RESEARCH
O&G Forum 2024; 34 – 2s: 605 - 610

COPPER BISMUTHATE NANOPARTICLES SYNTHESIS AND ELECTROCHEMICAL SENSING APPLICATION

Running title: copper bismuth nanoparticle synthesis and electrochemical sensing applications.

Muskan soni[1], Dr. Abirami Arthanari[2], Dr. Muthamizh Selvamani[3]
[1]Undergraduate student
Saveetha Dental College and Hospitals
Saveetha Institute of Medical and Technical Science (SIMATS)
Saveetha University, Chennai, India
[2]Senior Lecturer
Department of Forensic Odontology
Saveetha Dental College and Hospitals
Saveetha Institute of Medical and Technical Science (SIMATS)
Saveetha University, Chennai - 600077, India
Mail id: abiramia.sdc@saveetha.com
[3]Assistant professor-research
Department of Physiology
Saveetha Dental College and Hospitals
Saveetha Institute of Medical and Technical Science (SIMATS)
Saveetha University
Chennai - 600077, India

Corresponding Author:
Dr. Abirami Arthanari
Senior Lecturer
Department of Forensic Odontology
Saveetha Dental College and Hospitals
Saveetha Institute of Medical and Technical Science (SIMATS)
Saveetha University
Chennai - 600077, India
Mail id: abiramia.sdc@saveetha.com

Abstract
INTRODUCTION: Copper bismuthate nanoparticles have garnered significant attention in recent years due to their unique properties and their potential applications in various fields, particularly in electrochemical sensing. These nanoparticles possess a unique combination of properties derived from the synergistic effects of copper and bismuth, making them highly desirable for the development of advanced sensing devices. The synthesis of copper bismuthate nanoparticles involves the controlled formation of nanoscale particles with specific properties and structures. various synthetic methods have been explored, including chemical precipitation, solvothermal synthesis. hydrothermal synthesis. and template.
assisted methods.
Aim: Aim of the study is to synthesize copper bismuthate nanoparticles and investigate their potential applications in electrochemical sensing.
Materials and method: 3.314 grams of bismuthe nitrate was taken in 30 mol of distilled water and was kept for stirring up to 20 minutes. Later 0.8283 grams of copper nitrate was added in 30 ml of distilled water. The solution was maintained a PH 12 by addition of sodium hydroxide, and kept in hydrothermal reactor for 180c for 12 hrs centrifuged and dried at 80c for 8 hrs.
Result: Characterization of the nanoparticle sample was conducted using EDX spectrum analysis and XRD analysis from which data confirming the formation of copper bismuth oxide nanoparticles. The electrochemical sensing capacity of the nanoparticle was analyzed using cyclic voltammetry in comparison to bare carbon electrode. The results show a significant amount of redox activity of hydroquinone at the corresponding applied voltages.
Conclusion: The Synthesised copper bismuth oxide was modified on the surface of the electrode in order to sense the hydroquinone through the electrochemical method.

Key words: copper bismuth oxide, electrochemical sensing , nanoparticle, hydroquinone,

INTRODUCTION

Hydroquinone, also known as quinol, is an aromatic organic compound that is a type of phenol , a derivative of benzene . Hydroquinone is produced by 2 ways, cumene process and a second route that involves hydroxylation of phenol over a catalyst. Hydroquinone has a variety of uses like it is a major component in most black and white photographic developers for film and paper,it is also used in industrial activities such as oil refinery, cosmetics, dye, pharmaceutical, textile, pesticide, antioxidant, plastic, photostabilizer and more(1)(2).

In human medicine, hydroquinone (HQ) is used as a topical application for skin whitening for reducing the color of the skin. The topical toxicity of hydroquinone arises because it is a strong oxidant rapidly converted to the melanocyte toxic products, benzoquinone and dihydroxy benzoquinone. These byproducts may cause depigmentation(3).

There are several important health issues that need to be considered and HQ is potentially hazard- ous to the environment because of its significant toxic effect and difficult to degrade. Several concerns about HQ and its application have been reported. And so it is necessary to develop a rapid and accurate detection method for sensitive and selective deter- mination of HQ(4). A wide range of methods have been developed to determine HQ, such as chromatography(5) [5], capillary electrophoresis(5,6) [6], spectrophotometry(7) [7] and electrochemical methods. Although these techniques usually require a complicated and time-consuming sample pretreatment process, and involve expensive instruments and long analysis time, which makes them difficult for routine analysis.

