

Synthesis and Structural Characterization of Polyaniline–Cupric Oxide Nanocomposites for Potential Gas Sensor Applications

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Abstract: Metal oxide composites based on polyaniline (PANI) have garnered significant interest because of their intriguing structural, electrical, and sensing characteristics. In the current study, chemical oxidative polymerization was used to create PANI/CuO nanocomposites with various weight ratios. X-ray diffraction (XRD) analysis was used to prepare and evaluate five samples with different polyaniline and cupric oxide compositions. The XRD analyses verified the crystalline monoclinic structure of CuO and the semi-crystalline nature of PANI. The composites' crystallinity and diffraction peak intensity were greatly impacted by the addition of CuO to the PANI matrix. The produced nanocomposites' structural alterations suggest that they could be used in gas sensing devices. According to the results, PANI/CuO composites could be useful materials for gas sensor applications in the future.

Keywords: Chemical Polymerization, XRD, Polyaniline, Cupric Oxide, Nanocomposites, Gas Sensor.

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I. INTRODUCTION

In light of their superior electrical conductivity, environmental stability, and ease of production, conducting polymers have become significant functional materials. [1] Polyaniline (PANI) has drawn a lot of attention among conducting polymers due to its easy manufacturing process, affordable price, and adjustable electrical characteristics.[2] When mixed with metal oxides, PANI-based composites show improved structural and functional properties that are appropriate for sensor applications.[3] CuO is a p-type semiconductor with excellent thermal stability, a narrow band gap, and exceptional catalytic capabilities. CuO can enhance the PANI matrix's crystallinity and surface contact behavior, making the composite appropriate for applications involving sensing. Chemical oxidative polymerization was used in the current investigation to create PANI/CuO nanocomposites with various composition ratios. X-ray diffraction analysis was the technique employed for structural characterization.[4] To look at the prepared composites' crystallinity and phase development.

II. EXPERIMENTAL METHODOLOGY

➤ Materials

The synthesis was carried out using aniline monomer, ammonium persulfate (APS), hydrochloric acid (HCl), and

powdered cupric oxide (CuO). Every chemical utilized was of analytical quality.

➤ Synthesis of PANI/CuO Nanocomposites

Chemical oxidative polymerization was used to create PANI/CuO nanocomposites. Initially, aniline monomer was dissolved in acidic medium and stirred continuously. To create distinct composite samples, CuO powder was added in varying weight percentages.[5]

As an oxidizing agent, ammonium persulfate solution was gradually added dropwise while being continuously stirred. For the purpose of polymerization, the reaction mixture was kept at a low temperature. After filtering and washing with ethanol and distilled water, the precipitates were allowed to dry at room temperature.

The composition ratios of synthesized samples are listed in Table 1.

➤ X-Ray Diffraction Analysis

Cu-K α radiation with a wavelength of 1.5406 Å was used in the X-ray diffraction (XRD) technique to characterize the structure of the produced samples. Over an appropriate 2 θ range, the diffraction patterns were captured.

