AIRO JOURNALS
Peer Reviewed
Multidisciplinary
National

ISSN:2321-3914
Volume: 1 Issue: 1
January 2024
Impact Factor: 10.2
Subject: Physics

EXPLORING THE MULTIFACETED CHARACTER OF COPPER OXIDE NANOPARTICLES: A COMPREHENSIVE STUDY ON THEIR STRUCTURAL, OPTICAL, ELECTRICAL, AND MAGNETIC ATTRIBUTES

SUBHAJIT GHANA
SC19BPHDPH002
Enrollment No.
PHYSICS
Dr. SUDHAKAR SINGH
SARDAR PATEL UNIVERSITY, BALAGHAT

DECLARATION: I AS AN AUTHOR OF THIS PAPER /ARTICLE, HERE BY DECLARE THAT THE PAPER SUBMITTED BY ME FOR PUBLICATION IN THE JOURNAL IS COMPLETELY MY OWN GENUINE PAPER. IF ANY ISSUE REGARDING COPYRIGHT/PATENT/ OTHER REAL AUTHOR ARISES, THE PUBLISHER WILL NOT BE LEGALLY RESPONSIBLE. IF ANY OF SUCH MATTERS OCCUR PUBLISHER MAY REMOVE MY CONTENT FROM THE JOURNAL WEBSITE. FOR THE REASON OF CONTENT AMENDMENT /OR ANY TECHNICAL ISSUE WITH NO VISIBILITY ON WEBSITE/UPDATES, I HAVE RESUBMITTED THIS PAPER FOR THE PUBLICATION. FOR ANY PUBLICATION MATTERS OR ANY INFORMATION INTENTIONALLY HIDDEN BY ME OR OTHERWISE, I SHALL BE LEGALLY RESPONSIBLE. (COMPLETE DECLARATION OF THE AUTHOR AT THE LAST PAGE OF THIS PAPER /ARTICLE.

Abstract

This paper digs into the multifaceted idea of copper oxide nanoparticles, incorporated through the co-precipitation technique. Through a careful portrayal process including checking electron microscopy, X-beam diffraction, X-beam photoelectron spectroscopy, and Fourier change infrared spectroscopy, key properties were revealed. Quiet, the nanoparticles displayed a round morphology with a typical size of roughly 42 nm, exhibiting a glasslike monoclinic stage. Optical examination through diffuse reflectance spectroscopy uncovered a blue-moved band hole of 1.46 eV. Furthermore, electrical conductivity measurements revealed a value of 0.15 S/m, while magnetic assessments using vibrating sample magnetometry demonstrated weak ferromagnetic behaviour at room temperature, primarily attributed to oxygen vacancies and thermal energy-induced spin ordering, underscored by the reduction in particle size. This comprehensive investigation sheds light on the intricate interplay of structural, optical, electrical, and magnetic features inherent in copper oxide nanoparticles.

Keywords: *Multifaceted, Copper Oxide Nanoparticles, Structural, Optical, Electrical, Magnetic Attributes*

1. INTRODUCTION

The study of nanoparticles has become a fascinating area in the fields of nanoscience and nanotechnology, with many chances for creativity and learning. Of these nanoparticles, copper oxide nanoparticles are especially interesting since they have a wide range of characteristics and uses. We explore the complex properties of copper oxide nanoparticles in this extensive work, examining their structural, optical, electrical, and magnetic properties with great care and analytical rigor.

The structural details of copper oxide nanoparticles are the main focus of our work. The crystalline forms of these small structures are remarkably diverse, ranging from cupric oxide (CuO) to cuprous oxide (Cu2O), each having unique atomic arrangements and structural characteristics. We seek to unravel the intricate lattice structures and grain morphologies inherent to these nanoparticles, shedding light on their fundamental structural properties and offering insights into their synthesis and stability through advanced characterization techniques like transmission electron microscopy (TEM) and X-ray diffraction (XRD). Moreover, our investigation goes beyond structural analysis to include the optical behaviors of copper oxide nanoparticles. Because of their surface plasmon resonances and size-dependent quantum confinement effects, these nanoparticles have special optical features. We attempt to clarify the absorption, emission, and scattering behaviors of copper oxide nanoparticles across the electromagnetic spectrum by using spectroscopic techniques like UV-Vis absorption spectroscopy and photoluminescence spectroscopy. This will help to clarify their potential uses in optoelectronic devices, sensing platforms, and photovoltaic technologies.

