International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

RESEARCHERID
THOMSON REUTERS

[Alange, 10(7): July, 2021]
IC™ Value: 3.00

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

STRUCTURAL AND OPTICAL PROPERTIES OF CuO NANOPARTICLES SYNTHESIZED BY CHEMICAL COPRECIPITATION METHOD

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DOI: https://doi.org/10.29121/ijesrt.v10.i8.2021.7

ABSTRACT

Cupric oxide (CuO) nanoparticles were synthesized by chemical co-precipitation method using copper nitrate and sodium hydroxide pellets as a source material. Crystalline nature was studied through x-ray diffraction. Optical properties of synthesized CuO nanoparticles were investigated by UV–visible absorption spectroscopy. X-ray diffraction study reveals that CuO nanoparticles are in monoclinic structure. The average crystallite size of CuO nanoparticles was calculated by using Debye-Scherrer formula, crystalline size was found to be around 15 nm. The UV-Visible absorption spectrum of CuO nanoparticles shows a strong blue shift compared to that of bulk. The band gap energy was calculated from the absorption spectra. The Energy band gap was found to be of prepared CuO nanoparticles 3.27eV.

KEYWORDS: XRD, UV-Visible, nanoparticles, CuO.

1. INTRODUCTION

Metal oxide nanoparticles, such as ZnO, CdO, and copper oxide (CuO), have attracted attention mostly because of their excellent antibacterial [1], optical and electrical properties [2], gas sensor application [3, 4]. Among the metal oxide, copper oxide is one of the p-type semiconductors material [5] with narrow band gap of 1.2 eV is extensively used in various applications such as solar energy conversion [6], gas sensor [7, 8], energy storage device [9] applications. However, these novel properties can be improved by synthesis in CuO nanostructures that shown excellent performance comparing to bulk counterpart. Researchers and scientist are trying to modify properties of CuO nanoparticles for various application.

Recently, Aklilu Guale Bekrub et al [10] synthesized CuO nanoparticles by a microwave-assisted method using Cordia africana Lam. Aparna Y, et al. [11] reported that CuO nanoparticles act as a good catalyst in chemical reactions. They have prepared CuO nanoparticles by sol gel technique and concluded that XRD pattern revealed CuO nanoparticles have monoclinic structure. EDX analysis shows pure that CuO nanoparticles are pure and free from impurities. SEM shows good agglomeration of CuO nanoparticles. Lanje AS, et al. [12] studied that CuO nanoparticles are rectangular in shape with average size of 5-6 nm with monoclinic structure are synthesized by aqueous precipitation method. Wongpisutpaisana N, et al. [13] proposed that well defined CuO nanoparticles are synthesized by a sono-chemical synthesis by the assistance of ultrasound with the reaction time up to 30 min and calcination at 600-700 °C. Zhu H, et al. [14] proposed a wet chemical method to synthesize stable CuO nanofluids in a large-scale. Different copper salts resulted in different particle morphologies. Size and shape of clusters of primary nanoparticles are affected by concentration of copper acetate and reaction time. Kannaki K, et al.,[15] proposed the hydrothermal route for synthesis of copper oxide nano particles. It is confirmed by XRD analysis. The UV-Visible study shows the radiation in red region can be applicable for fabrication of optoelectronic devices. Ayask HK, et al. [16] synthesize of copper oxide nanoparticles using copper hydroxide by mechanochemical process. The main advantage of this study is CuO nanoparticles with narrow size distribution without subsequent annealing during the process. Karthik AD, et al. [17] the present investigation reports, the novel synthesis of Copper and Copper oxide nanoparticles using Chemical reduction method and its physicochemical characterization Rani R, et al.,[18] Purewal Monoclinic CuO nanoparticles were synthesized by reverse micelle

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

technique. Size and morphology were characterized by using XRD, and TEM techniques. Ahamed M, et al.,[19] it describes the structural and antimicrobial properties of copper oxide nanoparticles (CuO nanoparticles) synthesized by a very simple precipitation technique. The properties of CuO nanoparticles can be tuned by using of different synthesis method [20, 21] and doping of various metal ions [22].

In this article, using a simple and low-cost approach, CuO nanoparticles were synthesized using chemical coprecipitation method and their structural and optical properties were investigated using different characterization techniques.

2. MATERIALS AND METHODS

The AR grade chemicals were used for synthesis of CuO nanoparticles, copper (II) nitrate [Cu (NO3)2], sodium hydroxide (NaOH) and double distilled water were used. All materials were purchased and used without further purification, while synthesis 1.0 M Cupric nitrate was added to 100 ml of distilled water and the solution was magnetically stirred for 30 min. Sodium Hydroxide solution was added drop wise to the above solution till the solution pH reached 14. The above solution was magnetically stirred for 4 hours till a precipitate brown for CuO was formed. The precipitate was washed by acetone and ethanol and distilled water and the precipitate was dried to powder form. The powder was annealed at 500°C for 6 hours for good crystallinity and removal unwanted impurity.

3. RESULTS AND DISCUSSION

3.1 X-ray diffraction Study

The XRD patterns of prepared CuO nanoparticles are shown in Figure 1. From the XRD pattern, it is observed that formation of CuO nanoparticles having single-phase with monoclinic structure[23]. The obtained diffraction peaks in XRD pattern were well match with JCPDS card number 89 - 5899. The observed sharp peaks indicated that the obtained nanoparticles contained high crystallinity nature. In the XRD pattern peaks were observed at 32.5°, 35.5°, 38.7°, 48.8°, 53.4°, 61.5°, 66°, 68°, and 75.9°. The crystallite size was calculated from Scherer's formula, $t = 0.94 \lambda / \beta \cos\theta$, [24] where t is the average crystallite size of the particle, λ is the wavelength of the electron beam, β is the full width at half maximum (FWHM) of the peak and θ is the Bragg's angle of diffraction. No peaks of impurities are found in XRD pattern of CuO. The peaks are broad due to the nano-size Effect. The average crystallite size of CuO nanoparticles is found to be 15 nm.

