Chapter 20
Preparation of Copper Oxide (CuO) Nanoparticles and their Bactericidal Activity

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ABSTRACT
Single crystalline nanoparticles of copper oxide (CuO) having almost uniform particle size of \(~40\pm10\text{nm}\) have been synthesized by a facile and versatile route. The technique employed is free from toxic solvents, organics, and amines, and is based on a simple reaction of copper powder and de-ionized water (DI) at very low temperatures of \(180^\circ\text{C}\). The morphology, chemical composition, and crystalline structure of the nanoparticles were carefully investigated by the various characterization techniques. Besides simplicity, the advantages of producing nanoparticles by this method are that it is easy, flexible, fast, cost effective, and pollution free. The synthesized nanoparticles are under investigations for various applications including their antibacterial activity.

1. INTRODUCTION
As a semiconductor with a narrow band-gap (\(E_g = 1.2\text{eV}\)), Copper oxide (CuO) is a unique monoxide compound (in monoclinic phase, different from normal rock salt type structure) for both fundamental investigations and practical applications. It has been used as heterogeneous catalysts in many important chemical processes, such as degradation of nitrous oxide with ammonia and oxidation of carbon monoxide, hydrocarbon and phenol in supercritical water. CuO can also be used as gas sensor, optical switch, magnetic storage media, lithium batteries and solar cells owing to its photoconductive and photochemical properties (Sambandan et al., 2005; Liu et al., 2006). It
is well known that copper oxide have been used to disinfect liquids, solids and human tissue for centuries. Today it is used as water purifier, an algaecide, a fungicide and a nematocide as well as an antibacterial and antifouling agent (Ren et al., 2009).

It is well known that copper oxides can be conveniently obtained by thermal decomposition of copper salts (Han et al., 2008; Wang et al., 2002; Mang et al., 2008; Xu et al., 1999). However, it is too difficult to control the grain size of resulting copper oxide (CuO) particles through methods available, which is one of the essential requirements/conditions for the synthesis of nanomaterials. Moreover, the production in all cases required either elevated temperatures including prolonged reactions under special conditions or other tedious procedures in presence of harmful gases. In addition, most of the pathways suggested for the synthesis of CuO nanocrystals involve environmentally malignant chemicals and organic solvents which are toxic and not easily degraded in the environment. Environmental friendly chemical synthesis requires alternative solvents such as ionic liquids, liquid and water. Water is particularly attractive because it is inexpensive, safe, environmentally benign and bestowed with many virtues especially under supercritical conditions (Vostrikov et al., 2009).

Encouraged by the interesting and useful results (Shah et al., 2009), we decided to apply the approach to copper metal. Interestingly, uniform sized nanoparticles were obtained by a simple reaction of copper powder and de-ionized water at very low temperature of 180°C. The diameter of nanoparticles ranges from 30-50nm with an average diameter of 40nm. The bactericidal efficacy of the as prepared nano-CuO against Escherichia coli (Grame negative) and Staphylococcus aureus (Grame positive) bacteria was investigated. The reported method besides being organics free is economical, fast, environmentally benign and free of pollution, which will make it suitable for large scale production. The aim of the study is to provide the feasibility of the simple route for the preparation of copper oxide nanostructures without additives and to test their antibacterial efficiency. The prospects of the process are bright and promising.

2. EXPERIMENTAL

2.1. Materials

Copper powder (Cu powder, Ranbaxy with diameter > 5μm) was used as a source of copper and was cleaned by ultra-sonication in acetone and water for 10 minutes in each solvent. The de-ionized water was prepared in the laboratory. Teflon lined stainless steel was used for preparation purpose.

2.2. Preparation

2 mg of copper powder was added to 20 ml of de-ionized water in a glass vial. Few drops of ethylenediamine (en) were added to reaction mixture to avoid agglomeration. The reaction mixture was sonicated for about 30 minutes in a glass veil, transferred into a stainless steel Teflon lined metallic bomb of 100ml capacity and sealed under normal conditions. The closed chamber was then placed inside a preheated box furnace and the mixture was heated slowly (2°C/min) to 180°C and maintained at this temperature for 12 hours. The furnace is allowed to cool after the desired time and the resulting suspension was centrifuged to retrieve the product, washed and then finally vacuum dried for few hours.

2.3. Characterization

The as synthesized powder was directly transferred to FESEM chamber without coating. The morphology and the size of the products were carried out using high resolution FE-SEM (FEI NOVA NANOSEM-600) coupled with energy dispersive x-ray spectrometer (EDX). The features