Materials International
Open Access Journal (ISSN: 2668-5728)

Article
Volume 7, Issue 1, 2025, 9
https://doi.org/10.33263/Materials71.009

Synthesis and Characterization of CuO Nanoparticles for Potential Application in Latent Fingerprint Development

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Scopus Author ID 57214113275
Received: 1.07.2024; Accepted: 2.01.2025; Published: 13.02.2025

Abstract: Nanoparticles with a high surface area and small particle size are untapped reservoirs for various applications. The present study focuses on synthesizing and characterizing copper oxide (CuO) nanoparticles for potential use in latent fingerprint development. CuO nanoparticles were synthesized following a novel precipitation process employing cupric chloride di-hydrate [$CuCl_2 \cdot 2H_2O$] and glacial acetic acid. The morphology and size distribution were examined by Field Emission Scanning Electron Microscopy (FE-SEM) and particle size analysis, which showed that the nanoparticles formed were primarily hexagonal and had an average size below 100 nm. The crystalline nature of the nanoparticles, which confirms the hexagonal wurtzite structure of CuO, was verified by X-ray diffraction (XRD) study. The potential use of these CuO nanoparticles in latent fingerprint production was investigated through preliminary testing on a range of surfaces. It has been observed that these nanoparticles helped improve the contrast and visibility of the latent fingerprints, hence effectively revealing the same. The encouraging outcomes pointed towards the prospective application of the synthesized CuO nanoparticles in forensic research. Improvements in fingerprint detection methods could result from more optimization and analysis of their qualities, which would help law enforcement with criminal investigations.

Keywords: criminal investigations; CuO nanoparticles; FE-SEM; latent fingerprint; XRD.

1. Introduction

Fingerprints are still regarded as one of the most important categories of tangible evidence for identification. Generally speaking, three types of fingerprint evidence can be discovered at a crime scene: latent prints, impression prints, and visible prints, also known as patent prints. Latent prints need to be developed or enhanced for their visualization to be possible, as they are not visible to the human eye [1]. Over the years, many new methods have been devised for latent fingerprint detection. However, the powdering method is still the standard for treating latent prints in fingerprint detection [2]. This method is easy, does not require complex instrumentation, and can be carried out on the spot efficiently by a trained expert with very accurate results [2]. The powder sticks to any oils, perspiration, or other residue left on by a fingerprint when it is sprayed on the afflicted area. Since the early 1900s,

the powdering technique has been employed. During this time, numerous formulations of fingerprint powder have been developed; each consists of a resinous material for good adhesion and a colorant for contrast [2]. Over the years, hundreds of formulas for fingerprint powder have been created. Fingerprint powders are generally classified into four classes: metallic, luminescent, thermoplastic, and regular [3]. Identification can proceed once suitable quality images have been interpreted. Three levels of characteristics are present in the generated fingerprint images: firstly, the fundamental ridge pattern (arch, loop, or whorl); second, the finer points of fingerprints (ridge ending, bifurcation, delta, core, crossover, lake); and third, the ridge path deviation, width, shape, pores, and other details [4]. The majority of the conventional methods involve chemical reactions or physical interaction between the developing agent and one or more than one component of the finger-mark residues, which consists of a varied mixture of water, triglycerides, fatty acids, sterols, inorganic salts, proteins, and amino acids [5-7].

Some of the best-known methodologies and reagents used for latent finger-mark development on different surfaces involve colored, luminescent, magnetic, or thermoplastic powders, powder suspension/small particle reagents (SPR), cyanoacrylate fuming, fluorescent dyes, vacuum metal deposition, silver nitrate/physical developer (PD), ninhydrin solution [8-10].

Nanotechnology involves working with materials at a scale of 1 to 100 nanometres, offering numerous applications across scientific fields. Within forensic science, nano forensics is an emerging area utilizing nanoparticles or nano-sensors to aid in criminal investigations, including developing latent fingerprints. While conventional methods like fingerprint powders and chemical techniques suffer from drawbacks such as poor visibility and smudging, nanoparticle-based approaches overcome these limitations. Gold, silver, zinc oxide, silicon oxide, aluminum oxide, carbon, quantum dots, and rare earth metals are among the nanoparticles successfully utilized for developing latent fingerprints on various surfaces [11].