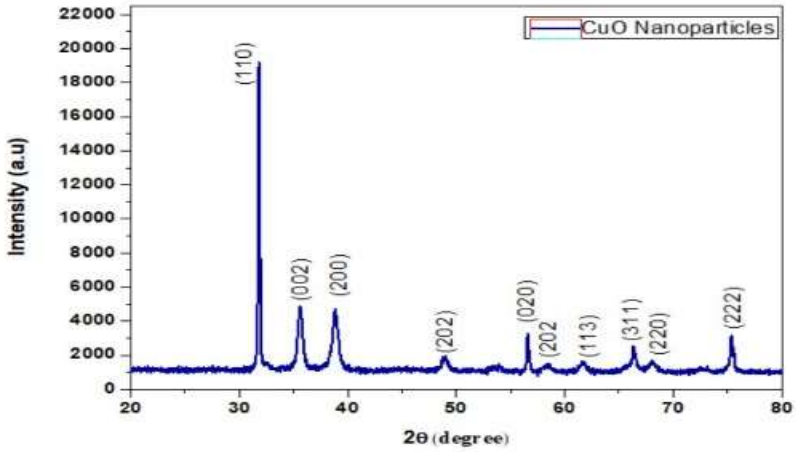

Fig.1 X-ray diffraction pattern of CuO nanoparticles

ISSN: 2277-9655
Impact Factor: 5.164
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3.2. UV-Visible Absorption Spectroscopy

The optical properties of the prepared CuO nanoparticles were investigated using UV–visible spectrophotometer in the wavelength range of 300–800 nm. Fig.2. shows the UV Visible spectra of CuO nanoparticles. The absorbance vs. wavelength plots were converted to Tauc's plot and band gap energy was calculated with the help of Tauc's equation[25, 26].

$$Ahν = A (Hν − Eg) ½,$$

where α is the absorption coefficient, hν is the incident photon energy, and A is a constant. Fig4. Extrapolation curve for band gap determination of as synthesized CuO nanoparticles

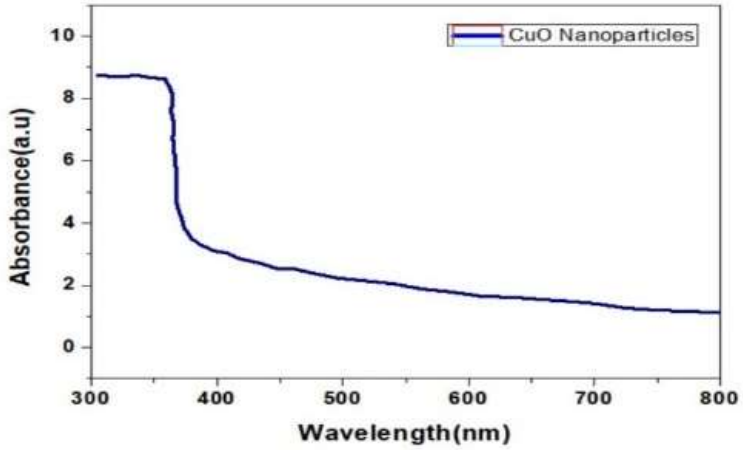

Fig.2. UV Vis absorption spectra of CuO nanoparticles

Tauc's plot draws between $(αhν)^2$ and hν. Its slope represents band gap energies of CuO nanoparticles. The energy band gap of the CuO nanoparticles was observed 3.27 eV, which are large than that of bulk CuO particles[27]. The variation of bandgap could also relate to quantum size effect in different CuO nanostructures [28].

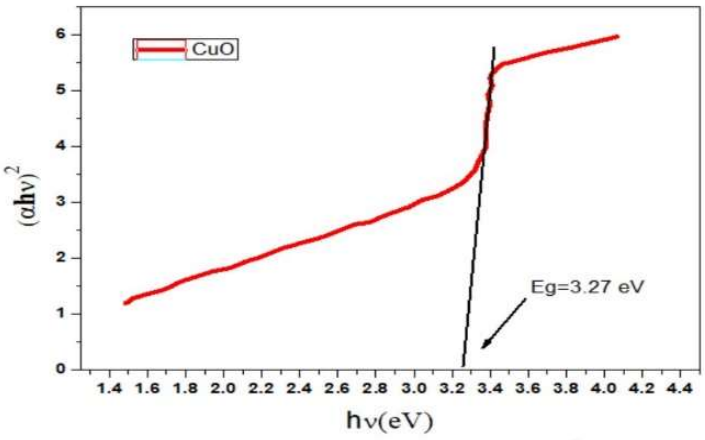

Fig.3. Extrapolation curve for band gap determination of CuO nanoparticles

If the direct band gap is higher than the indirect band gap, the materials will be crystalline[29, 30]. The calculated direct band gap value was 3.27 eV, which was higher than the bulk band gap value. The observed increasing band gap could be ascribed to the presence of intragap states and quantum confinement effect.

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4. CONCLUSION

CuO nanoparticles successfully synthesized by simple chemical co precipitation method. The structural and optical properties of the prepared CuO nanoparticles investigated and confirmed using XRD and UV-VIS spectroscopy. According to Scherer's formula, the average particle size of the sample is 15 nm. Band gap energy of CuO nanoparticle is 3.27 eV, obtained from the UV-VIS absorbance spectra, which is higher than that of the bulk. The present work will contribute to the understanding of related optical, and structural properties of CuO nanomaterials.

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