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Crafting CuO Thin Films: Structural and Morphological Insights

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ABSTRACT

Herein, we present the deposition of Copper oxide thin film (CuO) on a microscopic glass slide, by spray pyrolysis method. Spray pyrolysis is an easy, cheap, chemical technique for preparing high-quality thin films. The film was evaluated for structural and morphological properties using X-ray Diffractometer and FESEM. The characteristics exposed Monoclinic structured film. Morphological studies reported that a dense, uniform thin film was formed with optimal small capsules grains.

Keywords: Copper oxide, Spray pyrolysis, thin film.

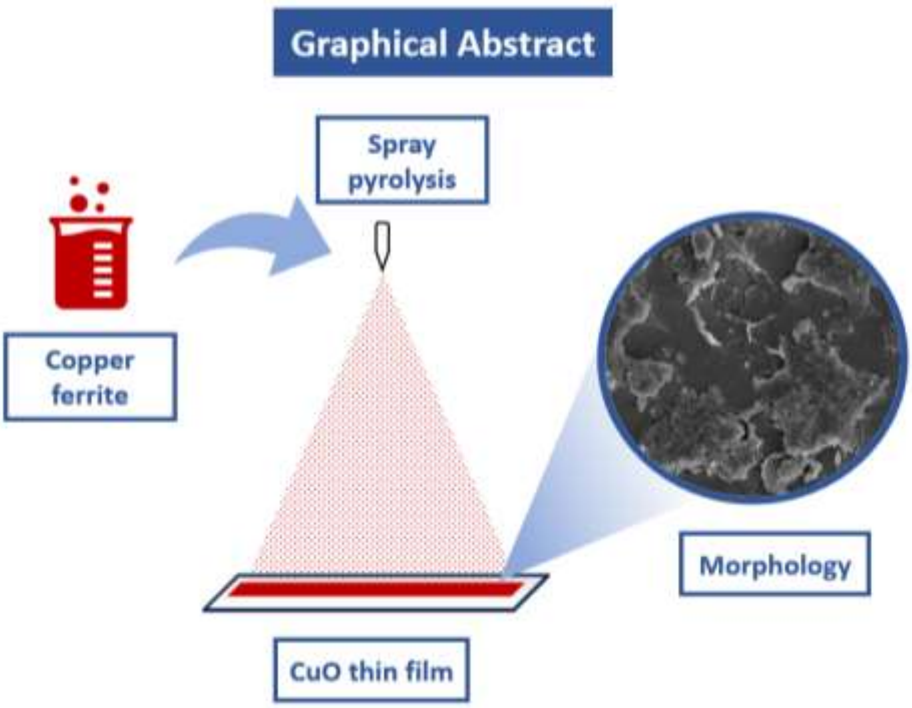

Fig1: Graphical Abstract.

1. Introduction

Thin films have attracted significant attention in scientific research and industrial applications due to their versatile properties. These materials are widely employed in sensors, optoelectronic devices, detectors, and energy storage systems. Copper oxide (CuO) is a binary transition metal oxide semiconductor belonging to the p-type category, characterized by a narrow band gap, excellent chemical stability, and notable electrical conductivity. These properties make CuO a promising candidate for various applications, including supercapacitors [1], gas sensors [2], photocatalysis [3], and solar cells [4]. Several deposition techniques are employed to synthesize uniform and adherent polycrystalline CuO thin films, such as chemical vapor deposition [5], sputtering

[6], pulsed laser deposition [7], successive ionic layer adsorption and reaction (SILAR) [8], electrochemical deposition [9], chemical bath deposition [10], and spray pyrolysis [11]. Among these methods, spray pyrolysis is considered one of the most effective techniques for thin film deposition, owing to its simplicity, cost-effectiveness, and scalability. It does not require vacuum systems or high-quality substrates, making it suitable for large-area thin film fabrication in industrial applications [12].

In the present work, CuO thin films were deposited using the spray pyrolysis technique. The synthesized thin films were characterized by X-ray diffraction (XRD) and field emission scanning electron microscopy (FESEM) to investigate their structural and morphological properties.

2. Experimental details

Substrate cleaning is an initial step to approach good quality thin films of high uniformity and excellent adherence. In the present work soda lime glass substrates (76x25x1mm) has been used to deposit CuO thin film. Initially, slide was washed three to four times with soap solution. The washed slide was subjected to chromic acid solution for 24 hours. In the last, the slide was removed from chromic acid solution and washed three to four times with distilled water.

