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Effect of precursors medium on structural, optical and dielectric properties of CuO nanostructures

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ABSTRACT

The current work presented the effect of different precursor's medium on structural, optical, morphological, dielectric and complex impedance properties of CuO nanostructures prepared via sol-gel technique. The structural and surface morphology analysis of the as-synthesized samples are carried out by using the X-ray diffraction (XRD) and SEM. XRD study revealed that the as-synthesized CuO nanostructures are pure phase with monoclinic structure. The average crystallite size (D) of CuO nanostructures deliberated via Scherrer's formula is found to be increasing for S1, S2 and S3 samples, respectively. Photoluminescence and Fourier-transform infrared spectroscopy analysis also divulged that, the synthesized samples i.e. CuO is a pure phase with monoclinic structure. The optical energy band gaps (E_g), estimated through Tauc plots are found to be 3.7, 3.5 and 2.6 eV for S1, S2 and S3 samples, respectively. The AC conductivity (σ_{AC}), dielectric constants (ε') and dielectric loss ($\tan\delta$) of all the samples were premeditated at room temperature in the frequency range 10 Hz–5 MHz. All characterization results revealed that different precursors (i.e. copper salts) play a significant function in modification the structural, morphological, optical and dielectric properties of CuO nanostructures for industrial applications.

1. Introduction

Over past decades, transition metal oxide at nanoscale have engrossed extensive research curiosity in the scientific society because of their unique optical, magnetic, catalytic and mechanical properties and the forthcoming applications in various fields of science and technology [1,2]. However, such unique properties are robustly reliant on the nanostructures dimensions, shapes, composition, and structures. Due to these distinctive and enthralling property of materials at nano scale, they can be used in nano scaled modren electronic devices [3,4]. Among transition metal oxide, cupric oxide (CuO) nanostructures has become a hot topic and have encouraged intensive research curiosity due to their exceptional properties [5–7]. Being p-type and a narrow band gap semiconductor, CuO has been broadly premeditated because of its diverse potentials applications in different fields, for example solar cells, heterogeneous catalysts, gas sensors, high temperature superconductors, field emission emitters, lithium-ion batteries and electrochemical capacitors [8–16]. At the nanoscale, CuO nanostructures with the decrease in the particle size, may demonstrate distinguishing properties which can be drastically unlike from bulk counterparts [17]. Moreover, cupric oxide has been rewarded more deliberation owing to its elegant advantages such as inexpensive, non-toxic, giant theoretic capacity (670 $mAhg^{-1}$) values, simple preparation and environmental friendliness

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[18]. Hence, the synthesis of CuO nanostructures has immersed considerable interest because of their optimistic applications in optoelectronic devices. To accomplish the controlled synthesis of CuO nanostructures, different synthesis constraints can be implemented to direct the morphology and properties of these structures. It is noticed through literature that precise studies of the experimental constraints revealed that the cupric source, reaction time, concentration, temperature and pH value of the precursor medium significantly persuade the growth, morphologies, and particle size of the final subsequent CuO nanostructure [9,19] and reveal different optical, electrical, and catalytic properties [18]. Phiwdang et al. [20] in (2013) synthesized CuO nanostructures by precipitation method using different precursors and reported that different precursors has a sturdy influence on shape, size and morphologies of CuO nanostructures. In 2016, Siddiqui et al. [21] studied the consequence of Cu precursor medium salts synthesized via facile and sustainable technique and conclude that physical and chemical property of CuO nanostructures are vastly reliant on cupric salts. Researchers have used different cupric salts such as $CuSO_4$, $CuCl_2$ and $C_4H_6CuO_4$ to synthesize CuO nanostructures. Although, the influence of unusual precursors i.e. cupric salts are not discussed in detailed. In the current work, we report sol-gel synthesis of CuO nanostructures for three different precursors (i.e. cupric salts) with the precisely similar synthetic procedure. A relative study between three distinct precursors i.e. cupric salts such as cupric sulphate ($CuSO_4$), cupric chloride ($CuCl_2$) and cupric acetate ($Cu(CH_3COO)_2$) are made to investigate the influence of different precursors salt medium on CuO.

Consequently, in the current paper, by keep in view of the exceeding, we present a proficient attempt to explored the structural, morphological, optical and dielectric properties of CuO nanostructures prepared by sol-gel method via using different precursors medium. The intent of current study is to explored the persuade of different precursors medium on the structural, morphological, optical and dielectric properties of CuO nanostructures as a component for a series of scientific and industrial applications. Our results conclusively show that the different precursor medium shows a crucial function in tuning the structural, morphological, optical and dielectric properties of CuO nanostructures.

2. Experimental

2.1. Chemicals

For the synthesis of CuO nanostructures, the precursor materials used were copper sulphate ($CuSO_4$), copper chloride ($CuCl_2$) and copper acetate($Cu(CH_3COO)_2$) and the stabilizing agent was potassium hydroxide KOH (Loba Chemie, India), absolute ethanol (C_2H_5OH, 99%, China) and deionized H_2O (New Delhi, India). The chemicals used for the synthesis of CuO nanostructures in the present work were of analytical grade.

2.2. Synthesis

CuO nanostructures were synthesized through sol gel method by using different percursors medium such as copper sulphate ($CuSO_4$), named as S1 copper chloride ($CuCl_2$) named as S2 and copper acetate ($C_4H_6CuO_4$) named S3. In a distinctive process, 0.3 M copper sulphate solution was mixed in 50ml of deionized H_2O. Afterward than that a 40 ml of 3 M KOH solution which was prepared separtely is mix to the 0.3 M copper sulphate solution by the assistance of magnetic stirrer. The final obtained product i.e. black precipitates was filtered and washed 4–5 times with distilled H_2O and ethanol (C_2H_5OH) to get rid of the impurities and surfeit surfactant. Finally,the resulting black product was dried in electrcic oven under air at 90 °C for 18 h for analysis. The similar procedure took up to synthesize the S2 and S3 samples of CuO nanostructures.

2.3. Characterization

The as synthesized powder samples were illustrated by X-ray diffractometer (XRD) in order to verify the crystalline character and pure phase formation. The surface morphology of as prepared samples were carried out by scanning electron microscope (SEM). In order to understand the effect of different precursor's medium on the optical properties of the as synthesized CuO nanostructures, Photoluminescence (PL) spectra, Fourier Transform Infrared (FTIR) and UV–vis spectrum were recorded at room temperature. To study the electrical transmission mechanism and uniqueness of as prepared CuO nanostructures, the complex impedance analysis (CIS) of CuO nanostructures were recoreded on silver coated pellets at room temperature through Potentiostat/Galvanostat in the wide frequency range from 10 Hz–5 MHz.

3. Results and discussion

3.1. X-Ray diffraction studies

Fig. 1(a) illustrate the room temperature XRD patterns of CuO nanostructures prepared via sol gel method through different precursor's medium salt. From the XRD pattern as depicted in Fig. 1, it is observed that all samples synthesized via sol gel method can be indexed as CuO with monoclinic crystal phase and match fit with the previous reported data (JCPDS No. 801916) [22]. It is also apparent that there is no impurities, such as $Cu(OH)_2$ or Cu_2O, exist in the XRD pattern which shows that as prepared samples are in pure phase. Furthermore, it is too evident from the Fig. 1 that the XRD peaks shifting towards lower Bragg's angles which indicates the increase in lattice parameters. Fig. 1(b) shows the shifting of XRD peaks of