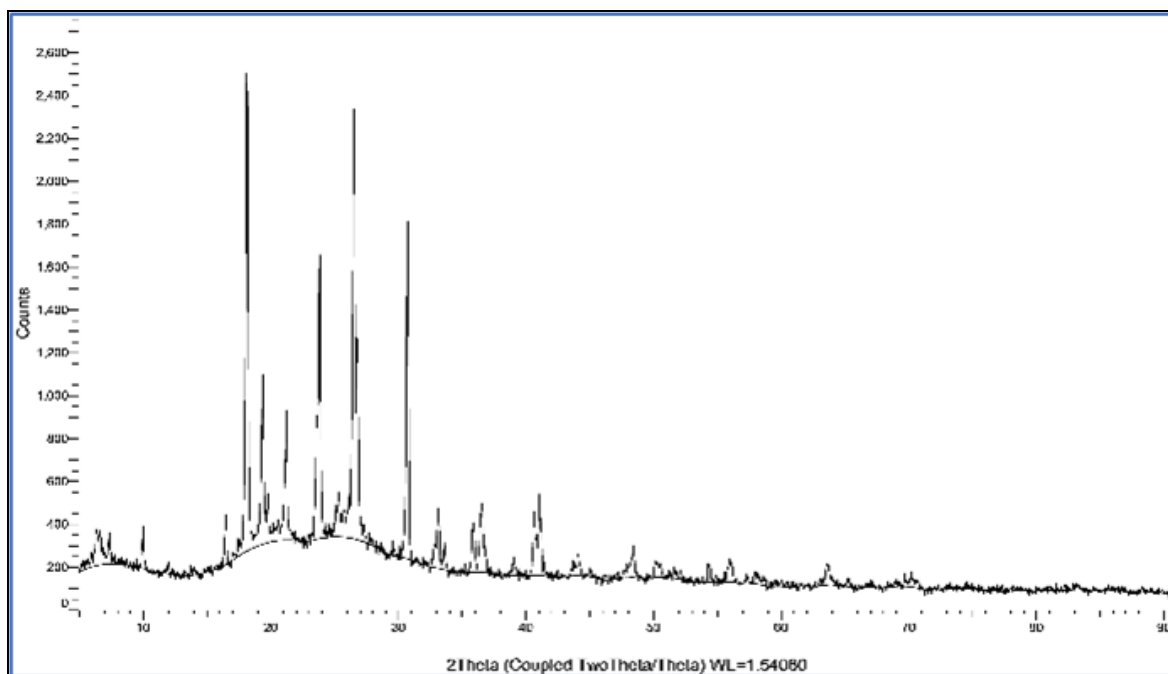
III. RESULTS AND DISCUSSION

➤ *XRD Analysis*

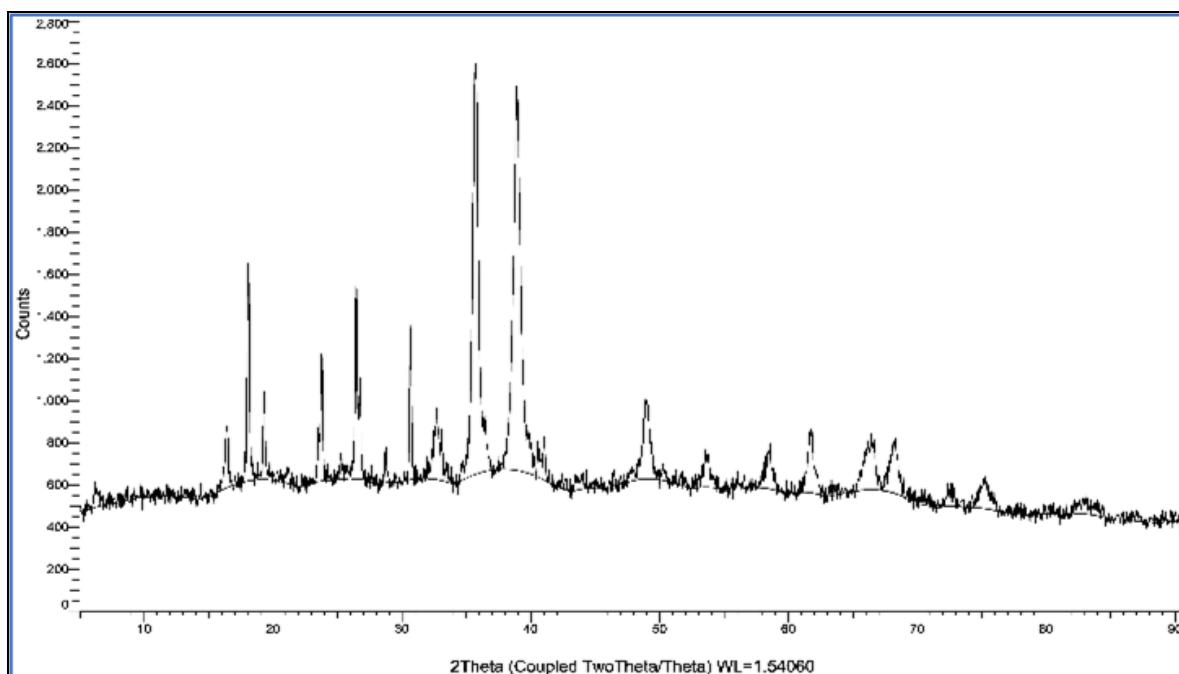
The XRD patterns of synthesized PANI/CuO nanocomposites are shown in Figure 1.

