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# Electroluminescence and UV Characterization of CuO/PS Nanocomposites for Optoelectronic Applications

**Priyanka Dubey**[1]
Deptt. of Physics, Govt. Science College Jabalpur, (M.P.), India
priyaphysics56@gmail.com

**R.K. Kuraria**[2]
Vice chancellor, Awdhesh Pratap Singh University, Rewa, M.P., India

**R. katare**[3]
Deptt. of Physics, Govt. Science College Jabalpur, (M.P.), India

**Shashi R. Kuraria**[4]
Deptt. of Physics, Govt. Science College Jabalpur, (M.P.), India

## ABSTRACT

The development of polymer-based nanocomposites with tailored electrical and optical properties is crucial for advanced optoelectronic applications. In this study, copper oxide (CuO) nanoparticles were synthesized via the sol–gel method and incorporated into a polystyrene (PS) matrix at varying concentrations (1 wt%, 3 wt%, and 5 wt%). The electroluminescent behavior was evaluated using voltage–brightness measurements, while voltage–current analysis assessed electrical conductivity across different frequencies. UV–Visible spectroscopy investigated optical absorption and band gap modulation. Results indicate that the 5 wt% CuO/PS nanocomposite exhibited superior performance, with a low turn-on voltage, high brightness (90 a.u. at 290 V), enhanced current conduction, strong UV absorption in 200–350 nm, and a reduced optical band gap 3.8 eV. These findings confirm that CuO/PS nanocomposites are promising candidates for LEDs, UV photodetectors, optical filters, and high-frequency optoelectronic devices.

**Keyword-** CuO nanoparticles, polystyrene, nanocomposites, electroluminescence, UV–Visible spectroscopy, optoelectronics

## 1. Introduction

The steady development of the optoelectronic technologies has further escalated the need to develop new materials, which have superior electrical, optical, and mechanical characteristics at low cost and are easy to fabricate. Important materials in optoelectronic applications, like light-emitting diodes, photodetectors, optical sensors, and display panels, are those that have efficient charge transport, controllable light emission, and controllable optical absorption. Polymer-based nanocomposites in this respect have shown themselves as contenders considering that they are flexible, lightweight, chemically stable, and compatible with large-area and low-temperature processing methods (M. Ibrahim et al., 2015). Polymerization based on transparency, excellent film-forming ability, good dielectric properties, polymer like polystyrene (PS) finds wide usage in the electronic and optical industry. Nonetheless, pure polymers are not highly electrically conductive and optoelectronic functional and therefore cannot be readily used in sophisticated optoelectronic applications. To eliminate these shortcomings, it has been effective to consider the incorporation of inorganic semiconductor nanoparticles into polymer matrices (Yassin, 2023). The resulting polymer nanocomposites include improved electrical, optical and electroluminescent features because of synergistic interactions amid the polymer host as well as the inorganic filler.

Copper oxide (CuO) has been of primary interest due to its narrow band gap, p-type semiconducting properties, high absorption coefficient, chemical stability, and environmental friendliness among other things in the group of inorganic semiconductors (Al-Jumaili et al., 2021). CuO nanoparticles have found wide application in photovoltaics, sensors, photocatalysis, and optoelectronic device applications. CuO nanoparticles can be used to localize the energy states when embedded in a polymer matrix, increase density of charge carriers and enhance effective charge transfer and recombination mechanisms (Beecroft & Ober, 1997). The properties of CuO render it a good choice of filler material in order to improve the optoelectronic behavior of systems made of polymers. Electroluminescence (EL) is an important effect in optoelectronic materials, the emission of light by a material when a foreign electric field is applied to it. The basis of electroluminescence in polymer nanocomposites is charge injection, transport, trapping and radiative recombination at dislocations or polymer / nanoparticle interfaces (Kausar et al., 2022). The factors which have great impact on the efficiency of electroluminescence are the concentration of filler used, dispersion of the particles, voltage applied and the frequency of operation. It is thus crucial to study the voltage, which are voltage to brightness as well as voltage to current properties in order to comprehend the electroluminescent behaviors and charge transport processes in nanocomposites systems.

