

Photocatalyst of Zinc Oxide - Nanocomposite and Their Applications as Antimicrobial

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Structured Abstract

Background: Zinc oxide (ZnO) nanocomposites show strong potential as antimicrobial agents, driven by their photocatalytic ability to generate reactive oxygen species (ROS) and release Zn²⁺ ions that disrupt bacterial cells. Despite their promise, challenges remain due to ZnO's wide bandgap (~3.37 eV), limiting activation under visible light, along with high recombination rates of charge carriers and reduced efficacy against biofilms.

Methods: This review analyses the mechanisms of ZnO's antimicrobial activity including ROS generation, Zn²⁺ ion release, and membrane disruption. Strategies to enhance photocatalytic performance were examined, including metal doping (e.g., Ag, Cu), hybridization with reduced graphene oxide (rGO), and formulation with natural antimicrobials. Several composite combinations were studied, such as ZnO with MWCNTs, Au, or CMC/AAC hydrogels, to enhance stability and efficiency.

Results: ZnO's bandgap can be reduced through doping with Mn, Cu, or S, expanding its light absorption into the visible range. Doped and hybridized ZnO nanocomposites showed enhanced antibacterial and photocatalytic activities against both Gram-positive and Gram-negative bacteria. Biofilm resistance was reduced by increasing exposure time, combining ZnO with other agents, or using structured carriers like hydrogels. Furthermore, selective toxicity toward microbial cells over human cells was achievable with biofunctionalized ZnO.

Conclusion: ZnO nanocomposites offer significant potential for antimicrobial applications, particularly in medical devices, food packaging, and wastewater treatment. Enhancements in visible light activation and reduced charge recombination can improve performance. Continued research is needed for safe, efficient, and practical use in real-world applications.

Keywords: Zinc Oxide Nanoparticles, Antibacterial, Photocatalyst, Bandgap Engineering, Reactive Oxygen Species

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