Table 1 Material Synthesis & Sample Scheme

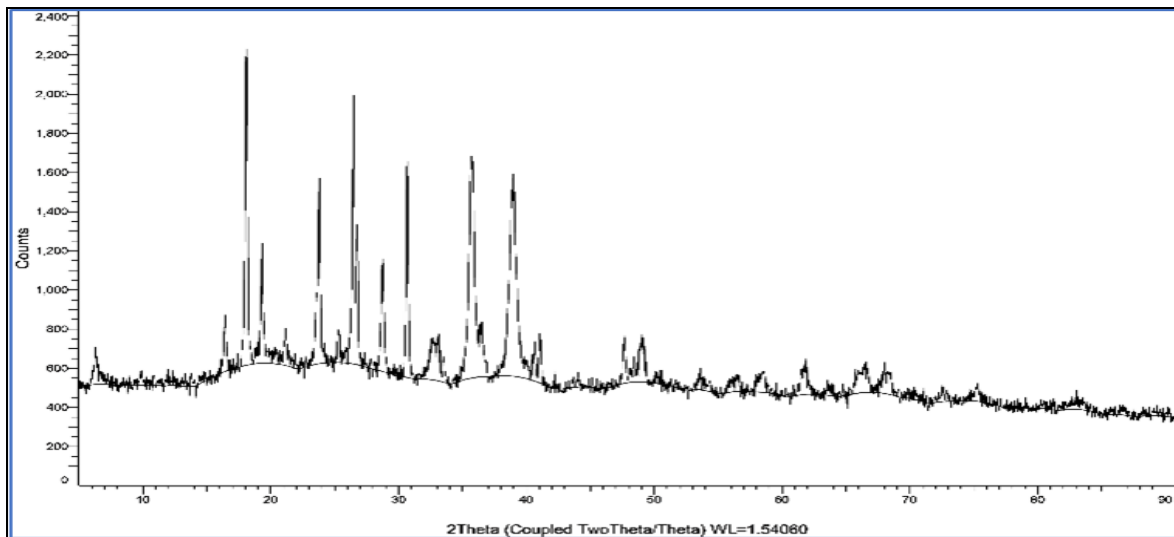
Sr. No.	Sample	PANI (%)	CuO (%)	Composition Ratio
1	S-1	100	0	1 g : 0 g
2	S-2	75	25	0.75 g : 0.25 g
3	S-3	50	50	0.50 g : 0.50 g
4	S-4	25	75	0.25 g : 0.75 g
5	S-5	0	100	0 g : 1 g