Copper bismuthate nanoparticles have garnered significant attention in recent years due to their unique properties and their potential applications in various fields, particularly in electrochemical sensing. These nanoparticles possess a unique combination of properties derived from the synergistic effects of copper and bismuth, making them highly desirable for the development of advanced sensing devices(8).

The synthesis of copper bismuthate nanoparticles involves the controlled formation of nanoscale particles with specific properties and structures. Various synthetic methods have been explored, including chemical precipitation, solvothermal synthesis, hydrothermal synthesis, and template- assisted methods. These methods allow for the precise control of particle size, morphology, and composition, which ultimately determine the nanoparticles' electrochemical performance(8,9).

Copper bismuth oxide is a p-type spinel metal oxide that has been synthesized using a variety of techniques, including solid state, metal organic decomposition electrochemical method, sol-gel method, sono-chemical approach, microwave method, thermal deposition, hydrothermal synthesis, and complexation(10)(10,11). The mild hydrothermal technique employed in this study results in spherical shape for CuBi2O4 nanoparticles. CuBi2O4's properties make it useful in a variety of fields. Because of its high oxidation potential, this metal oxide is used as a cathode in lithium batteries. Its small band gap energy also leads to its employment as a sensitizer semiconductor. Furthermore, the low photon energy results in a robust reaction to visible light(12)(12,13).

Other characteristics, including photocatalytic activity, dielectric properties, and magnetic features, have lately been explored. So far, no prior research has been conducted to establish heterogeneous catalytic activity of CuBi2O4. As a result, we use suitable data to illustrate the structural and catalytic properties of this sample in our research(14). Lastly, FT-IR analysis confirmed the structure's synthesis, and FE-SEM determined its morphology.

MATERIALS AND METHODS

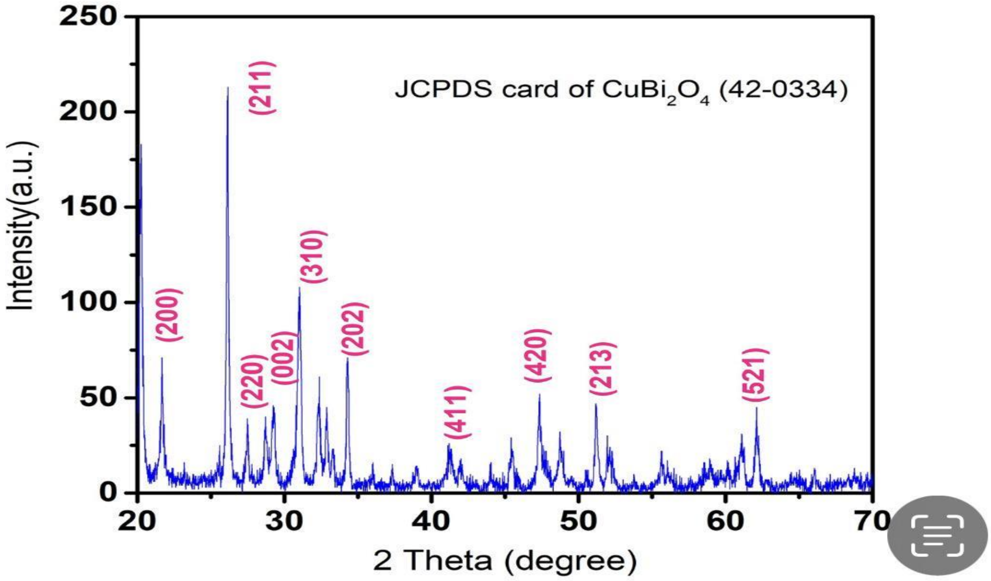
Fig1: This figure shows the synthesis of copper bismuth oxide nanoparticle.