Apart from their optical and structural characteristics, copper oxide nanoparticles also have interesting electrical and magnetic properties that make them very desirable for a variety of technological uses. We aim to clarify the charge transport mechanisms and electronic band structures intrinsic to these nanoparticles via thorough electrical characterization using methods like conductivity measurements and field-effect transistor (FET) analysis, paving the way for their application in conductive coatings and nano electronic devices. In addition, we investigate the magnetic characteristics of copper oxide nanoparticles by means of magnetization studies and magnetic measurements, delving into phenomena like spin-dependent transport and superparamagnetic and opening the door for their application in spintronic devices and magnetic storage media. Essentially, our thorough investigation aims to reveal the complex nature of copper oxide nanoparticles in the areas of structural, optical, electrical, and magnetic characteristics. We hope to gain a deeper knowledge of these nanoparticles' behavior and uncover their enormous potential for technological innovation and advancement in a wide range of disciplines by exploring their nuances at the nanoscale. By means of rigorous testing and analysis, our goal is to make a meaningful contribution to the rapidly developing fields of nanoscience and nanotechnology. We will do this by utilizing the exceptional characteristics of copper oxide nanoparticles to drive us toward an unparalleled future.

2. REVIEW OF LITREATURE

Al-Mushki et al. (2022), provides a thorough analysis of the characteristics of CdO–NiO–Fe2O3 nanocomposites made via self-combustion. They clarified the complex relationship between polyvinyl alcohol concentrations and the properties of the resultant nanocomposites through their investigation. This work has potential implications in antibacterial agents and furthers our understanding of mixed metal oxide nanoparticles.

AlYahya et al. (2018) their investigation of cuprous oxide (Cu2O) nanocubes to the literature. The size-dependent magnetic and antibacterial capabilities inherent in these nanostructures are revealed by the solvothermal synthesis of these nanocubes. Their results open the door to customized applications in magnetic and antibacterial technologies by highlighting the significance of nanoparticle size in determining material properties.

Chauhan et al. (2021) examine the copper oxide nanoparticles' optical and structural characteristics, clarifying the relationship between structural changes and antibacterial action. They shed light on the various structural arrangements of copper oxide nanoparticles and how they relate to antibacterial applications through their thorough investigation. This work facilitates the creation of new antibacterial agents by adding an important piece to the puzzle of nanoparticle behavior.

Jahnavi, Tripathy, and Rao (2020) The researchers clarified the complex relationship between copper doping and the final material properties through painstaking experimentation and analysis. Their research holds promise for use in electronic materials, where control over structural and magnetic properties is crucial, in addition to adding to our basic understanding of doped metal oxide nanoparticles.

Khaliq et al. (2022) examine the hydrothermal production and characterization of Mg1-xNixFe2-xCrxO4 nanoparticles. The researchers examine how doping affects the structural, optical, electrical, magnetic, and photocatalytic capabilities of the nanoparticles by methodically changing the doping composition. Their research shows the promise of these nanoparticles in a variety of applications, from electrical devices to photocatalysis, and emphasizes the adaptability of doping techniques in modifying material properties.

3. PREPARATION METHOD

As outlined in Fig. 1, copper oxide nanoparticles were made by the substance precipitation strategy with cupric acetic acid derivation, icy acidic corrosive, and sodium hydroxide. 10 ml of weakened chilly acidic corrosive was added to one molar fluid arrangement of cupric acetic acid derivation, and the combination was continually fomented for 45 minutes at room temperature. Subsequent to warming the blend to around 70° C, 20 ml of a molar sodium hydroxide fluid arrangement was added dropwise while being overwhelmingly mixed. From that point onward, this arrangement was warmed to a consistent temperature of somewhere in the range of 70 and 80° C while being continually fomented for very nearly five hours. The arrangement's tone logically different from blue to a caramel dark tone, implying the production of nanoparticles of copper oxide. The earthy dark encourage that came about was dried for three hours at 120° C in a hot air stove. From that point onward, the powder was dried and calcined for three hours at 300° C. At last, the copper oxide nanoparticle dark powder was created.