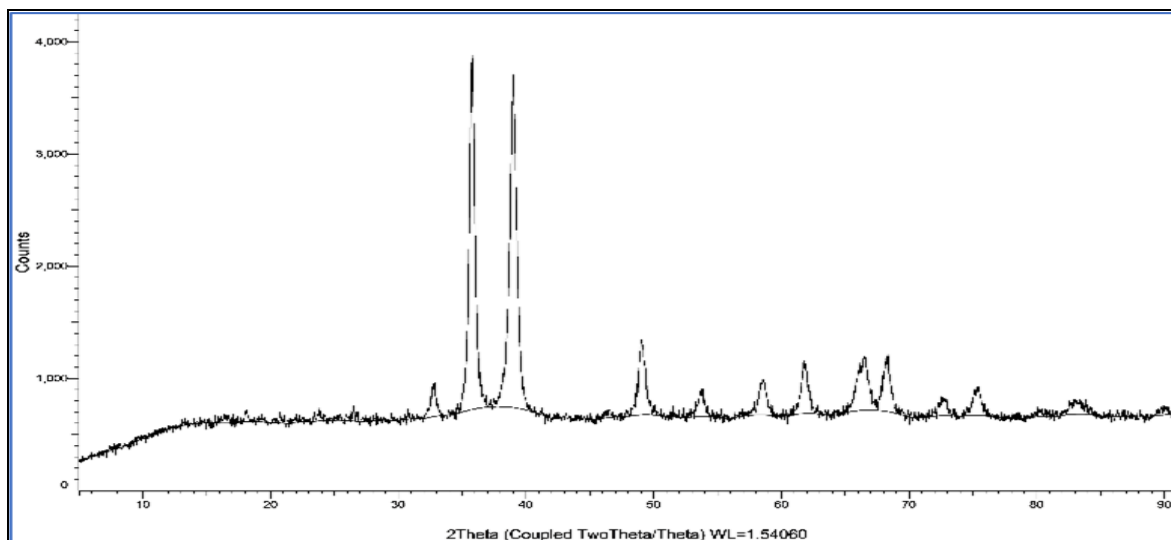
S-1



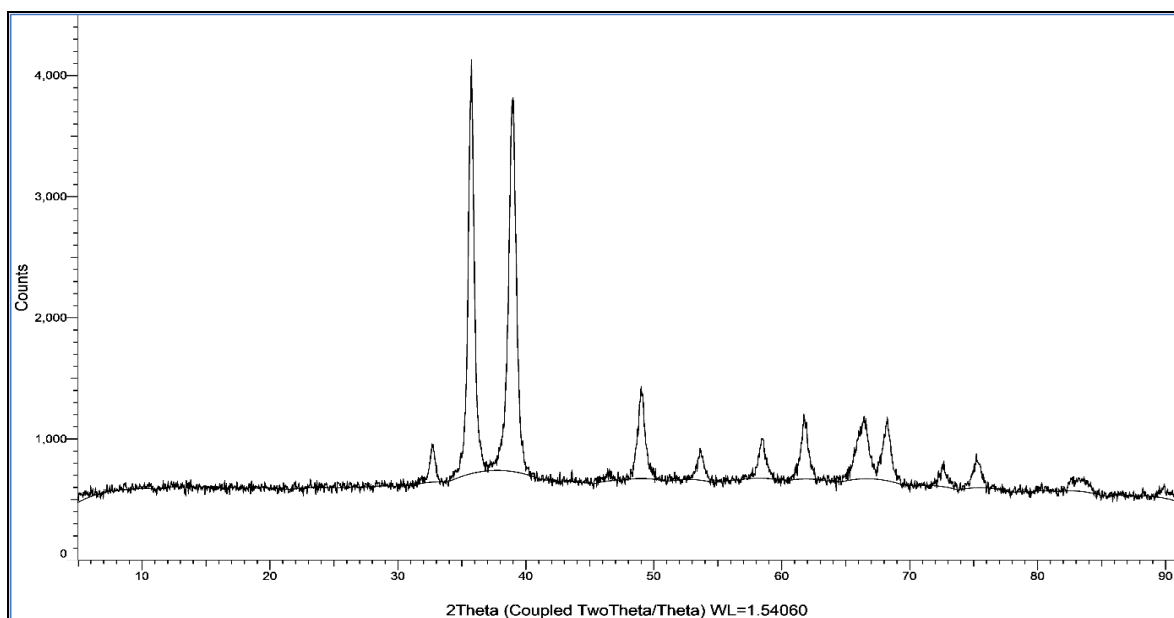
S-2



S-3



S-4



S-5

Fig 1 XRD Patterns of PANI/CuO Nanocomposites with Different Composition Ratios.(S-1 to S-5)