In the present work, we report the synthesis of novel CuO nanoparticles to be employed for latent fingerprint development. Nanoparticles with particle sizes ranging from 1 to 100 nm have superior adhesion to fingerprint residues, leading to a significant increase in the visibility of latent prints. These materials can effectively develop prints on various surfaces, including porous materials, which are challenging for conventional techniques. Traditional fingerprinting methods often suffer from low sensitivity and can be hazardous. In contrast, nanoparticles provide a safer and more effective alternative, allowing for the development of weeks or even months-old prints, enhancing detection capabilities, and making them versatile tools in forensic investigations.

2. Materials and Methods

For the present work, Cupric chloride di-hydrate [HIMEDIA], Glacial acetic acid [LobaChemie], Sodium hydroxide (NaOH) [HIMEDIA], Sonicator (Digital Ultrasonic Cleaner, 80W), Magnetic stirrer, pH meter and Centrifuge were used as procured. Copper oxide nanoparticles were prepared following a self-devised novel method for synthesizing CuO nanoparticles. 100 ml of 0.2 M aqueous (using distilled water) cupric chloride dehydrate solution was prepared in a clean beaker.

$$CuCl_2.2H_2O + H_2O \rightarrow Cu^{2+} + +2Cl^{-} + 2H_2O$$

To the above solution, 1 ml of glacial acetic acid was added in a dropwise manner under constant stirring over a magnetic stirrer.

$$Cu^{2+} + 2CH_3COOH \rightarrow Cu(CH_3COO)_2 + 2H^+$$

The resultant solution was heated for 1 hour at 100°C. An 8M solution of NaOH was added slowly under constant ultra-sonication to the mixture.

$$Cu(CH_3COO)_2 + 2NaOH \rightarrow Cu(OH)_2 + 2CH_3COONa$$

And monitor the pH till the pH of 14 is attained. On pH change, the color of the solution changes from blue to black immediately.

$$Cu(OH)_2 \xrightarrow{\Delta} CuO + H_2O$$

A large quantity of black precipitates was formed at the bottom of the beaker. The precipitates were centrifuged at 3000 rpm for 5 minutes, washed 2 times with deionized water, and again centrifuged for another 5 minutes. Thus, obtained precipitates were air-dried for 24 hours and labeled as CuO nanoparticles.

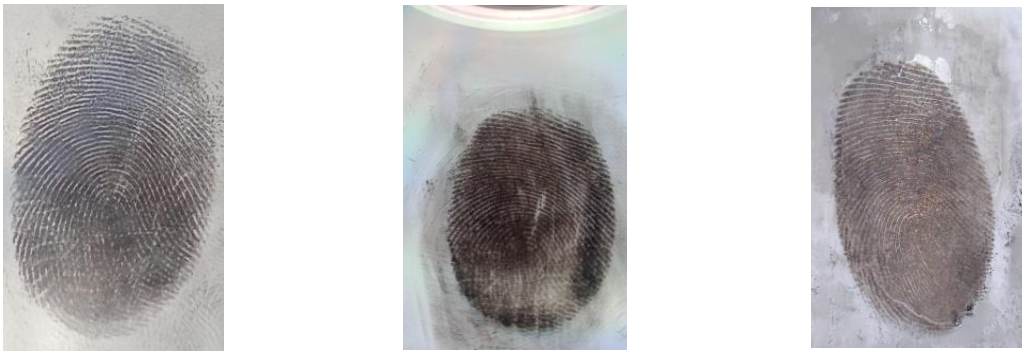
$$CuCl_2.2H_2O + 2CH_3COOH + 2NaOH \rightarrow CuO + 2CH_3COONa + 2HCl + H_2O$$

The prepared nanoparticles were black, as depicted in Figure 1.

Figure 1. Synthesized CuO nanoparticles.

