World Academy of Science, Engineering and Technology
International Journal of Chemical and Materials Engineering
Vol:20, No:05, 2026

Green Synthesis of Metal Oxide and Silver Nanoparticles Using Citrus Peel Extracts: Antibacterial, Antidiabetic, and Photovoltaic Applications

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Abstract : Traditional chemical synthesis methods for nanoparticles (NPs) often involve environmental hazards, complex procedures, and low yields. Green synthesis has emerged as a safer, cost-effective, and eco-friendly alternative. Citrus peel, an agricultural byproduct, provides a sustainable source of bioactive compounds capable of reducing and stabilizing metal ions, enabling the production of biocompatible NPs with valuable biomedical, photovoltaic, and environmental applications. This study aims to develop a green synthesis approach for producing metal oxide and silver nanoparticles (AgNPs) using citrus peel extracts, evaluating their antibacterial, antidiabetic, and photovoltaic properties. Nanoparticles were synthesized via aqueous citrus peel extracts, which served as natural reducing and capping agents. The synthesized NPs were characterized using techniques such as X-ray diffraction (XRD), scanning electron microscopy (SEM), and UV-Vis spectroscopy to confirm their crystalline structure, morphology, and stability. Antibacterial efficacy was tested against common pathogenic bacteria, while antidiabetic activity was assessed through in vitro α-amylase inhibition. Photovoltaic properties were evaluated by incorporating the NPs into dye-sensitized solar cells (DSSCs). The synthesized NPs demonstrated distinct crystalline phases and spherical morphology, with notable stability and size uniformity. AgNPs showed significant antibacterial activity against tested pathogens, with enhanced inhibition at higher concentrations. In α-amylase inhibition assays, both metal oxide and AgNPs displayed dose-dependent antidiabetic potential. The DSSCs exhibited promising photovoltaic efficiency, confirming the feasibility of these NPs in light energy applications. Citrus peel-mediated synthesis of metal oxide and AgNPs provides a green, scalable method for producing nanoparticles with multifaceted applications. The findings highlight the potential of these NPs as eco-friendly agents in antibacterial and antidiabetic therapies and as components in renewable energy devices. This approach not only utilizes agricultural waste but also aligns with sustainable development goals by reducing synthetic chemical usage and environmental impact.

Keywords : antibacterial activity, citrus peel extract, green synthesis, metal oxide nanoparticles, silver nanoparticles
Conference Title : ICAGC 2026 : International Conference on Applied Green Chemistry
Conference Location : Berlin, Germany
Conference Dates : May 20-21, 2026