The broad diffraction peak of the pure PANI sample (S-1) indicated that it was semi-crystalline and somewhat amorphous. Periodicity along and perpendicular to the polymer chain is represented by the large peak seen at $2\theta = 20^\circ$ – 25° . [6] The crystalline monoclinic phase structure of the pure CuO sample (S-5) was confirmed by its strong diffraction peaks. CuO's distinctive diffraction peaks were seen at several 2θ positions, which are consistent with conventional JCPDS data. [7] PANI and CuO diffraction features were noted for composite samples S-2, S-3, and S-4. As the concentration of CuO in the composite increased, so did the intensity of CuO peaks. This demonstrates that the CuO particles were successfully incorporated into the PANI matrix. [8]

The interaction between conducting polymer and metal oxide particles causes structural alteration, as seen by the increased crystallinity of composites with increasing CuO content. In future sensing applications, these structural characteristics might be advantageous for adsorption and interaction with gas molecules. [9] The Scherrer equation can be used to estimate the size of the crystallite:

$$D = K\lambda/\beta\cos(\theta)$$

Where:

D = crystallite size

K = shape factor

λ = X-ray wavelength

β = full width at half maximum

θ = Bragg diffraction angle.

IV. CONCLUSION

Chemical oxidative polymerization was effectively used to create PANI/CuO nanocomposites with various composition ratios. PANI's semi-crystalline structure and CuO's crystalline behavior were verified by XRD investigation. [10] As the concentration of CuO grew, the diffraction peak intensity rose, suggesting that the composites' crystallinity had improved. The structural features indicate that synthetic PANI/CuO nanocomposites could be good options for future gas sensor uses.

REFERENCES

- [1]. Gospodinova, N., & Terlemezyan, L. (1998). *Conducting polymers prepared by oxidative polymerization: Polyaniline*. Progress in Polymer Science, 23, 1443–1484. DOI:10.1016/S0079-6700(98)00008-2.
- [2]. Verma, A., Gupta, R., Verma, A. S., & Kumar, T. (2023). *A review of composite conducting polymer-based sensors for detection of industrial waste gases*. Sensors and Actuators Reports, 5, 100143. DOI:10.1016/j.snr.2023.100143.

- [3]. Virji, S., Huang, J.-X., Kaner, R. B., & Weiller, B. H. (2004). *Polyaniline nanofiber gas sensors: Examination of response mechanisms*. Nano Letters, 4(3), 491–496. DOI:10.1021/nl035122e.
- [4]. Beygisangchin, M., Abdul Rashid, S., Shafie, S., Sadrolhosseini, A. R., & others. (2021). *Preparations, properties, and applications of polyaniline and polyaniline thin films — a review*. Polymers, 13(12), 2003. DOI:10.3390/polym13122003.
- [5]. Stejskal, J., & Gilbert, R. G. (2002). *Polyaniline. Preparation of a conducting polymer* (IUPAC Technical Report). Pure and Applied Chemistry, 74(7), 857–867. DOI:10.1351/pac200274050857.
- [6]. Singh, S. K., Shukla, R. K., Kumar, R., Tripathi, U. K., & Mishra, S. K. (2022). *Investigation on PANI/CuO nanocomposites for ammonia gas sensing applications*. Materials Letters, 309, 131325. DOI:10.1016/j.matlet.2021.131325.
- [7]. Zulfiqar, N., Inam, F., Khudayberganov, I., Noori, A., Khan, I. U., et al. (2026). *Sustainable synthesis and photocatalytic insights into Ag-doped copper oxide nanoparticles: a comparative study*. Scientific Reports, 16, 2815. DOI:10.1038/s41598-025-32715-2.
- [8]. Cullity, B. D. (1978). *Elements of X-Ray Diffraction* (3rd ed.). Addison-Wesley.
- [9]. International Centre for Diffraction Data (ICDD). (PDF-2 Database) Entry 01-080-1917 (CuO, tenorite). [ICDD Powder Diffraction File]
- [10]. (Anonymous for ACS) (2025). *Polyaniline/CuO Nanoparticle Composites for Use in Selective H₂S Sensors*. ACS Sensors, 10(7), 5108–5119. DOI:10.1021/acssensors.5c00530.