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Preparation of CuO/ZnO Nano-Particles Using Sol-Gel Technique and Studying the Characterization

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HIGHLIGHTS

- The sol-gel technique was used to make Nano composite particles NCPs of ZnO-CuO.
- FESEM scans revealed nanoparticles incorporated in the ZnO-CuO matrix with particle sizes ranging from 60.76 to 145.1 nm.
- The density of the aforesaid samples was 0.1382, 0.1418, and 0.1469 g/cm3 in that order, increasing as the calcined duration increased.
- This promotes crystal formation, and CuO/MgO has strong catalytic activity for advanced applications.

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ABSTRACT

Copper oxide (CuO) and zinc oxide (ZnO) are two of the most promising oxides under development right now. The sol-gel technique was used to make Nano composite particles NCPs of ZnO-CuO. The copper (II) nitrate rehydrate 0.1M and zinc nitrate hex hydrate 0.1M liquids were mixed in a 1:1 ratio, and the gel was formed at 80 °C, then dried and calcined for various times 500 °C (3, 5, and 7 hours). Particle size analyzer (PZA), X-ray diffraction (XRD), field emission scanning electron microscopy (FESEM), and apparent density were used to characterize the CuO/MgO particles. The x-ray diffraction results showed that the phases of the composite particles were pure. FESEM scans, on the other hand, revealed nanoparticles incorporated in the ZnO-CuO matrix with particle sizes ranging from 60.76 to 145.1 nm. The density of the aforesaid samples was 0.1382, 0.1418, and 0.1469 g/cm$_3$ in that order, increasing as the calcined duration increased. This promotes crystal formation, and CuO/MgO has strong catalytic activity for advanced applications.

1. Introduction

Because of their unique physical and chemical features, innovative materials have sparked a surge in interest in recent years. The particle size of these materials is dictated by the conditions under which they were prepared in the lab. As a result, various experimental procedures have been used in the synthesis of nanoparticles, including the sol-gel technique and liquid-solvent techniques. [1], as well as others. For the first time in history, sol-gel processing techniques have been applied for decorative and building materials; numerous new uses have been developed in the recent century. Sol-gel techniques are now reaching their maximum potential, allowing new generations of advanced materials to be prepared that are not readily accessible by other techniques while still using moderate, low-energy conditions[2]. Initially, based on empirical evidence, but later on, a more scientific basis as modern characterization techniques became available. Sol-gel techniques are now reaching their maximum potential, allowing new generations of advanced materials to be prepared that are not readily accessible by other techniques while still using moderate, low-energy conditions. Individual properties of transition metal oxides (TMO) such as MnO_2, RuO_2, TiO_2, ZnO, $BaTiO_3$, ReO_3, NiO_2, CuO, and others have resulted in numerous technical applications. These applications include microelectronics, bio and gas sensors, batteries, solar cells, fuel cells, super capacitors, pigments, and multiferroics. These materials have unique and useful electrical and magnetic properties. The TMO mixing produces sophisticated compounds with a wide range of characteristics. [3-7] Transition metal oxides are particularly interested in copper oxide nanoparticles because of their usefulness as Nano fluids [8], antibacterial applications [10], catalysis[11], superconductors[12], energy storage systems[13], and anti-cancer agents[14]. To date, mechanical, physical, biological, and hybrid approaches have been used to make copper oxide nanoparticles [15]. ZnO.NPS has been used in various technologies and industries, including optoelectronics,