SYNTHESIS OF CuBi2O4 (copper bismuth oxide)

In this method, at first 0.8283 Cu(NO3)2 was dissolved in 25 ml of distilled water and stirred for 20 min. Then 3.314l Bi(NO3)2 was added to the solution and stirred for 20 min again. After that, the solution of 25 ml was kept in the hydrothermal reactor at 180°C for 12 hrs maintained at PH 12 by addition of Sodium hydroxide(NaOH). Later the solution was centrifuged and dried at 80c for 8hrs. When the reaction was completed, it was cooled to room temperature and drop testing was done for electrochemical sensing applications.

RESULTS

Graph 1 shows the XRD analysis of copper bismuth oxide. Figure 2 represents the FE Scanning Electron Microscopy images and the elemental composition o copper bismuth oxide. The figure 3 depicts the electrochemical mechanism of hydroquinone. The Graph 2 illustrates the DBV analysis of copper bismuth oxide modified GCE towards hydroquinone.



Graph 1 XRD analysis of copper bismuthe oxide

XRD stands for X-ray diffraction, which is a technique used to analyze the crystal structure of materials.In XRD analysis, a powdered sample is exposed to a beam of X-rays, and the resulting diffraction pattern is recorded.

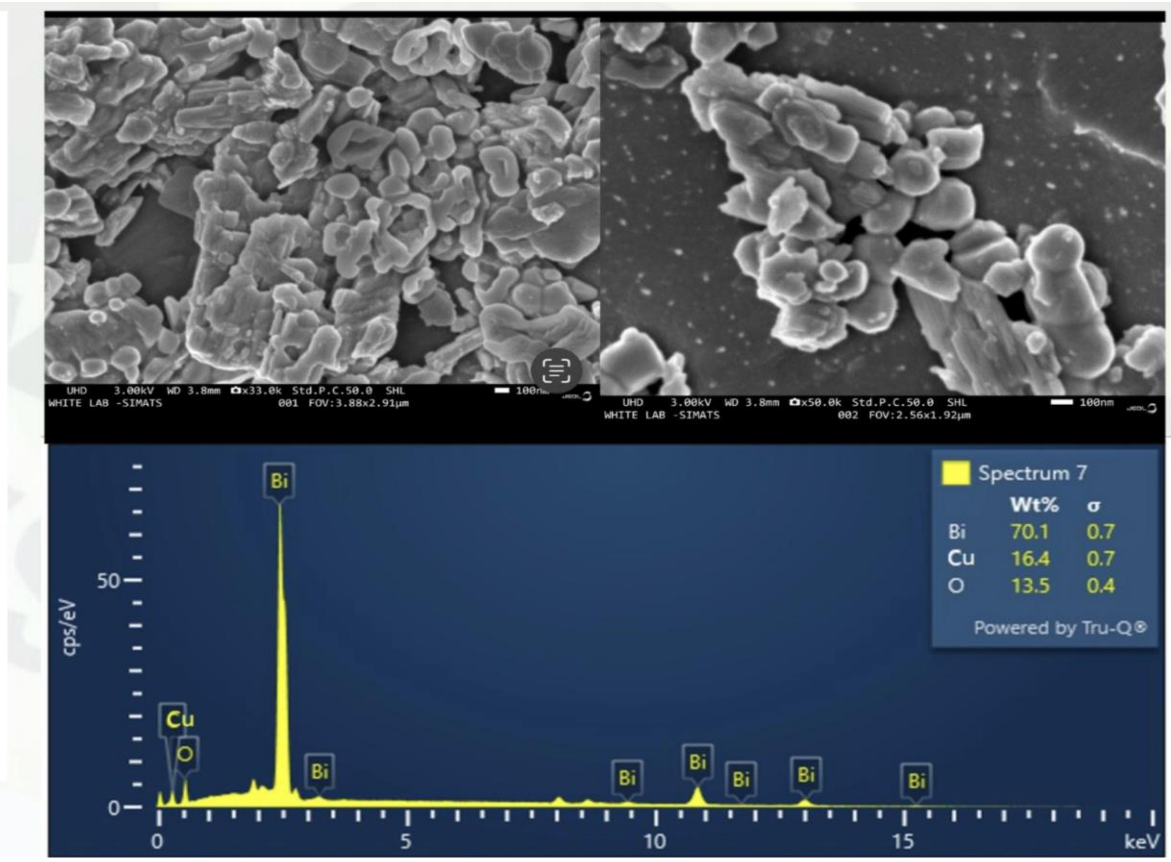


Fig 2 FE SEM IMAGES and EDX(Elemental analysis)

Scanning Electron MICroscopY SEM providing valuable information about the morphology, structure, and composition of materials at high resolution.