Besides electrical and electroluminescent qualities, optical characterization is also important in determining the suitability of materials to be used in optoelectronics. UV Visible spectroscopy is a potent method used in studying electronic transitions, alterations of the band structure, and light matter interactions of nanocomposites. When incorporated into a clear polymeric backbone like PS, the inclusion of CuO nanoparticles is able to change the optical absorption characteristics of the material, especially in the ultraviolet (Nguyen et al., 2009). Increased UV absorption and tunable optical features are very desired in the field of use which includes the UV photodetectors, optical filters, and protective coating.

CuO nanoparticles were prepared in a sol-gel method in this study, and embedded in a poly-styrene matrix to create CuO /PS nanocomposites of varying loadings of CuO. The electroluminescent characteristics were measured by voltage-brightness characteristics, whereas voltage-current characteristics were used to measure the electrical characteristics at different frequencies. The UV-visible absorption spectroscopy was used to determine the impact of the addition of CuO on the optical characteristics of the nanocomposites. In this work, we aim to determine a clear correlation between two variables, which are the CuO concentration, electrical response, electroluminescent efficiency and optical absorption properties (Abdulhasan et al., 2024; Agam et al., 2020; Danagody et al., 2025; Ratnawulan et al., 2021). The findings of the experiment at hand offer valuable guidelines of the structure-property associations of the CuO/PS nanocomposites and exhibit their prospects of application in optoelectronics. The critical improvement in the electroluminescence, the frequency-sensitive electricity feature, and deep UV absorption of these nanocomposites emphasizes their external adaption in light-generating devices, UV-sensitive devices, as well as in sophisticated optoelectronic circulations.

## 2. Materials and Methods

Materials and procedures that were adopted to synthesize and characterize the CuO/PS nanocomposites are described. It involves the procedure of preparation of CuO nanoparticles through sol gel method, integration of the same into polystyrene substrate at varying concentrations, and the procedures that were employed in the electrical, electroluminescent, and optical characterization.

### 2.1 Materials

Prerequisite materials used in the production of the CuO nanoparticles included copper chloride ($CuCl_2$) and sodium hydroxide (NaOH). The solvent that was used in the synthesis process was ethanol. The polymer matrix employed in nanocomposites preparation was polystyrene (PS). Chemicals were of high quality and were not purified anymore.

### 2.2 Synthesis of Copper Oxide Nanoparticles

The sol–gel technique was used to prepare copper oxide nanoparticles. The first step involved the dissolution of 1.5 g of sodium hydroxide (NaOH in 40 ml of ethanol then continuous stirring with the help of the magnetic stirrer at room temperature. In another beaker, with the same conditions 1g of copper chloride ($CuCl_2$) was dissolved in ethanol and stirred and stirred as well. The solution of NaOH was dropwise added to the solution of $CuCl_2$ and stirring. Micromolecular amounts of NaOH were then added to the solution to initiate a chemical reaction, and the color of the solution was visibly changed to black, which was a sign of the formation of copper oxide gel. This was stirred in 30 minutes to ensure the mixture had fully reacted. The attained gel was filtered using filter paper and washed with distilled water extensively to collect traces of impurities. The sample was subsequently dried at room temperature and the sample turned dark brown and thus indicating the formation of CuO nanoparticles.

### 2.3 Preparation of CuO/PS Nanocomposites

The synthesized CuO nanoparticles were embedded to the polystyrene matrix to obtain the CuO/PS nanocomposites of varying concentrations of CuO, i.e. 1 wt%, 3 wt%. and 5 wt.% CuO nanoparticles needed were suspended evenly in PS matrix to obtain homogeneity. The resulting electrical, electroluminescent, and optical characterization of the resulting nanocomposites was carried out.

3. Results and Discussion

### 3.1 Voltage–Brightness Characteristics

The voltage-brightness properties give invaluable understanding on electroluminescent properties of polymer nanocomposites under a definite electric field.

