Bismuth-Enhanced Silicon Nanowires: Exploring Their Antimicrobial Potential

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Abstract

Targeted eradication of bacteria using nanomaterials has gained prominence as a solution to antibiotic-resistant microorganisms. A synergistic hybrid structure, integrating nanostructured surfaces with nanowire arrays and plasmonic metal nanoparticles, represents a promising approach. In this context, this study focuses on the functionalization of silicon nanowires (SiNWs) with bismuth nanoparticles (BiNPs) to design a novel and cost-effective antibacterial agent. High-density needle-like SiNWs were synthesized via metal-assisted chemical etching, with BiNPs anchored through thermal evaporation. Morphology, elemental composition, and structural analysis confirmed the formation of the BiNPs@SiNWs nanocomposite. The hydrophilic nature of BiNPs@SiNWs facilitates antifouling by reducing bacterial contamination. These nanocomposites exhibit near-perfect absorbance, reaching 99%, particularly in the near-infrared range overlapping with three biological windows, promoting reactive oxygen species (ROS) generation and efficient photothermal effects that harm bacteria. The antibacterial properties against gram-negative *Escherichia coli* and gram-positive *Staphylococcus epidermidis* were assessed using colony-forming units, fluorescence staining, and scanning electron microscopy, revealing impressive bacteriostatic effect and bactericidal rates of 96% and 99%, respectively. The mechanisms underlying these effects were thoroughly elucidated, showing sustained efficacy across multiple cycles. BiNPs@SiNWs display significant potential as a novel and efficient antibacterial agent for diverse biomedical applications.

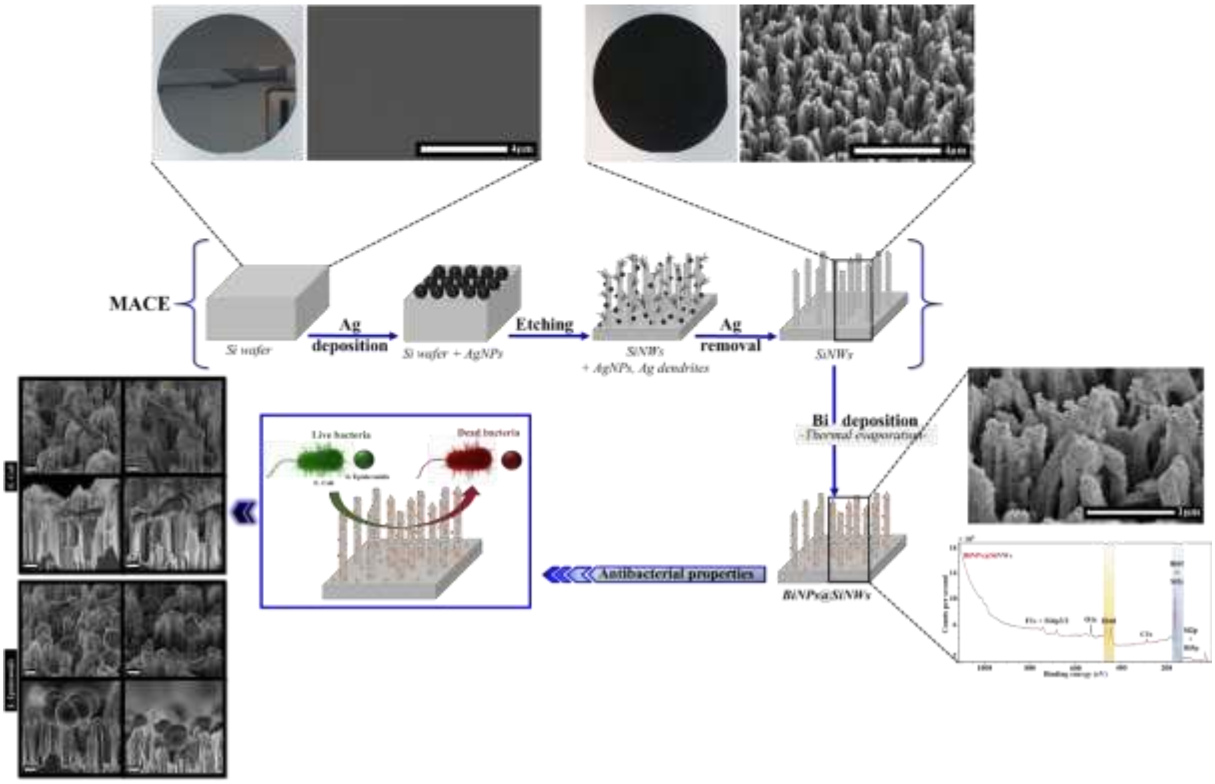

Figure 1. Bismuth-coated silicon nanowires composite as an efficient antibacterial agent