PHYSICAL AND OPTICAL PROPERTIES OF CuO NANOSTRUCTURES

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Abstract:
In this study, cupric oxide (CuO) nanoparticles were synthesized via hydrothermal method. The samples were characterized by X-ray diffraction, , field emission scanning electron microscope. Using CuO nanostructure analyzes UV absorption spectra. Using these absorption spectra, we further examined the CuO nanostructure to explore the possibility of using them as a material for applications such as solar cell and gas sensors.

Keywords: Cupric oxide (CuO), hydrothermal method, optical properties

Introduction:

Many researchers are interested in transition metal oxide (TMO) semiconductor nanostructures because of their tunable bandgap and enhanced active functional properties such as optical, electronic, gas sensing and magnetic [1]. Another intriguing reason for the widespread study of TMO semiconductors is their oxygen vacancy content. Oxygen vacancy can be thought of as a point defect that occurs widely on the surface during synthesis. These oxygen vacancies may alter the material's band gap [2-3]. Different semiconductors and transition metal oxides, including, WO_3, Cu_2O, ZnO, SnO2, and CuO [4-6], have recently attracted attention due to their favourable physical and chemical characteristics, particularly their high activation and ease of availability.CuO is a p-type semiconductor with a 1.2 eV band gap. CuO is used in a wide variety of applications due to its abundance and environmental compatibility solar cells, gas sensors, photo catalysis, super capacitor, and so on [3,7-10].

Attempts are made to prepare CuO nanostructures with various morphologies using various methods such as spray pyrolysis, electrochemical techniques, hydrothermal treatments, sono chemical method, and wet chemical methods. The hydrothermal procedure is the most commonly used to create nanomaterials. This method can be used to dissolve insoluble materials or to create dissolved materials from materials already present in aqueous solutions under high pressure and high temperature [11-13]. This method of producing CuO has been regarded as a low-cost and environmentally friendly method.

CuO nanomaterials' optical behaviour is primarily evaluated using UV-vis and photoluminescence techniques to investigate electronic transitions in semiconductors, such as band-edge or near-band-edge transitions. There are only a few works based on UV-vis analysis available. CuO nanoparticles were synthesised using a simple and low-cost method in this article, and their optical properties were investigated using various characterization techniques.

2. Experiments

2.1 Materials

Materials: Copper acetylacetonate, Sodium hydroxide, distil water, ethanol

2.2 Synthesis of CuO nanostructure:

Synthesis route from precursors of copper acetyl acetonate [$Cu(C_5H_7)_2$ In the first approach 3.5 gram copper acetylacetonate used with 0.4 gram Sodium hydroxide (NaOH) and distilled water as solvent. These solutions will keep in stainless steel autoclaves at temperatures 150 °C for 10 hours then allow cool to room temperature naturally. A dark precipitate will collect after being filtered and wash with distilled water and absolute ethanol to remove the residue of inorganic/organic impurities. . The final products dried at 60°C for 48 h in hot air oven**.**

2.3 Material characterizations

To determine the crystal phase CuO photocatalyst powders, X-ray powder diffraction (XRD) analysis was carried out at room temperature) with Cu Kα radiation (λ = 0.15406 nm), over the 2θ collection range of 0–80◦. The FE-SEM (Field Emission Scanning Electron Microscope) images and EDX (Energy-dispersive X-Ray) spectra were obtained from ZEISS-LEO SUPRA-55 and JEOL-JCM-6000 plus, The UV-Visible investigations of the synthesized photo-catalysts were finished on Carry-60 UV/Vis spectrometer.

3. Result & Discussion

The CuO nanolayer's XRD pattern is shown in Fig. 1, which demonstrates the sample's crystalline structure.Two major peaks can be seen in the XRD patterns around2θ = 37° and 2 = 39°, which are the (111) and (111) reflections of the CuO phase, respectively [14].