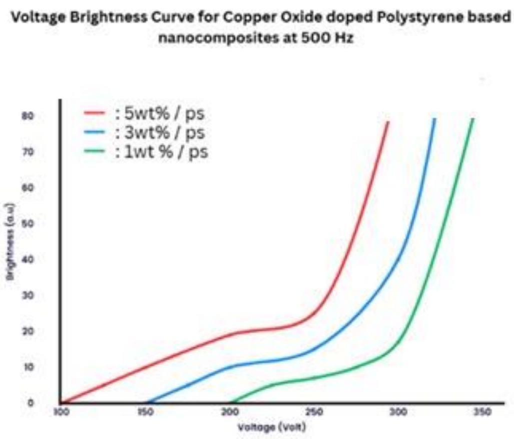


Figure 1 Voltage brightness Curve for copper oxide doped polystrene based nano composites at 500 hz

The voltage–brightness characteristics at 500 Hz clearly show composition-dependent electroluminescence. For 1 wt% CuO/PS, brightness starts increasing near 200 V, reaches about 10 a.u. at 250 V, and rises sharply to nearly 80 a.u. at 350 V. The 3 wt% CuO/PS sample shows an earlier turn-on around 160–170 V, achieves 15 a.u. at 250 V, and reaches 90 a.u. near 330 V. The 5 wt% CuO/PS nanocomposite exhibits the lowest threshold (120 V), shows 20 a.u. at 220 V, and attains 90 a.u. at 290 V, confirming superior electroluminescent efficiency due to enhanced charge transport and recombination.

### 3.2 Voltage–Current Characteristics at 500 Hz

Voltage current characteristics are also critical to the study of behavior of charge transport and electrical conductivity of Nanocomposites. This subsection compares the effect of CuO loading on current conduction at 500 Hz in PS nanocomposites by focusing on how conductive pathways and enhanced carrier mobility will occur with an increase in nanoparticle concentration.

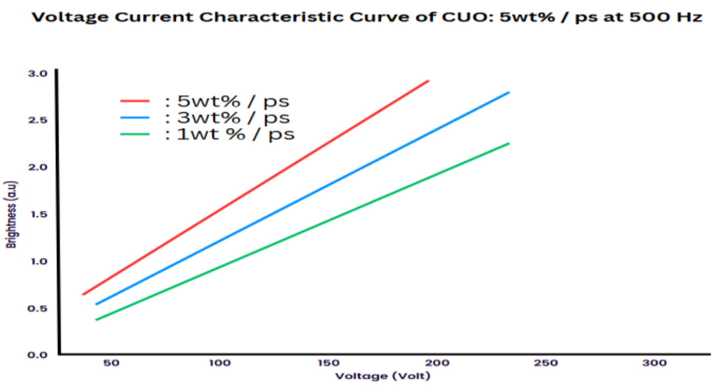


Figure 2 Voltage current characteristics curve of CuO 5wt%/ ps at 500hz

Figure 2 illustrates the voltage–current characteristics of CuO/PS nanocomposites at 500 Hz, showing a linear increase in current with applied voltage for all compositions. At 50 V, the current is approximately 0.4 a.u. (1 wt%), 0.5 a.u. (3 wt%), and 0.6 a.u. (5 wt%). At 200 V, currents rise to about 2.2 a.u., 2.6 a.u., and 2.9 a.u., respectively. The higher current in the 5 wt% CuO/PS sample indicates enhanced charge carrier density and reduced transport barriers due to increased CuO loading, confirming improved electrical conductivity and efficient charge transport pathways within the nanocomposite system.

### 3.3 Frequency-Dependent Voltage–Current Behavior

Frequency is one of the significant factors that influence the electrical behavior of polymer nanocomposites owing to polarization and charge hopping.

