitioned to a red-brown hue, as depicted in figure 2.

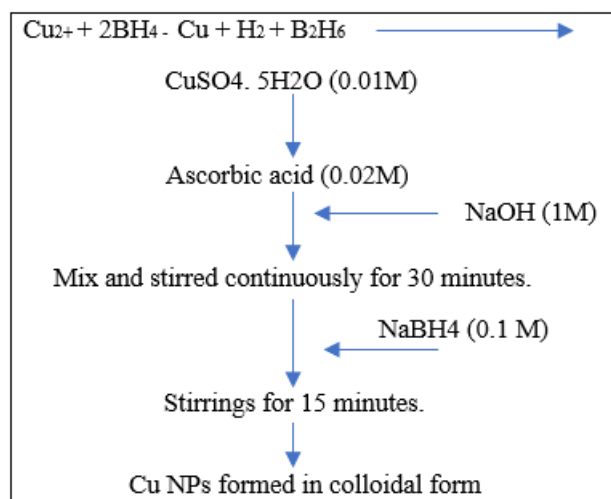


Figure 1: Flow chart of experiment process of synthesis

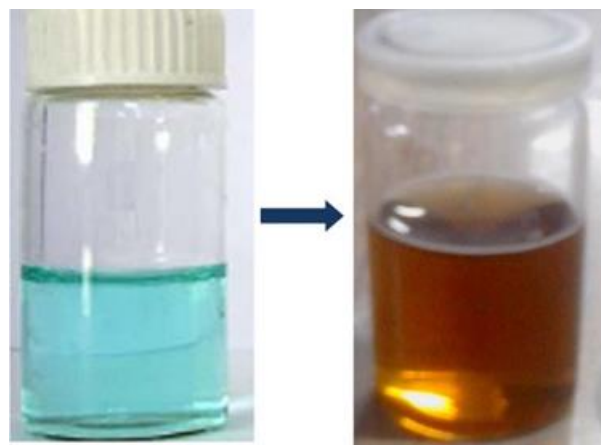
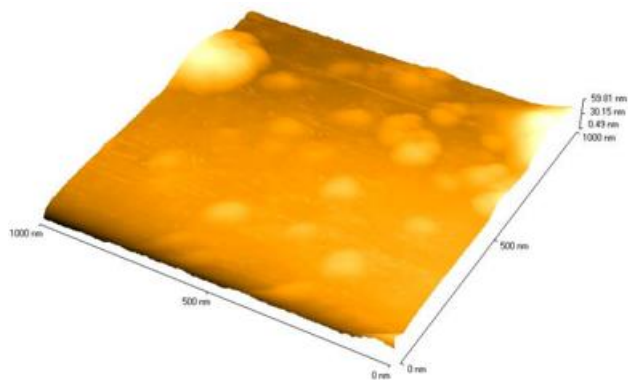


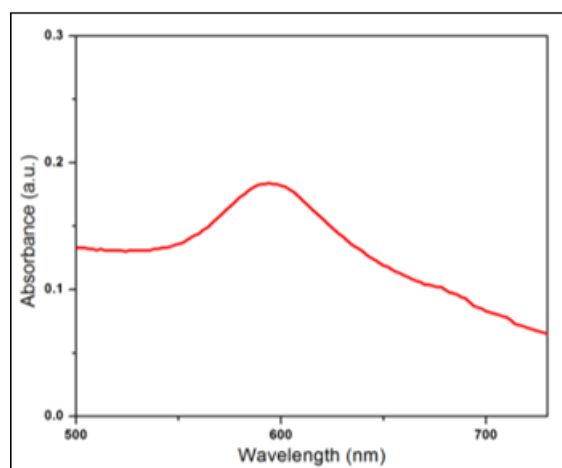
Figure 2: Cu nanoparticles solution turned into dark brown colour