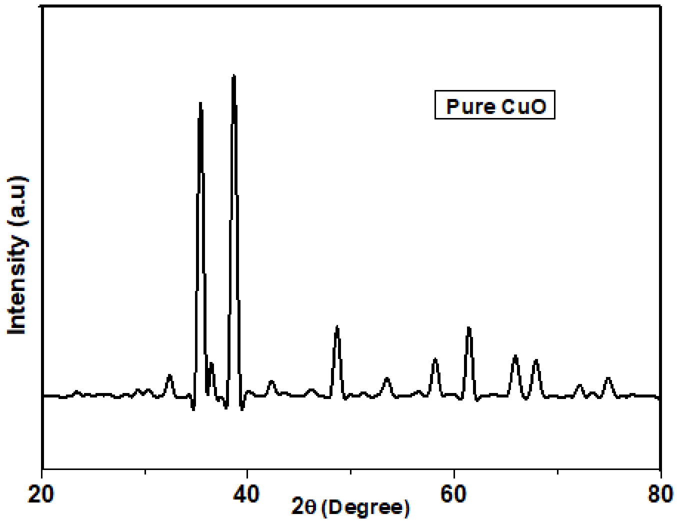

Fig1. XRD pattern of pure CuO nanostructure.

Fig 2 shows the surface after the growth of CuO nanostructures. The nanostructure growth indicates needle like structure. CuO nanonedles are depicted in Fig 2 in the typical FESEM pictures. CuO nanowires in huge numbers can be seen plainly. The CuO nanonedles with diameters ranging from 30 to 80 nm and lengths between 2 µm

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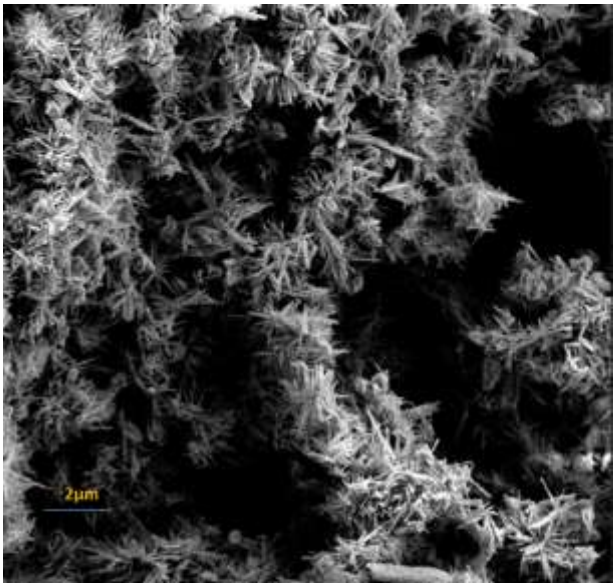

Fig 2. FESEM images of pure CuO nanostructure.

In order to detect the elements present in the CuO nanostructures, EDS analysis was carried out (Fig 3). The spectrum indicates the presence of copper [Cu], and oxy-gen [O]. No other impurity was detected. the formation of CuO was confirmed from the EDS. The corresponding weight and atomic percentage of oxygen, copper were given.

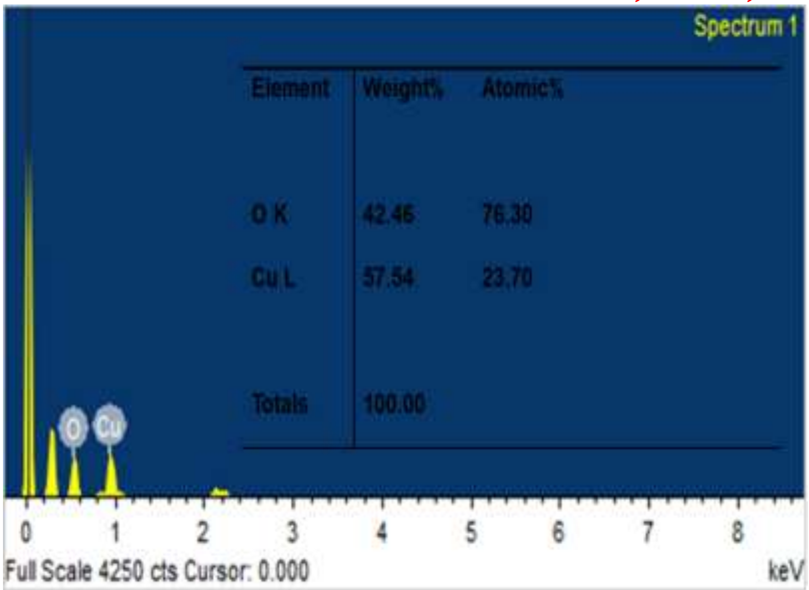

Fig 3. EDS of pure CuO nanostructure.