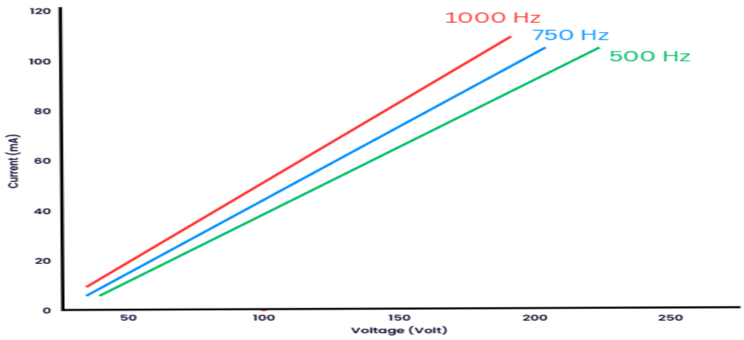


Figure 3 Voltage vs current plot

The voltage–current plot illustrates the frequency-dependent electrical response of the CuO/PS nanocomposite. At 50 V, the current is approximately 7 mA (500 Hz), 9 mA (750 Hz), and 11 mA (1000 Hz). As the voltage increases to 200 V, the current rises to about 100 mA at 500 Hz, 105 mA at 750 Hz, and 110 mA at 1000 Hz. The linear V–I behavior indicates stable conduction, while the higher current at increased frequency reflects enhanced polarization and faster charge hopping between CuO nanoparticles, confirming suitability for high-frequency optoelectronic applications.

### 3.4 SEM Analysis

The SEM images reveal the microstructural features of CuO/PS nanocomposites: uniform dispersion of CuO nanoparticles within the polystyrene matrix, minimal agglomeration, and surface roughness indicative of strong interfacial adhesion, supporting efficient charge transport and enhanced electroluminescent and optical behavior.

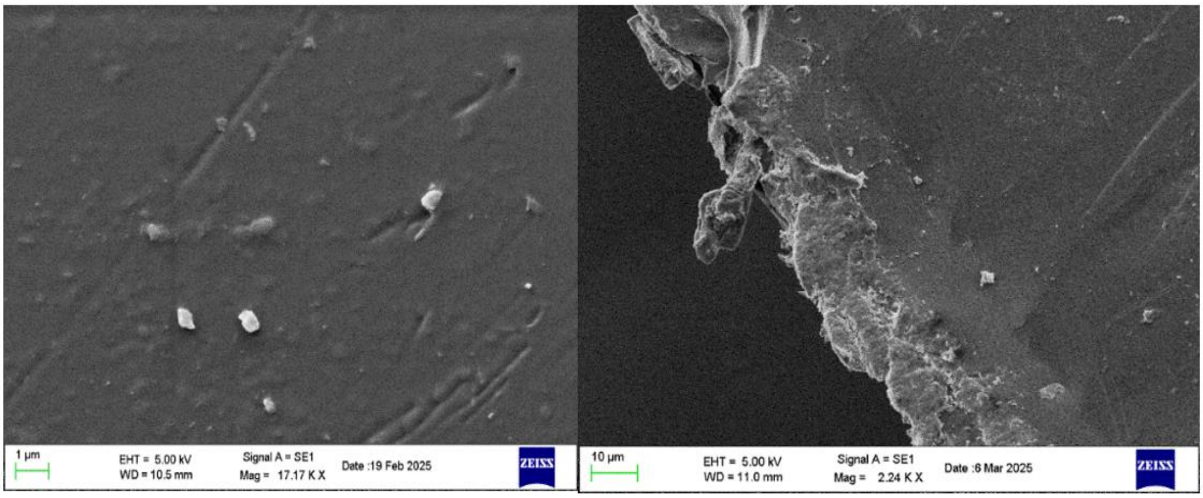


Figure 4 SEM Image of CuO/PS Nanocomposites

### 3.5 UV–Visible Absorption Analysis and band gap energy

UV–Visible absorption spectroscopy was employed to investigate the influence of CuO nanoparticle incorporation on the optical absorption behavior and band gap energy of polystyrene. This analysis provides insight into electronic transitions, band gap modulation, and light–matter interactions within CuO/PS nanocomposites.