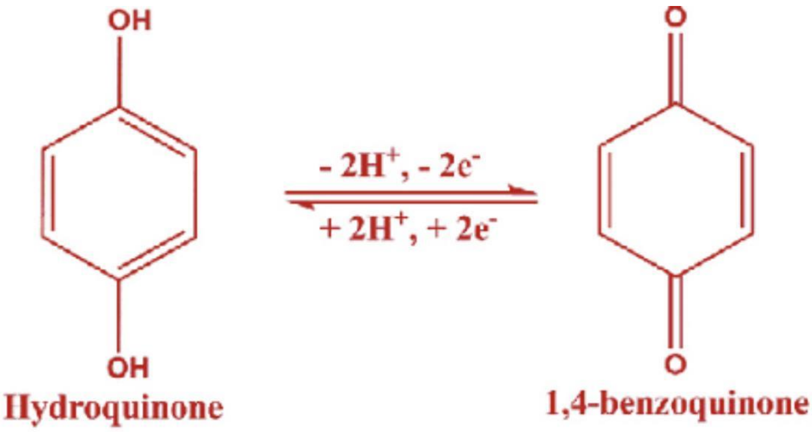
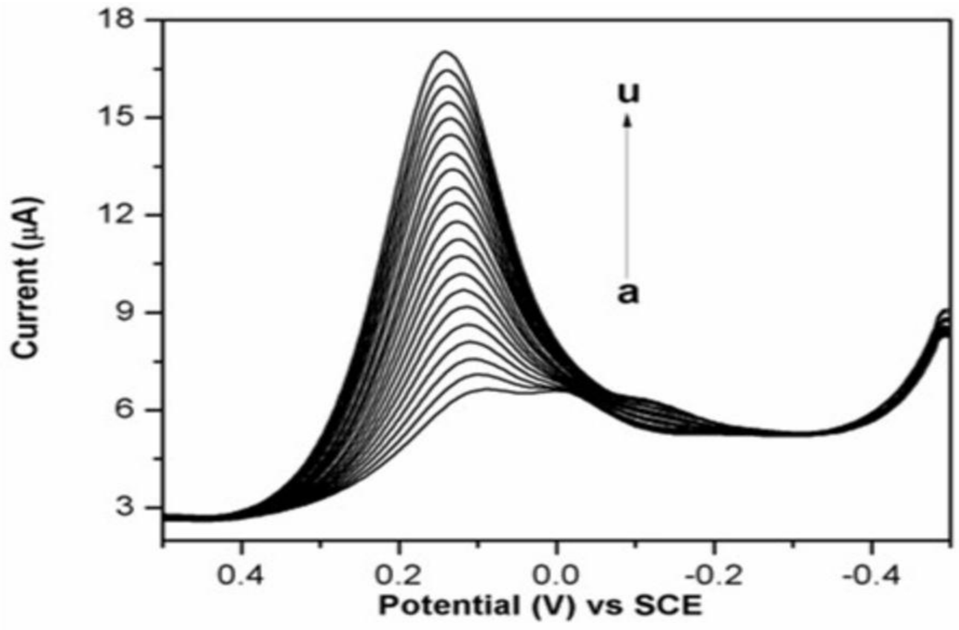


Fig 3 Hydroquinone electrochemical Mechanism



Graph 2:DBV analysis of copper bismuth oxide modified GCE towards hydroquinone.

DISCUSSION

The electrochemical sensing applications of copper bismuthate nanoparticles are particularly promising. Electrochemical sensors are widely used for the detection and quantification of various analytes in fields such as environmental monitoring, biomedical diagnostics, and food safety. Copper bismuthate nanoparticles exhibit excellent electrochemical properties, such as high surface area, good conductivity, and favorable catalytic activity, which make them ideal candidates for sensing applications.

The unique properties of copper bismuthate nanoparticles enable them to enhance the performance of electrochemical sensors in several ways(15).