**Figure 3:** 3D photographic view of Brownish colour of Cu nanoparticles From 15 to 55 nm

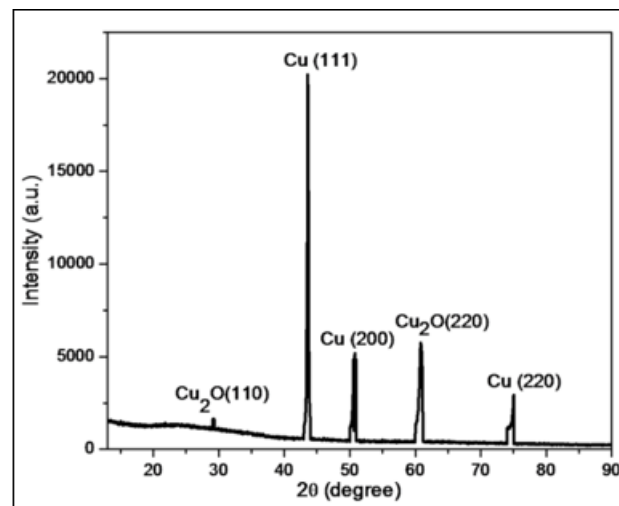
### 3. Results and Discussions

The stability of Cu colloidal solution in air was investigated through the measurement of Cu NPs absorption using UV - visible spectroscopy. The absorption band of copper nanoparticles was found to be within the range of 500 - 600nm. The UV - visible absorption spectra of Cu NPs obtained through the chemical reduction method (CRM) are depicted in figure 3. This spectrum was captured immediately after the synthesis of the particles. The figure illustrates absorption peaks at 588 nm, confirming the presence of copper nanoparticles in the solution. The initial blue - green color transformed into red - brown, a color shift attributed to surface plasmon resonance (SPR). Metals exhibit SPR in the visible region due to the presence of free electrons, resulting in the intense colors observed. These properties are evident in Cu, Ag, and Au owing to the existence of free electrons.



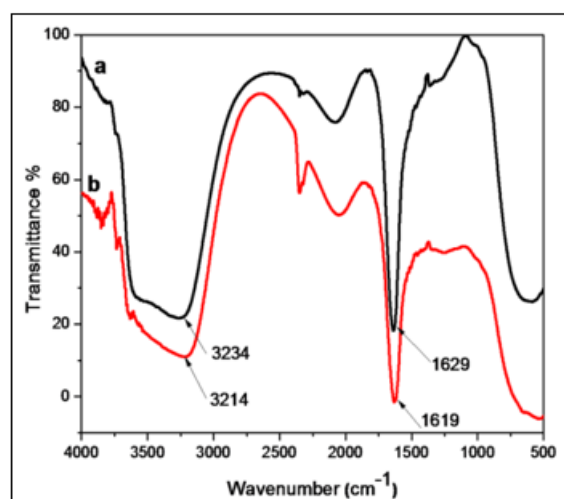
**Figure 4:** UV - Visible spectra of Cu nanoparticles

Atomic force microscopy (AFM) is a significant tool for investigating the morphology of nanoparticles. Tapping mode AFM imaging is specifically utilized for the examination of copper nanoparticles. The AFM image depicted in Figure 4 showcases copper nanoparticles (3D) with particle sizes varying from 14 nm to 55 nm in a  $2 \mu\text{m} \times 2 \mu\text{m}$  region.



**Figure 5:** XRD Pattern of Cu nanoparticles

The X - ray diffraction (XRD) analysis of the copper nanoparticles synthesized reveals a face - centered cubic (FCC) crystal structure, as depicted in figure 5. The diffraction pattern displays characteristic peaks at 2 - theta values of 43.4°, 51.1°, and 74.9° corresponding to the (111), (200), and (220) planes, respectively. Additionally, two peaks attributed to cuprous oxide ( $\text{Cu}_2\text{O}$ ) are observed at 29.1° and 60.5° for the (110) and (220) planes, respectively. The presence of  $\text{Cu}_2\text{O}$  suggests the partial oxidation of the copper nanoparticles due to exposure to dissolved oxygen in the solution [14, 15]. It is worth noting that copper nanoparticles readily oxidize in the presence of oxygen from the ambient atmosphere, forming an oxide layer on their surface. Consequently, the synthesis of copper nanoparticles can be achieved in an atmospheric environment, at room temperature, and under atmospheric pressure using de - ionized water as a solvent, eliminating the need for additional chemical processes [15 - 16].



**Figure 6:** FTIR spectra of Cu nanoparticles

the FTIR spectra of copper nanoparticles and de - ionized water. A large absorption of the hydroxyl group (O - H) of de - ionized water appears at 3234  $\text{cm}^{-1}$  and 3214  $\text{cm}^{-1}$ , respectively, before and after the production of nanoparticles, in the 3500–3000  $\text{cm}^{-1}$  range, indicating a 20 units red shift of this polar group. The widening of the - OH band in the FTIR spectra is thought to be caused by both intramolecular

and intermolecular hydrogen bonding. The interaction of copper nanoparticles with the –OH group may be the cause of this wave number drop [17]. The C=C bond is responsible for the bands in the 2000–1500 cm<sup>-1</sup> range. Prior to the production of nanoparticles, this link is visible at 1629 cm<sup>-1</sup>, and it shifts at 1619 cm<sup>-1</sup>. The reason behind the change in wave numbers was illustrated above.

#### 4. Conclusion

This study examines the creation of copper nanoparticles, or Cu NPs, using the chemical reduction technique (CRM). The typical size of CRM - prepared copper nanoparticles is between 14 and 55 nm. The appearance of the absorption peak at 591 nm indicates that copper nanoparticle production has occurred. The development of copper nanoparticles along various crystallographic planes is attributed to the observed fcc XRD peaks. Cuprous oxide (Cu<sub>2</sub>O), a different phase that is equally visible, demonstrates how copper nanoparticles partially oxidize when oxygen is dissolved in the solution.

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