Synthesis and Characterization of Copper Oxide (CuO) Nanoparticles

D. Vandana Reddy¹ T. Bala Narasaiah²

¹M. Tech ²Professor

¹Department of Nanotechnology

²JNTUA College of Engineering, Anantapur, India

Abstract— Transition metal oxides play crucial role in several areas of physics, chemistry, and materials science. Nano-scale materials have tremendous interest in their unique thermal, electronic, electrical and optical properties. Copper oxide (CuO) has great catalytic activities which can be utilized in biosensors and electrochemical super capacitors. It can also be used as a catalyst and semiconductor in solar energy. In the present work, copper oxide nanoparticles are synthesized by using sol-gel process. The structure and morphology of the nanoparticle is characterized by using X-Ray Diffractometer (XRD), Field Emission Scanning Electron Microscope (FESEM) and UV-Vis spectroscopy analysis. The XRD pattern shows that nanoparticles are crystalline, nano-sized and the crystal structure of CuO nanoparticles is monoclinic and average size of particles is found to be 18.5nm which is determined by using the Debye Scherrer formula. The UV-Vis spectra of CuO nanoparticle show that the particles have energy band gap of semiconductor. FESEM analysis indicates that prepared product consists of uniform flake like structure.

Key words: Copper Oxide (CuO)

I. INTRODUCTION

The nanostructured semiconductor materials are very important because they can be used in various applications like optoelectronics, sensors, electrode active materials, electrical and electronic applications. The CuO nanoparticles are P-type semiconductors having the narrow band gap of 1.8 eV which can be used in solar cells, gas sensors, catalysis and magnetic storage media [1]. One of the most significant parameters in the preparation of nanoparticles is to control the particle size, crystallinity, and morphology. There are various methods to synthesize the CuO nanoparticles such as hydrothermal method [2], spray pyrolysis [3], thermal decomposition [4], electrochemical method [5], and microwave irradiation [6], sonochemical [7].

In the present study, Sol-gel method is used for synthesizing the copper oxide nanoparticles. Characterization of nanoparticles is done by using XRD, FESEM and UV-Vis absorption spectra to find the particle size, crystallinity, morphology and energy band gap of the nanoparticle.

II. EXPERIMENTAL PROCEDURE

A. Raw Materials

Copper chloride dihydrate (CuCl₂.2H₂O) is used as a precursor, sodium hydroxide (NaOH) pellets act as a reducing agent, hydrochloric acid (HCl) is used for maintaining pH levels and distilled water are used. All these chemicals are analytical grade and are used without any further purification.

B. Synthesis of CuO Nanoparticles

Copper Oxide Nanoparticles are prepared by using a Sol-gel process, which is the simple and low-cost method. Firstly, take 0.03 M of copper chloride dihydrate and 0.25 M of sodium hydroxide pellets dissolved in 100ml of distilled water in a 250ml conical flask. The solution is kept under vigorous stirring and heating up to 50°C for a period of one hour. During this process the mixture colour frequently changes from blue to black colour and precipitate forms. After this the precipitate is cooled to room temperature, then centrifuged and washed with distilled water several times to remove the impurity ions. After that, the black coloured paste is dried at 50°C in an oven. The obtained dried particles are calcined at 400°C for 3 hrs for phase stabilisation.

\[
\text{CuCl}_2.2\text{H}_2\text{O} + 2\text{NaOH} \rightarrow \text{Cu(OH)}_2 + 2\text{NaCl} + 2\text{H}_2\text{O}
\]

\[
\text{Cu(OH)}_2 \rightarrow \text{CuO} + \text{H}_2\text{O}
\]

III. RESULTS & DISCUSSION

A. Characterization of particles

1) FESEM

The Field Emission Scanning Electron Microscope having the higher magnification which gives greater resolution. The morphology of a CuO nanoparticle which is shown in fig.1. The FESEM image is collected at magnification of 50,29 KX, this indicates that the nanoparticles are well dispersed uniform flake like crystalline structure.

2) XRD Analysis

The XRD pattern of CuO nanoparticle is shown in fig.2. All the peaks in the graph show that the nanoparticle has monoclinic tenorite structure and it is verified with JCPDS File No.01-080-1916. The average size of a CuO nanoparticle is found by using the formula of Debye Scherrer.

\[
D = \frac{0.9\lambda}{\beta \cos \theta}
\]

Where

\( \lambda \) = wavelength of X-rays (1.54 nm)

\( \beta \) = full width half maxima of a peak

\( \theta \) = angle of the peak

From this formula, the average size of a CuO nanoparticle is found at 18.5nm.
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Fig. 1: Morphology of CuO nanoparticles using FESEM at 200 nm

Fig. 2: XRD pattern of CuO nanoparticles

B. UV-Vis Absorbance Spectra
The UV-Vis absorbance spectrum is used to study the optical properties of prepared CuO nanoparticles. Using the spectrum the band gap and electronic transitions are determined. Whenever semiconductors absorb a photon of energy which is larger than the gap of a semiconductor, then an electron is moved from valance band to conduction band there happens an abrupt increase in the absorbance of material to the wavelength relating to band gap of energy. The electronic transition depends on the relation between the absorption coefficient (α) and the incidental photon energy. The electronic transitions are two types which is direct and indirect transitions, when the electron momentum is conserved it is direct transition otherwise it is indirect transition.

The band gap of CuO nanoparticles from absorption spectra is derived from the following relation:

\[ ( \alpha h \theta )^n = A ( h \theta - E_g ) \]

Where
- \( \alpha \) = absorption coefficient
- \( h \theta \) = incident photon energy
- \( A \) = material dependent constant
- \( E_g \) = optical band gap
- \( n = 2 \) for direct transitions
- \( n = \frac{1}{2} \) for indirect transitions

The absorption spectrum of copper oxide nanoparticles has the highest peak at 385 nm that corresponds to near UV region which is shown in fig.3. The electronic transitions of Tauc plot for direct and indirect allowed transitions of CuO nanoparticles are shown in fig.4, 5. This tauc plot is plotted against photon energy Vs \(( \alpha h \theta )^n\).

IV. CONCLUSIONS
The transitional CuO nanoparticle is prepared via sol – gel method. From the present study the XRD analysis gives that prepared CuO nanoparticles are crystalline, monoclinic tenorite structure with average particle size of 18.5 nm, FESEM shows that uniform flake like crystalline structure and UV – Vis absorbance spectra proves that CuO nanoparticles are having semiconductor energy band gap of 2.4 and 1.8 eV. From this it can be concluded that the copper oxide nanoparticles can be used in optoelectronics, biosensors and electrochemical sensors.
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REFERENCES


