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Green Synthesis and Characterization of Silver-Doped ZnO Nanoparticles Using Tobacco Leaf Extract: A Novel Hydrothermal Approach for Antibacterial and Antifungal Applications

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Abstract
A green synthesis of pure zinc oxide and silver-doped zinc oxide nanoparticles (ZnO and Ag-ZnO NPs) is reported. This eco-friendly method utilizes tobacco leaf aqueous extract as a reducing and stabilizing agent, combined with a hydrothermal process at 120℃ for 6 hours to control nanoparticle formation. The study aimed to synthesize, characterize, and evaluate the antimicrobial activity of Ag-ZnO NPs. Characterization techniques included FTIR, XRD, SEM, UV–Vis, and PL spectroscopy, along with BET surface area analysis. FTIR confirmed functional groups, while X-ray diffraction (XRD) validated the hexagonal wurtzite ZnO structure. SEM imaging revealed a nanosheet morphology. UV–Vis analysis showed bandgap energy shifting with Ag doping: 2.02 eV (pristine ZnO) to 2.29 eV (3% Ag), 2.53 eV (5% Ag), and 3.53 eV (1% Ag). BET analysis indicated a decrease in surface area (132.251 m^2/g for pristine ZnO to 85.005 m^2/g for 1% Ag and 65.318 m^2/g for 5% Ag) and pore volume with higher Ag content. PL spectroscopy examined electron–hole recombination. Antimicrobial activity against Staphylococcus aureus, Escherichia coli, and Candida albicans was evaluated via disk diffusion assay, using ciprofloxacin and fluconazole as controls. Two-way ANOVA revealed significant differences in the zone of inhibition (ZOI) across varying concentrations and Ag doping levels ($p < 0.005$). Enhanced antibacterial activity against S. aureus was observed with increasing Ag doping, while E. coli showed limited susceptibility. The NPs exhibited antifungal activity against C. albicans. Bandgap, surface area, and antibacterial activity are controllable characteristics suggesting applications in biomedicine, photovoltaics, and photocatalysis.

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