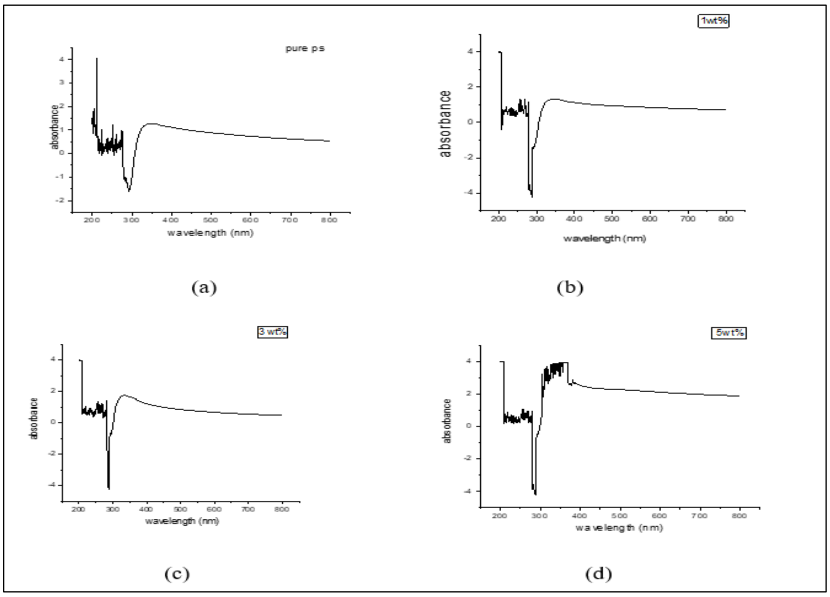


Figure 5 UV–Visible absorption spectra of pure polystyrene and CuO/PS nanocomposites with different CuO concentrations (a) Pure polystyrene (PS), (b) CuO/PS nanocomposite with 1 wt% CuO, (c) CuO/PS nanocomposite with 3 wt% CuO, and (d) CuO/PS with 5 wt% CuO

**Table 1 UV–Visible Absorption and Optical Band Gap**

| Sample | Absorption Edge (nm) | Peak UV Region (nm) | Optical Band Gap (eV) |
|---|---|---|---|
| **(a) Pure PS** | 285 | 270 | ~4.9 eV |
| **(b) CuO 1 wt%/PS** | 295 | 285 | ~3.8 eV |
| **(c) CuO 3 wt%/PS** | 310 | 295 | ~3.2 eV |
| **(d) CuO 5 wt%/PS** | 330 | 305 | ~2.6 eV |

### 4. Applications in Optoelectronics

The CuO/PS nanocomposites demonstrate strong potential for optoelectronic applications due to their composition-dependent electrical, optical, and electroluminescent performance. The 5 wt% CuO/PS sample exhibits high brightness of approximately 90 a.u. at 290 V, making it suitable for light-emitting devices, flexible displays, and indicator panels. Improved electrical conductivity is evidenced by currents reaching 2.9 a.u. at 200 V and 110 mA at 200 V and 1000 Hz, supporting use in high-frequency electronic circuits. strong UV absorption in the 200–350 nm range and a reduced band gap of 3.8 eV enable applications in UV photodetectors, optical filters, and UV-blocking coatings.

### 5. Conclusion

This study confirms that CuO/PS nanocomposites exhibit significantly enhanced electroluminescent, electrical, and optical properties with increasing CuO concentration. The

5 wt% CuO/PS sample showed the lowest turn-on voltage (120 V) and reached high brightness (90 a.u.) at 290 V, demonstrating superior electroluminescent efficiency. Voltage–current measurements indicated improved electrical conductivity, with currents up to 2.9 a.u. at 200 V and 110 mA at 200 V and 1000 Hz, reflecting enhanced charge transport and carrier density. UV–Visible spectroscopy revealed strong UV absorption in the 200–350 nm range and a reduced optical band gap of 3.8 eV, confirming enhanced light–matter interaction. SEM analysis showed uniform nanoparticle dispersion and minimal agglomeration. Overall, these results highlight the 5 wt% CuO/PS nanocomposite as an optimal candidate for LEDs, UV photodetectors, optical filters, and high-frequency optoelectronic applications.

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