Copper Ferrite is used in the present work to prepare CuO thin film. Molar concentrations of both precursors were kept same viz. 0.05M in 50ml double distilled water. The precursor solution was mixed using magnetic stirrer for 10 minutes and later it was filled in the spray gun. The heater was set to 300 C, deposition temperature. The carrier gas (air) was adjusted to 20 lpm. Nozzle to substrate distance was 20 cm. In the present work, the precursor solution was sprayed with flow rate of 5ml per minute to the hot glass substrate. The deposition was carried out for 10 minutes. Finally, the prepared CuO thin film was cooled to room temperature in the heating system and then different characterisations were carried out to study the prepared film.

3. Results and discussion

3.1 Structural analysis

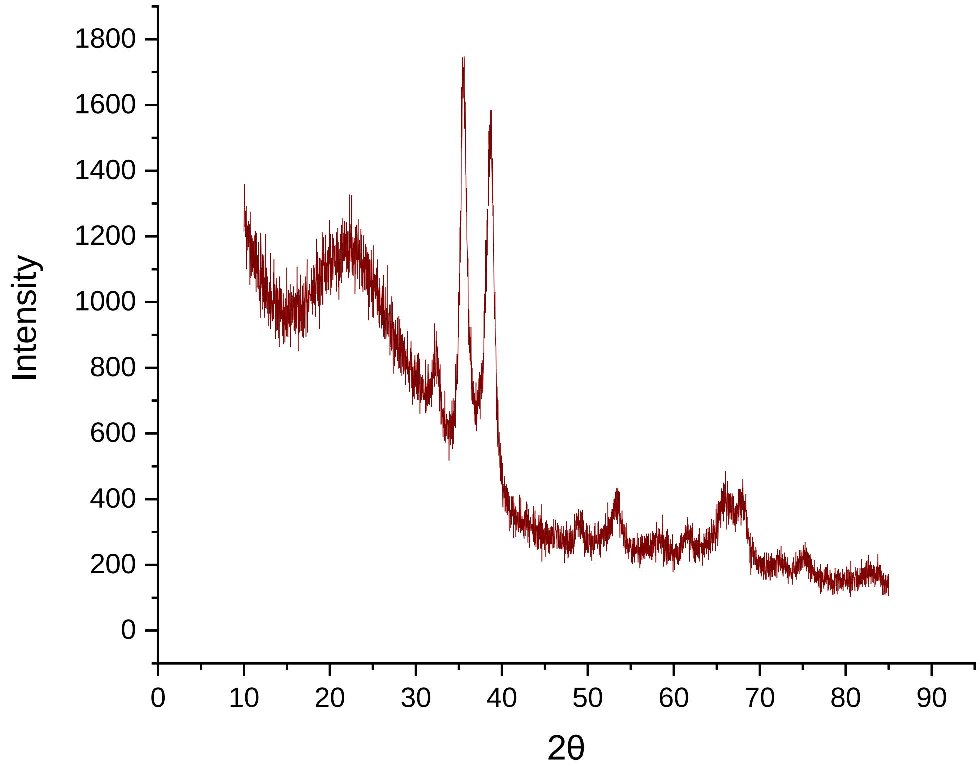

Fig2: XRD of CuO thin films.

X-ray diffraction is generally used to study structural properties of synthesised material in the form of powder or thin film. Above Fig. shows the X-ray diffractogram of CuO thin film. The multiple Bragg's diffraction peaks recorded confirm the monoclinic phase of as deposited CuO thin film. The Bragg peaks of high intensity were recorded at Bragg's angles, 2θ = 35.02 and 38.91 whereas additional weak peaks were located. The X-ray diffraction data of as deposited CuO thin film was in good agreement with JCPDC card-80-1916 [13, 14]. The different planes of orientation of as deposited film at different Bragg angles were reported as (-111), (111). High deposition temperature cause more number of planes of reflection in CuO thin film with significantly high intensity of corresponding peaks [15]. Grain size (D) of as deposited CuO thin film was calculated using Debye Scherrer's formula stated in equation

$$D = \frac{0.9\lambda}{\beta cos\theta}$$

Where, (β) is the half-width of full maxima, (k = 0.9) is Scherrer's constant and (λ =1.54 °A) is the Cu Kα-radiation wavelength. The average size of a crystallite for CuO was calculated to be 10.2 nm