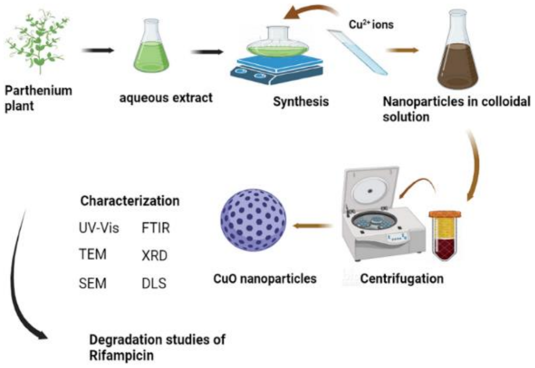

Figure 1: Plan for producing copper oxide nanoparticles

The following describes the chemical reaction that results from the reaction of cupric acetate with sodium hydroxide to create copper oxide nanoparticles.

$$CuCH_3(COO)_2.H_2O + NaOH \rightarrow Cu(OH)_2 + CH_3COONa$$

$$Cu(OH)_2 \rightarrow CuO + H_2O$$

4. RESULTS AND DISCUSSIONS

4.1 Morphological Studies

Fig. 2 shows the delegate SEM image of the produced copper oxide nanoparticles along with their size dissemination. It is discovered that the produced copper oxide nanoparticles are aggregated and have a spherical form. The copper oxide nanoparticles have a diameter that varies from 20 to 150 nm. The copper oxide nanoparticles had an average diameter of about 42 nm**.**

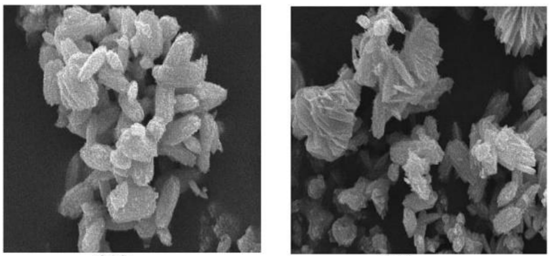
(A) (B)

Figure 2: SEM image b showing the particle size distribution of copper oxide nanoparticles

4.2 X-ray Diffraction Pattern

The delivered CuO nanoparticles' translucent nature, which relates to the monoclinic C2/c space bunch, is affirmed by the distinct XRD tops.

The sample's crystallite size, as determined by the Debye-Scherer formula, is 20.74 nm. The particle size determined by SEM measurements and the crystallite size determined by XRD measurements differ from one another.

Because a single particle is made up of several crystallites, the particle size is typically bigger than the crystallite size. An aggregate of many crystallites is called a particle. The size of the crystallite and the particle are the same when the particle is composed of a single crystallite. One crystallite may comprise the smaller particles in the 20 nm size range.

The following formula has been used to compute the lattice strain (ε).

$$\varepsilon = \frac{\beta}{4tan(\theta)}$$

where full width at half maxima is denoted by β. The sample's lattice strain is 0.0054.

4.3 Optical Properties

Difuse Refectance Spectroscopy has been utilized to decide and concentrate on the optical properties of the copper oxide nanoparticles, including the energy band hole, refractive list, and dielectric consistent (Table 1). The energy gap and refractive index, for example, are key characteristics that dictate how semiconductors behave optically and electrically. The Kubelka-Munk function F(R) and the sample's diffuse reflectance (R) have been related to find the band gap.

Table 2: Copper oxide nanoparticles: their optical characteristics

Optical parameters	Values
Band gap (Eg)	2.11 eV
Refractive index (n)	3.88
High-frequency dielectric constant ($\varepsilon\infty$)	9.12
Static dielectric constant ($\varepsilon 0$)	14.05

$$F(R) = (1 - R)^2/2R$$

The plot of (F(R) × hυ) 2 against energy (hυ). To find the band hole esteem, the straight ascent of this bend is extrapolated to meet at the x pivot. The band hole (Eg) of the delivered copper oxide nanoparticles is 1.45 eV. Mass copper oxide has a band hole of 1.20 eV. This 0.25 eV blue change in the band hole energy is brought about by the nanoscale copper oxide particles' quantum control impact. The semiconductor's transparency to incident spectrum radiation is represented by its refractive index. Herve–Vandamme postulated a relationship between semiconductors' energy gap and refractive index.