The synthesized CuO nanoparticles were characterized using various techniques such as X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR), and field emission scanning electron microscopy (FE-SEM) to get evidence for nanoparticle synthesis. X-ray diffraction of CuO nanoparticles was done from 00-80 degrees by Pananaytical Xpert Pro with Cu source X-ray wavelength 0.1542 nm. The FTIR spectrum was observed by mixing the powdered sample (1- 3%) with KBr (97-99%) to form a pellet, and the % transmittance in the Bruker spectrum 65 FTIR system was analyzed FE-SEM (JSM-7610F Schottky) was observed at a magnification of 50000x.

To develop latent Fingerprints, synthesized CuO nanoparticles were employed from three different non-porous surfaces, namely glass, CD (polycarbonate plastic), and steel. The standard method [12] was followed for the generation and attainment of fingerprints. The latent fingerprints were generated by pressing the right thumb of the subject individual onto the surface. The hence-produced latent fingerprints were developed using the powder dusting method [13], employing synthesized CuO nanoparticles, and excess of the powder was removed by tapping. The black-colored CuO nanoparticles helped develop clear images of the latent fingerprints, as depicted in Figure 2. However, on closer inspection, it was observed that the latent fingerprints developed from glass presented a distinct pattern compared to that from polycarbonate plastic that lacked the moisture content.



(a) **(b)** **(c)**

Figure 2. Fingerprint developed on **(a)** Glass; **(b)** CD (Polycarbonate Plastic); **(c)** Steel surface using CuO nanoparticles.

3. Results and Discussion

The synthesized CuO powder nanoparticles were characterized for the presence of crystalline phases. The XRD pattern shows intense diffraction peaks of the CuO at 28.893°, 31.569°, 33.757°, 35.41°, 38.63°, 44.24°, 45.345°, 48.64° and 66.13°. The crystallite size of CuO was found to be 100 nm, as shown in Figure 3. These results are in accordance with the ones obtained for Cuo nanorods [14].

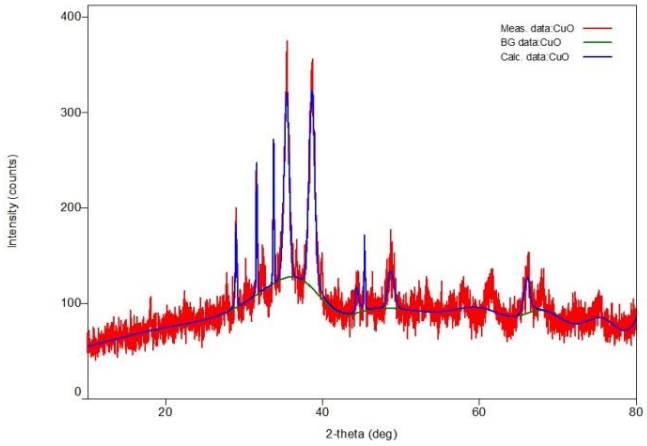
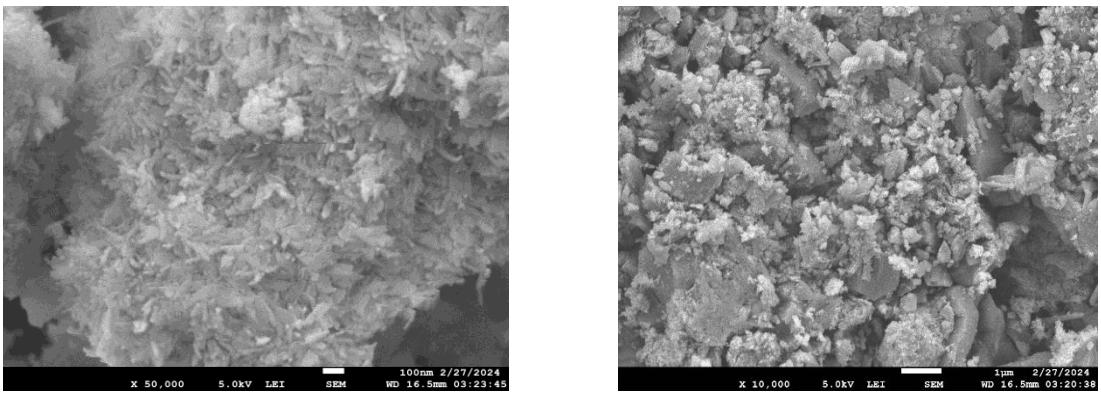
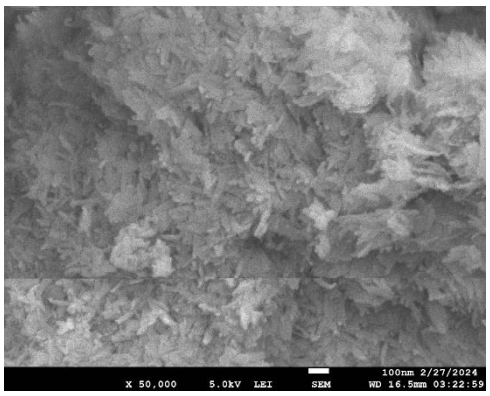