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piezoelectric and magnetic sensors, diagnostics, bio labeling, ceramic and rubber processing, and the atmosphere [16–18]. It can represent a wide range of bio-safe, non-toxic, and biocompatible nanostructures. ZnO has a lot of OH groups on its surface, which allows it to dissolve slowly in both acidic (like tumor cells and the tumor microenvironment) and strong basic environments. Biomedical researchers have taken notice of ZnO.NPS because of this property [19]. Because of their expanding usage in medicine as anti-angiogenesis, anti-platelet agents, anti-inflammatory drugs, dental products, cosmetics, narcotics, and gene transfer, ZnO.NPs have emerged as a prospective anti-cancer agent [20-21]. Composite materials are solids that comprise two or more separate constituent materials or phases of greater size than the atomic scale. Properties such as the elastic modulus are markedly different from those of a homogeneous material [22]. In terms of physicochemical qualities, CuO/ZnO Nano composites outperform pure ZnO and CuO nanostructures [23]. The optical and electrical properties of the CuO/ZnO hetero junction are also improved, making it a viable photocatalysis candidate [24]. Inorganic antimicrobials have been promoted for pollution control because they offer benefits similar to natural antimicrobials, such as decreased host disruption, more stable bacteria tolerance, and high selectivity [25]. Inorganic nanoparticles with antibacterial action and metal oxide nanoparticles are well-known. Metal oxides have rapid synthesis pathways that may be utilized to modify the size and shape of nanoparticles, and they are less expensive than metal nanoparticles such as silver and gold. Organic antibacterial alternatives such as zinc and copper oxides are thought to be effective [26].

This study aims to use the sol-gel process to manufacture (MgO – ZnO) Nano composite particles with good mechanical properties.

2. Experimental section

2.1 Materials

Analytical grade copper (II) nitrate rehydrate [Cu $(NO_3)_2.3H_2O$], extra pure with Mol. Wt. 241.60 from HIMEDIA (GRM1363-500G), Zinc nitrate hex hydrate [Zn $(NO_3)_2.6H_2O$], purified with Mol. Wt.: 297.49 from HIMEDIA (GRM691-500G) were used as starting materials; double distilled water was used as a solvent. Citric acid AR monohydrate ($C_6H_8O_7.H_2O$) with Mol. Wt. 210.14 From ALPHA (Sr.No:AL1238) was taken as a chelating agent.

2.2 Procedures

50 ml double distilled water was mixed with 0.1M copper (II) nitrate rehydrate [Cu $(NO_3)_2.3H_2O$] and 0.1M zinc nitrate hex hydrate [Zn $(NO_3)_2.6H_2O$] for the manufacture of CuO/MgO NCPs by sol-gel. 0.025 M citric acid was diluted into beakers separately in 50 ml distilled water. They used a magnetic stirrer to stir for 60 minutes. Citric acid was added drop-wise to the aforementioned mixture at room temperature. At a temperature of 80 °C and continual stirring, a gel forms after 3 hours. The gel is cured for 4 hours in an electric oven at 130°C. At a different time, the dry gel is claimed at 500 °C (3, 5, and 7 hours). The Cuo/ZnO Nano composite particles processes are shown in Figure 1.

2.3 Characterization

A powder X-ray Diffract meter (Shimadzu 7000; using Cuka radiation (k = 1.5418) in the range of 10–79 in steps of 0.0500 at a scan speed of 1/min) is used to study particle-phase purity and crystallinity. The morphological features and particle size were examined using scanning electron microscopy (FESEM), TESCAN (Czech Republic). We used the bettersize2000 laser particle size analyzer as a particle size analyzer. First, the apparent density of the particle was calculated. Then, the density of solid powders (CD, CuO/ZnO) that do not dissolve in water was measured using a pyrometer. To begin, weigh the pycnometer and the weight of the pycnometer with solid powder. Water was then added, and the weight of the water (Mw) was calculated [27].

3. Results and Discussions

3.1 Particle Size Analyser and Density Results

Figure 2-(a, b, and c) shows the particle size of CuO/ZnO with a ratio of 1:1 after 3 hours, 5 hours, and 7 hours, which are 0.647, 0.622, and 0.732 m, respectively. Because of the agglomerations of the particles, this assay could not identify the Nano scale in the size of the NCPs. Therefore, FESEM was used to measure the results. The density of the aforesaid samples was 0.1382, 0.1418, and 0.1469 g/cm^3 in order, with the density increasing as the claimed duration increased [28]. This is due to the elimination of superfluous holes and spaces, which drive crystal development.