The Herve-Vandamme connection relies on the classical oscillatory theory, which assumes a constant difference between UV resonance energy and band gap energy. Using the Herve–Vandamme relation, which is shown below, the refractive index can be calculated from the band gap value:

$$n^2 = 1 + \left(\frac{A}{E_g + B}\right)^2$$

where An and B are two mathematical constants that have particular upsides of 13.6 and 3.4 eV. It is found that the created copper oxide nanoparticles have a refractive file of 2.98. the Herve-Vandamme connection demonstrates that the CuO dainty film's refractive list esteem is 2.35. Our ongoing review's assessment of the refractive record an incentive for copper oxide nanoparticles is like the worth archived in the writing. Mass copper oxide has a refractive record of 2.6. The delivered copper oxide nanoparticles' refractive list, not entirely settled by the Herve-Vandamme connection, is hardly higher than the mass worth. Utilizing the accompanying relations, the upsides of the static dielectric steady ($\varepsilon 0$) and high-recurrence dielectric consistent ($\varepsilon\infty$) have been assessed to be 8.86 and 14.05, individually.

5. CONCLUSION

The morphology and glasslike construction of the copper oxide nanoparticles orchestrated by the synthetic precipitation approach were very much controlled, bringing about collected round particles with a breadth range from 20 to 150 nm and a typical measurement of around 42 nm. Their totaled structure, comprising of numerous crystallites, was shown by SEM imaging, which additionally upheld their monoclinic gem structure. Through optical portrayal, quantum imprisonment impacts were viewed as answerable for the blue change in the band hole energy to 1.45 eV when contrasted with mass copper oxide. Furthermore, the registered 2.98 refractive file was in great concurrence with values detailed in the writing, proposing amazing optical characteristics. These outcomes add to how we might interpret the creation and portrayal of nanomaterials and feature the capability of copper oxide nanoparticles for a scope of utilizations, from sensors to optoelectronic gadgets.

REFERENCES

1. *Al-Mushki, A. A., Ahmed, A. A. A., Abdulwahab, A. M., Al-Asbahi, B. A., Abduljalil, J. M., Saad, F. A., ... & Ghaithan, H. M. (2022). Structural, optical, and antibacterial characteristics of mixed metal oxide CdO–NiO–Fe2O3 nanocomposites prepared using a*

self-combustion method at different polyvinyl alcohol concentrations. Applied Physics A, 128(4), 279.

2. *AlYahya, S., Rani, B. J., Ravi, G., Yuvakkumar, R., Arun, A., Ameen, F., & AlNadhary, S. (2018). Size dependent magnetic and antibacterial properties of solvothermally synthesized cuprous oxide (Cu 2 O) nanocubes. Journal of Materials Science: Materials in Electronics, 29, 17622-17629.*
3. *Chauhan, A., Verma, R., Batoo, K. M., Kumari, S., Kalia, R., Kumar, R., ... & Imran, A. (2021). Structural and optical properties of copper oxide nanoparticles: A study of variation in structure and antibiotic activity. Journal of Materials Research, 36, 1496-1509.*
4. *Jahnavi, V. S., Tripathy, S. K., & Rao, A. R. (2020). Study of the structural, optical, dielectric and magnetic properties of copper-doped SnO2 nanoparticles. Journal of Electronic Materials, 49(6), 3540-3554.*
5. *Khaliq, N., Bibi, I., Majid, F., Arshad, M. I., Ghafoor, A., Nazeer, Z., ... & Iqbal, M. (2022). Mg1-xNixFe2-xCrxO4 synthesis via hydrothermal route: Effect of doping on the structural, optical, electrical, magnetic and photocatalytic properties. Results in Physics, 43, 106059.*
6. *Kumar, S. (2021). Influence of synthesis strategy on the formation of microspheres of self-assembled CuO rectangular nanorods and hierarchical structures of self-assembled Cu2O nanospheres from single precursor (copper (II) acetate monohydrate) and their structural, optical, thermal and magnetic properties. Materials Chemistry and Physics, 258, 123929.*
7. *Menazea, A. A., & Ahmed, M. K. (2020). Silver and copper oxide nanoparticles-decorated graphene oxide via pulsed laser ablation technique: Preparation, characterization, and photoactivated antibacterial activity. Nano-Structures & Nano-Objects, 22, 100464.*
8. *Menazea, A. A., Mostafa, A. M., & Al-Ashkar, E. A. (2020). Effect of nanostructured metal oxides (CdO, Al2O3, Cu2O) embedded in PVA via Nd: YAG pulsed laser ablation on their optical and structural properties. Journal of Molecular Structure, 1203, 127374.*
9. *Nagaraj, E., Karuppannan, K., Shanmugam, P., & Venugopal, S. (2019). Exploration of bio-synthesized copper oxide nanoparticles using Pterolobium hexapetalum leaf extract by photocatalytic activity and biological evaluations. Journal of Cluster Science, 30, 1157-1168.*
10. *Naseem, T., & Durrani, T. (2021). The role of some important metal oxide nanoparticles for wastewater and antibacterial applications: A review. Environmental Chemistry and Ecotoxicology, 3, 59-75.*
11. *Noreen, S., & Hussain, A. (2023). Structural, optical, morphological and magnetic properties of Cu0. 25M0. 75Fe2O4 (M= Mn, Mg, Ni and co) ferrites for optoelectronic applications. Optical Materials, 139, 113797.*
12. *Ravichandiran, C., Sakthivelu, A., Davidprabu, R., Valanarasu, S., Kathalingam, A., Ganesh, V., ... & AlFaify, S. (2019). In-depth study on structural, optical, photoluminescence and electrical properties of electrodeposited Cu2O thin films for optoelectronics: An effect of solution pH. Microelectronic Engineering, 210, 27-34.*