The XRD pattern of CuBi2O4 shown in Fig. 1 The crystallographic planes of CuBi2O4 are given as follows: (2 0 0), (2 1 1), (3 1 0), (2 0 2), (4 1 1), (2 1 3), (3 3 2) representing primitive crystal lattice (JCPDS No: 420334). the comparison of synthesized CuBi2O4 with JCPDS No: 420334 confirms the formation of CuBi2O4(16) .

FE-SEM has been used to investigate the shape and sizes of the synthesized material. Figure 2 depicts different spectacular examples of copper bismuth oxide. This image depicts micro rod particles with nano cubic shapes growing on their surface, creating a flower-like morphology. The size of the cuboid on each sphere is 100 nm. In another study The flexible copper sensor was effectively decorated with bismuth micro/nanodendrites using a simple preparation procedure, making it possible to detect Cd2+ and Pb2+ in sweat(17,18).

The constituent elemental percentages and weight percentages of various constituent elements present in CuBi2O4 are shown in Fig. 2. Further, energy dispersive X-ray analysis (EDAX) of CuBi2O4 shows elemental mapping of Cu, Bi, O respectively in fig 2b(17).

The fig 3 depicts the electrochemical mechanism of hydroquinone. This chemical molecule hydroquinone (C6H6O2) has two hydroxyl groups (OH) joined to a benzene ring. It has a clearly known electrochemical mechanism and is frequently utilized as a redox-active molecule in electrochemical investigations.In electrochemical cells, especially in the area of electrochemical sensing, this reversible redox reaction is frequently used because hydroquinone can operate as a redox mediator or an electron transfer agent. Due to its well-defined redox activity, it is frequently employed as a model compound to investigate electrochemical systems. Because it enables the detection of analytes through changes in hydroquinone's redox state, which can be easily monitored using electrochemical techniques like cyclic voltammetry and chronoamperometry, the electrochemical mechanism of hydroquinone is crucial in many applications, including the development of electrochemical sensors and biosensors(19).

Further DBV analysis of copper bismuth oxide was done . The Synthesised copper bismuth oxide was modified on the surface of the electrode in order to sense the hydroquinone through the electrochemical method. in a concentration dependent manner at 50 millivolts per second, and it showed the gradual increase in current that depends on the various concentrations.This analysis allows you to assess the electrochemical performance of the copper bisthmuthe oxide-modified GCE towards hydroquinone and can be used for various analytical applications, like detection of hydroquinone in environmental samples or as part of electrochemical sensors and biosensors.

The structural, optical, and electrochemical characterization revealed the unique properties of the synthesized copper bismuth nanoparticles, such as their peak potentials, current responses,Differential Pulse Voltammetry (DPV). This study demonstrates the successful synthesis of copper bismuthate nanoparticles and their effectiveness in electrochemical sensing applications. The findings suggest that these Nanoparticles hold great promise for a wide range of sensing applications.

CONCLUSION

This study effectively demonstrated the synthesis of single phase $CuBi_2O_4$ using a one-step hydrothermal technique. The experimental conditions resulted in a flower-like morphology of copper bismuth oxide, such as sphere microparticles with multiple cubic particles on their surface. Furthermore, the catalytic property of the produced material was studied, and the results revealed that this metal oxide has flawless performance and a high yield. $CuBi_2O_4$ also has a low hazardous characteristic, is an eco friendly and chemically stable catalyst, has a high reusability performance, and is easier to separate and work up, which aids in the identification of hydroquinone.

Future scope :

Further research can focus on the development of practical sensor devices can be expanded to address specific environmental and biomedical challenges monitoring of pollutants, heavy metals, or biological markers in water, air, or biological samples , therefore paving the way for innovative applications in various sectors and contributing to the development of sensitive, selective, and reliable sensing technologies.

CONFLICT OF INTEREST

There is no conflict of interest.

SOURCE OF FUNDING : Soni pharmaceutical

ACKNOWLEDGEMENT:

We extend our sincere gratitude to Saveetha Dental College and Hospital and Department of Forensic Odontology for their constant support and successful completion of this work.

Ethical clearance :

Since it is an in vitro study, the ethical clearance is not applicable.

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