3.2 Scanning electron microscopy (FESEM) results

Figure 3- (a,b, and c) depicts typical FESEM images of CuO/ZnO in various calcined at 500 °C at various times (3, 5, and 7 hours). The particle size of CuO/ ZnO Nano composites with small agglomeration was discovered to be around 73.80–120.3 nm after 3 hours of calcination, confirming fully nodular shaped particles CuO/ ZnO Nano composites with minor agglomeration. Particles size were 60.76–145.1 nm after 5 hours of claiming, and 64.60–133.5 nm after 7 hours of calcining. The production of nanoparticles in CuO/ MgO may be seen in FESEM pictures at all calcined periods. These findings are in line with material science discoveries, which show that grain size, temperature, and time are linked by an Arrhenius-type equation:

$$D^n - D_0^n = k0 \exp^{(-Q/RT)} (t-t_0) \quad (1)$$

Where D represents the ultimate grain size at time t, Do represents the initial grain size at a time to, k0 represents a pre-exponential factor, Q represents the activation energy, and T represents the temperature in Kelvin [30].

Figure 1: The preparation of CuO/ZnO NCPs

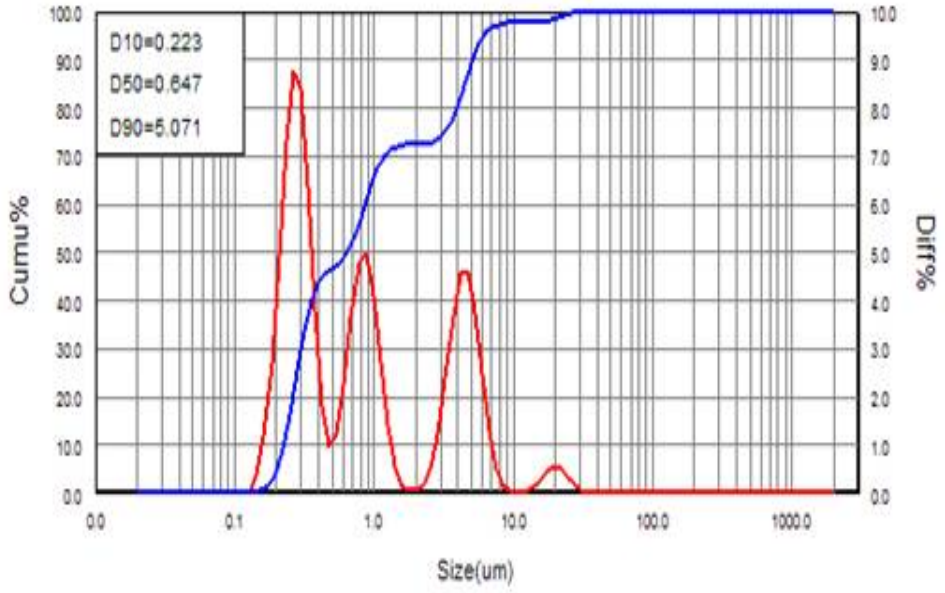

Figure 2: A Particle size of CuO/ ZnO NCPs calcined at 500 °C for 3 hours

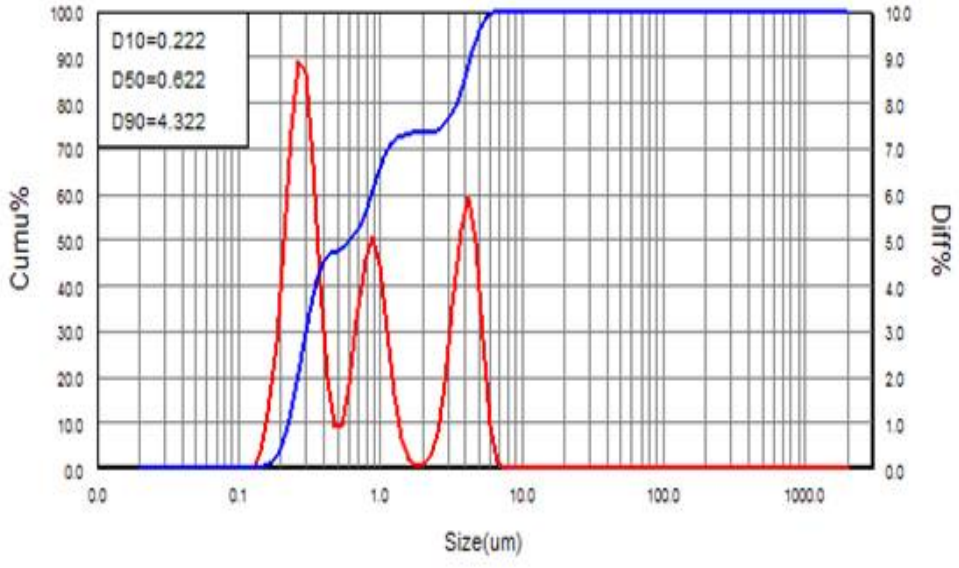

Figure 2: B Particle size of CuO/ ZnO NCPs calcined at 500 °C for 5 hours

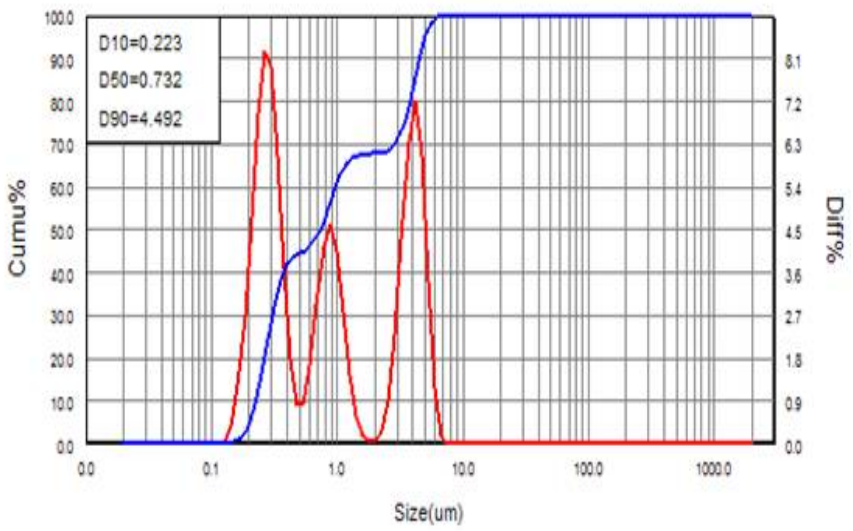

Figure 2: C Particle size of CuO/ ZnO NCPs calcined at 500 °C for 7 hours

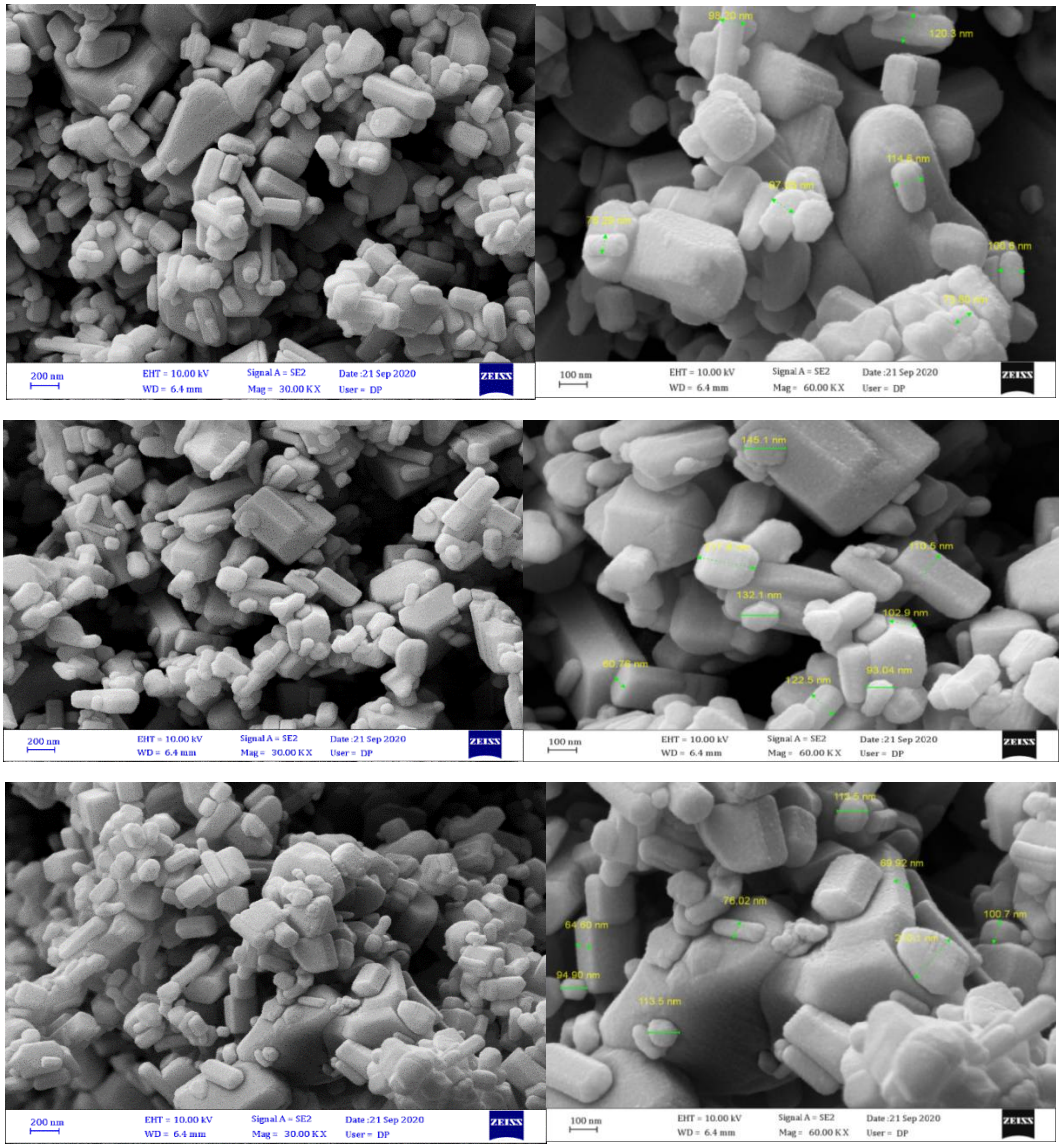

Figure 3: (A) FESEM image of CuO/ZnO NCPs calcined at 500 °C for 3 hours, (B) FESEM image of CuO/ZnO NCPs calcined at 500 °C for 5 hours, (C) FESEM image of CuO/ZnO NCPs calcined at 500 °C for 7hours

3.3 X-ray diffraction (XRD) results

Figure 4 depicts the XRD pattern. The spectrum shows that doped CuO Nano samples have high crystallinity. CuO and ZnO have a simple phase difference in Figure 4, demonstrating that both CuO and ZnO exist. In addition, CuO's diffraction profiles were reported at two values: 32.52° (110), 36.04° (011), 48.5° (202) (JCPDS44-0706), and ZnO's diffraction profiles were reported at two values: 31.82 (100), 34.50 (002), and 36.32 (101) (JCPDSno.36–1451) [31]. CuO monoclinic phase is indicated by the diffraction peak. CuO/ZnO Nano composites also showed a small peak at 38.8°, attributed to the CuO. (111). When ZnO was added to CuO, the diffraction intensities and angles improved considerably. According to the results of the X-ray investigation, the substance is crystalline and has a small granular size and a small pore size, which confirms the FESEM [32-34] results.