The bandgap value and kind of transition are identified by locating the absorption edge To investigate the energy band and the kind of electronic transitions, the absorption spectra were used. Fig 4 (a) displays the absorption spectra of CuO nanostructures, which exhibit a prominent fundamental absorption edge at a wavelength of 220 nm caused by a direct transition of electrons. Optical absorption demonstrates that we may identify a material's crystallinity by comparing the direct band gap to the indirect band gap.

Fig. 4(b) shows the functional relationship for CuO nanostructures between αhυ and photon energy. The linear portion can be extrapolated to the photon energy axis to determine the Eg value. The material will be crystalline if the direct band gap is greater than the indirect band gap [15]. 3.8 eV, which was greater than the bulk band gap value, was the computed direct band gap value (3.5 eV).There was just direct transition-related absorption seen here; an indirect transition absorption peak was not seen (Fig. 3b). The presence of might be used to explain the observed growing band gap.

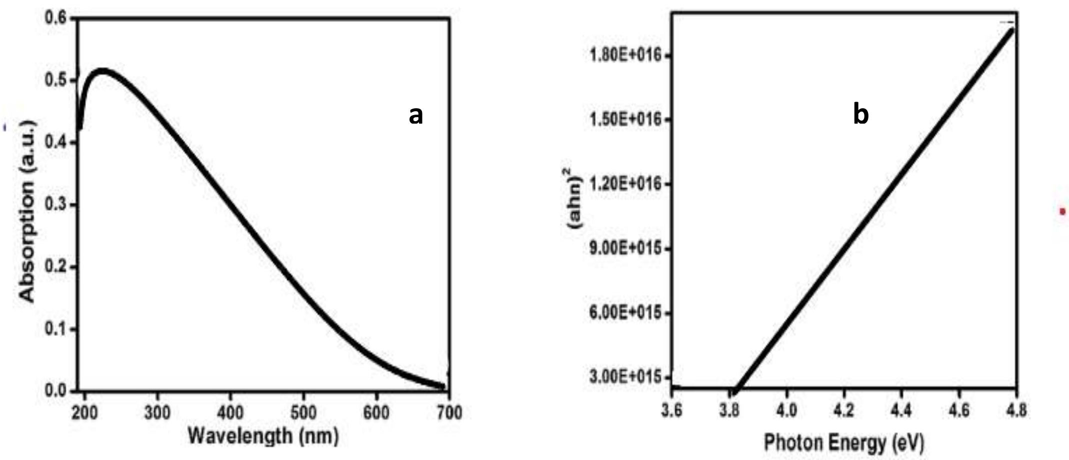

Fig 4. Optical properties of pure CuO nanostructure a) UV absorption and b) Band gap.

Conclusions:

The CuO nanostructures created for this work are crystalline, A uniform dispersion of CuO nanostructures may be seen in FESEM pictures. The produced nanostructure CuO is found to be crystalline in nature because the direct band gap is greater than the indirect band gap, according to optical absorption studies. Due to their small size, the CuO nanoparticles produced have a comparatively wide band gap, which causes the quantum confinement effect. Since it has a broad band gap, this nanomaterial could be employed in semiconductors.

References:

[1] S.Jimkeli Singh, P.Chinnamuthu, Highly efficient natural-sunlight-driven photo degradation of organic dyes with combustion derived Ce-doped CuO nanoparticles, Colloids and Surfaces A: Physicochemical and Engineering Aspects 625 (2021) 126864.
[2] H. Zhao, F. Pan, Y. Li, A review on the effects of TiO2 surface point defects on CO_2 photoreduction with H2O, J. Mater. 3 (2017) 17–32, https://doi.org/10.1016/j. jmat.2016.12.001.
[3] N. R. Dhineshbabu, V. Rajendran, N. Nithyavathy, R. Vetumperumal, Study of structural and optical properties of cupric oxide nanoparticles, Appl Nanosci (2016) 933–939.
DOI 10.1007/s13204-015-0499-2.
[4] Halil ̇Ibrahim Efkere, Ali Emre Gümrükçü, Yunus ̈Ozen , Barıs¸ Kınacı,Saime S¸ ebnem Aydın, Hakan Ates, Süleyman ̈Ozçeli, Investigation of the effect of annealing on the structural, morphological and optical properties of RF sputtered WO_3 nanostructure, Physica B: Physics of Condensed Matter 622 (2021) 413350. https://doi.org/10.1016/j.physb.2021.413350.
[5] Vijendra Singh Bhati, Mirabbos Hojamberdiev , Mahesh Kumar, Enhanced sensing performance of ZnO nanostructures-based gas sensors: A review, Energy Reports 6 (2020) 46–62. https://doi.org/10.1016/j.egyr.2019.08.070.
[6] H. Siddiqui, M.S. Qureshi, F.Z Haque, .Biosynthesis of Flower-Shaped CuO Nanostructures and Their Photocatalytic and Antibacterial Activities. *Nano-Micro Lett.* **12** (2020) 29 https://doi.org/10.1007/s40820-019-0357-y
[7] Iqbal, M., Ali, A., Ahmad, K.S. *et al.* Synthesis and characterization of transition metals doped CuO nanostructure and their application in hybrid bulk heterojunction solar cells. *SN Appl. Sci.* **1** (2019) 647 https://doi.org/10.1007/s42452-019-0663-5.
[8] Gun Chaloeipote, Rat Prathumwan, Kittitat Subannajui, Anurat Wisitsoraat, Chatchawal Wongchoosuk, 3D printed CuO semiconducting gas sensor for ammonia detection at room temperature. Materials Science in Semiconductor Processing, 123(2021) 105546doi:10.1016/j.mssp.2020.105546.
[9] Atta ur Rehman, Muhammad Aadil, Sonia Zulfiqar, Philips O. Agboola, Imran Shakir, Mohamed F. Aly Aboud, Sajjad Haider, Muhammad Farooq Warsi, Fabrication of Binary Metal Doped CuO Nanocatalyst and Their Application for the Industrial Effluents Treatment, Ceramics International, 47 (2021) 5929-5937. https://doi.org/10.1016/j.ceramint.2020.11.064
[10] S.K. Shinde, H.M. Yadav, G.S. Ghodake, A.A. Kadam, V.S. Kumbhar, Jiwook Yang, Kyojung Hwang, A.D.Jagadale, Sunil Kumar, D.Y. Kim, Using chemical bath deposition to create nanosheet-like CuO electrodes for supercapacitor applications, Colloids and Surfaces B: Biointerfaces181, 1 (2019) 1004-1011. https://doi.org/10.1016/j.colsurfb.2019.05.079.
[11] CY. Chiang, K. Aroh, SH Ehrman, Copper oxide nanoparticle made by flame spray pyrolysis for photoelectrochemical water splitting-Part I. CuO nanoparticle preparation. Int J Hydro Ener 37 (2012) 4871–4879. https://doi.org/10.1016/j.ijhydene.2011.10.033.
[12] K. Lee, W.S. Seo, J.T. Park, Synthesis and optical properties of colloidal tungsten oxide nanorods, J. Am. Chem. Soc. 12 (2003) 3408–3409.
[13] J. Li, X. Liu, J. Cui, J. Sun, Hydrothermal synthesis of self-assembled hierarchical tungsten oxides hollow spheres and their gas sensing properties, ACS Appl. Mater.Interfaces 19 (2015) 10108–10114.
[14] R. Etefagh , E. Azhir, N. Shahtahmasebi, Synthesis of CuO nanoparticles and fabrication of nanostructurallayer biosensors for detecting Aspergillus niger fungi, Scientia Iranica, Transactions F: Nanotechnology 20 (2013) 1055–1058. https://doi.org/10.1016/j.scient.2013.05.015.
[15] A. Asha Radhakrishnan, B. Baskaran Beena, Structural and Optical Absorption Analysis of CuO Nanoparticles, Indian Journal of Advances in Chemical Science 2 (2) (2014) 158-161.