13. *Ravichandiran, C., Sakthivelu, A., Davidprabu, R., Valanarasu, S., Kathalingam, A., Ganesh, V., ... & AlFaify, S. (2019). In-depth study on structural, optical, photoluminescence and electrical properties of electrodeposited Cu2O thin films for optoelectronics: An effect of solution pH. Microelectronic Engineering, 210, 27-34.*
14. *Rodríguez-Tobías, H., Morales, G., & Grande, D. (2019). Comprehensive review on electrospinning techniques as versatile approaches toward antimicrobial biopolymeric composite fibers. Materials Science and Engineering: C, 101, 306-322.*
15. *Thangamani, J. G., & Pasha, S. K. (2021). Hydrothermal synthesis of copper (II) oxide-nanoparticles with highly enhanced BTEX gas sensing performance using chemiresistive sensor. Chemosphere, 277, 130237.*

Author's Declaration

I as an author of the above research paper/article, hereby, declare that the content of this paper is prepared by me and if any person having copyright issue or patent or anything otherwise related to the content, I shall always be legally responsible for any issue. For the reason of invisibility of my research paper on the website/amendments/updates, I have resubmitted my paper for publication on the same date. If any data or information given by me is not correct, I shall always be legally responsible. With my whole responsibility legally and formally have intimated the publisher (Publisher) that my paper has been checked by my guide (if any) or expert to make it sure that paper is technically right and there in no unaccepted plagiarism and hentriacontane is genuinely mine. If any issue arises related to Plagiarism/ Guide Name/ Educational Qualification/ Designation/ Address of my university/college/institution/ Structure or Formatting/ Resubmission /Submission /Copyright /Patent/Submission for any higher degree or Job/Primary Data/Secondary Data Issues. I will be solely/entirely responsible for any legal issues. I have been informed that the most of the data from the website is invisible or shuffled or vanished from the database due to some technical fault or hacking and therefore the process of resubmission is there for the scholars/students who finds trouble in getting their paper on the website. At the time of resubmission of my paper I take all the legal and formal responsibilities, If I hide or do not submit the copy of my original documents (Andhra/Driving License/Any Identity Proof and Photo) in spite of demand from the publisher then my paper maybe rejected or removed from the website anytime and may not be consider for verification. I accept the fact that as the content of this paper and the resubmission legal responsibilities and reasons are only mine then the Publisher (Airo International Journal/Airo National Research Journal) is never responsible. I also declare that if publisher finds Any complication or error or anything hidden or implemented otherwise, my paper maybe removed from the website or the watermark of remark/actuality maybe mentioned on my paper. Even if anything is found illegal publisher may also take legal action against me

SUBHAJIT GHANA
Dr. SUDHAKAR SINGH

*****