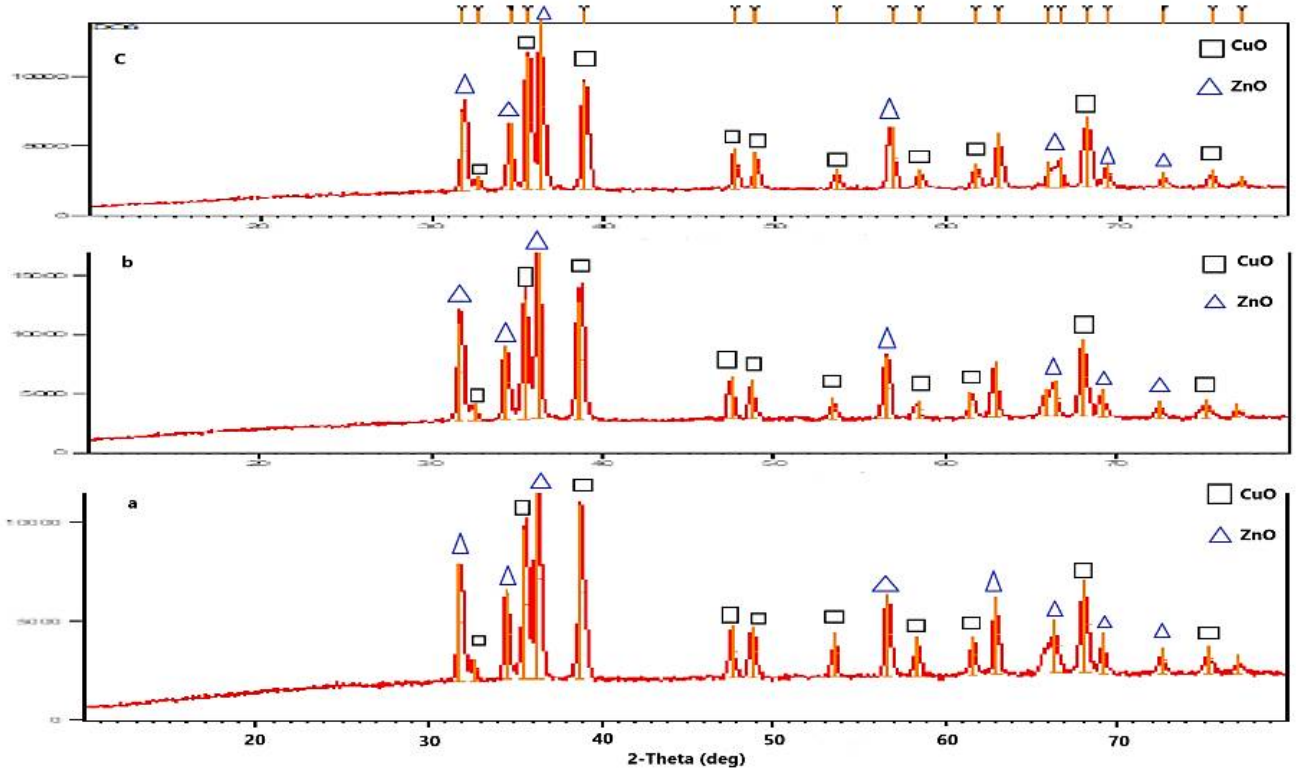

Figure 4: XRD image of CuO/ZnO NCPs calcined at 500 °C for (a) 3 hours, (b) 5 hours, and (c) 7 hours

4. Conclusions

Based on this study's tests' results, XRD data showing CuO and ZnO oxides, it is safer, easier to do, and more cost-effective. The peak of diffraction indicates CuO's monoclinic phase. In addition, it was observed that the diffraction profiles that correspond to ZnO are less owing to a lesser compositional ratio attributable to CuO's diffraction. From the X-ray examination results, the structural perfection and the growth features of the synthesized crystals were studied to eliminate excess pores and voids. The quality of the NCPs was visualized by observing the surface morphology using SEM studies. It can be observed that the particle size of CuO/ ZnO is about 60.76 –145.1nm, and it shows the nodular-shaped particles of CuO/ ZnO Nano composites with small agglomeration. The FESEM images of CuO/ ZnO prove the formation of nanoparticles at all calcined times. The SEM and particle size analyzer results showed the size and size distribution control. The synthesized NCPs could be promising materials for modern materials design due to all these properties.

Author contribution

All authors contributed equally to this work.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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