Figure 3. XRD of the synthesized CuO nanoparticles.

The fingerprints were successfully developed with the nanoparticle powder on non-porous substrates. The FE-SEM images of the synthesized CuO indicate that attained particles were below 100 nm in size and crystalline in nature and formed nanorods, as shown in Figures 4 (a,b,c). The morphology is quite similar to the CuO nanorods reported by scientists [14].



(a) **(b)**



(c)

Figure 4. FE-SEM of the synthesized CuO nanoparticles.

The FTIR spectrum of the synthesized nanoparticles exhibited characteristic peaks for CuO. The peaks at 628.48cm^{-1}, 2928.29cm^{-1}, and 168.87cm^{-1} are indicators of the synthesis of nanorods of CuO [14], as shown in Figure 5. The FTIR spectrum was compared to the one obtained for Cuo nanoparticles by Rual et al. [14], which exhibited bands at 2933 cm^{-1} and 3432 cm^{-1}, corresponding to the symmetric and asymmetric stretching vibrations of the O–H bond, respectively. The bands at 523 cm^{-1} and 1011 cm^{-1} indicate different modes of bending vibrations of the Cu–O bond. Additionally, the appearance of the peak at 1639 cm^{-1} indicates the stretching vibration of the Cu–O bond of copper(II) oxide nanoparticles.

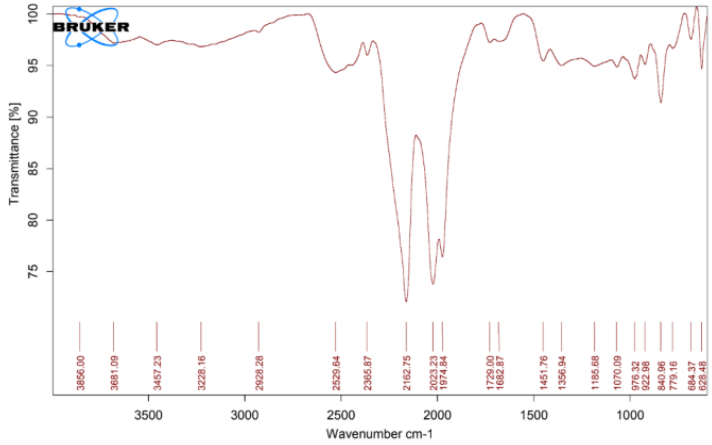


Figure 5. FTIR spectrum of the synthesized CuO nanoparticles.

The characterization studies ascertained that the synthesized CuO are nanoparticles in the form of nanorods.

4. Conclusion

A novel approach was successfully developed for the synthesis of CuO nanoparticles. The characterization studies carried out pointed towards the attainment of nanorods of CuO of size below 100 nm, as supported by the FSEM images and XRD data. The CuO nanoparticles were employed for latent fingerprint development from three random surfaces: glass, CD (polycarbonate plastic), and steel. Obtained results for the latent fingerprints developed by CuO nanoparticles were found to be very encouraging as they were easily distinguishable. They are excellent promising candidates for further study for the development of latent fingerprints from varied surfaces.

Funding

This research received no external funding.

Acknowledgments

Not applicable.

Conflict of Interest

The authors declare no conflict of interest.

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