3.2 Morphological analysis

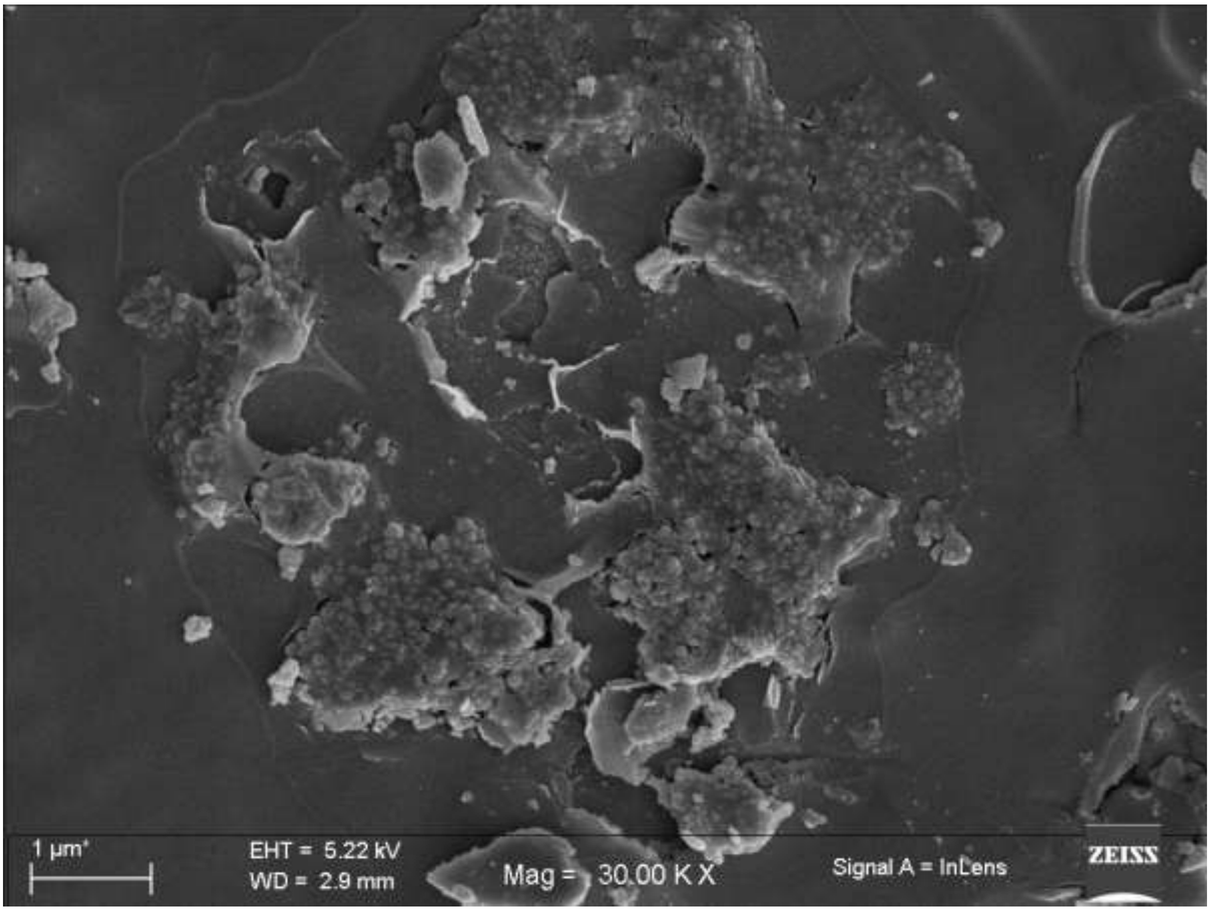

Fig3: FE-SEM micrograph CuO

The surface morphology showed uniform and dense distribution of tiny capsule like CuO particles with less number of voids. These CuO nanostructure lead to formation of cluster of balls due to agglomeration.

4. Conclusion

Thin film was prepared using spray pyrolysis method at substrate. The blackish deposited film was uniform and adherent. The as deposited film showed monoclinic structure. The calculated grain size of CuO thin film described the formation of nanosized particles. These nanosized particles were highly oriented along (-111) and (111) reflection planes. FESEM micrograph image explained distribution of clusters of CuO particles throughout the surface and film was covered with capsule-like structure and less voids. The as deposited thin films showed great potential towards photosensors and optical devices such as solar cells.

Credit authorship contribution statement

Digvijay: Central theme, Conceptualization, literature survey, Draft preparation. **Abhilash:** Methodology, Characterization analysis. **Kshitij:** Literature survey. **Chandrakant:** Supervision, Reviewing the manuscript.

Declaration of competing interest

The authors affirm that, there are no known financial interests or personal relationships that could have appeared to influence the research work reported in this paper.

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