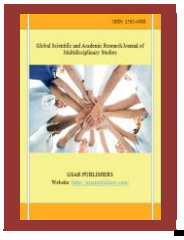

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Advanced Engineering of ZnO Nanoparticles: Enhancing Structural, Magnetic, and Optical Properties via Co and Cu Doping

By

Maryam Liaqat[1], Faiza Ashfaq[2], MAHNOOR[3], Usman Ibrahim[4], Safder Alam[5], Waheed Zaman khan[6], Muhammad Rehmat Ullah[7], Ijaz Ahmad[8]

[1]College of Electronics and Information Engineering, Shenzhen University 3688 Nanhai Blvd, Nanshan, Shenzhen, Guangdong Province, 518060, China
[2]Department of physics, University of Okara, Okara, Punjab, Pakistan
[3]Department of Physics, Khawaja Fareed University of Engineering and Information Technology, Rahim Yar Khan, Punjab, Pakistan
[4]Department of Chemistry, University of Agriculture Faisalabad 38000, Pakistan
[5]Department of Chemistry, Islamia College University of Peshawar, KPK 25120, Pakistan
[6]Department of Physics, Division of Science and Technology, University of Education, Lahore, Punjab 54770, Pakistan.
[7]Department of Metallurgical and Materials Engineering, University of Engineering and Technology Lahore, Punjab 54890, Pakistan
[8]Department of Physics, Division of Science and Technology, University of Education, Lahore, Punjab 54770, Pakistan

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Abstract

This study explores the systematic tuning of ZnO nanoparticles' structural, magnetic, and optical properties through Co and Cu doping, synthesized via the scalable co-precipitation method. X-ray diffraction confirmed the retention of the hexagonal wurtzite structure, with successful dopant incorporation reducing the crystallite size from 83.49 nm in pristine ZnO to 51.32 nm in Co-doped samples. Scanning electron microscopy revealed uniformly agglomerated nanoparticles with improved surface morphologies from doping. Fourier Transform Infrared spectroscopy confirmed the presence of Zn-O, Cu-O, and Co-O bonds, indicating structural and chemical changes within the ZnO matrix. Magnetic characterization showed room-temperature ferromagnetism, with Co-doped ZnO exhibiting superior saturation magnetization and coercivity compared to undoped and Cu-doped counterparts. These magnetic enhancements reflect the dopant's significant impact on ZnO's intrinsic properties. UV-visible spectroscopy revealed an increased optical bandgap from 4.09 eV in undoped ZnO to 4.34 eV in Co-doped ZnO, highlighting enhanced optical performance and potential for optoelectronic applications. These results demonstrate that Co and Cu doping improves the structural, magnetic, and optical properties of ZnO nanoparticles, expanding their applications in energy harvesting, photocatalysis, ultraviolet photodetectors, and next-generation optoelectronic devices. This research underscores the versatility of transition metal doping as a potent strategy to optimize ZnO nanoparticles' properties, establishing a foundation for developing ZnO-based multifunctional materials for advanced energy and electronic applications.

*Corresponding Author: **Maryam Liaqat**