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Quantitative evaluation of the antibacterial factors of ZnO nanorod arrays under dark conditions: Physical and chemical effects on *Escherichia coli* inactivation

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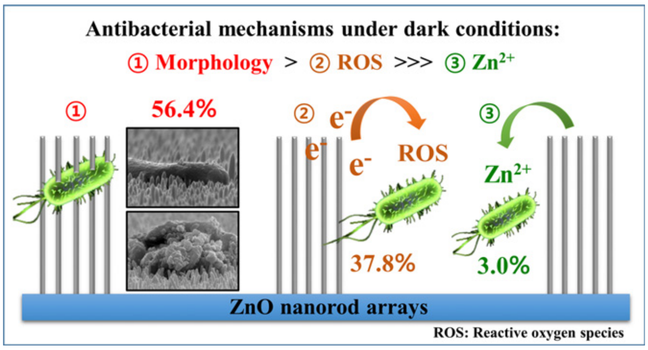
HIGHLIGHTS

- Antibacterial mechanism of ZnO nanorod (NR) arrays against *E. coli* was investigated.
- The morphological effect as mechanical rupture was predominant for *E. coli* inactivation.
- The inactivation by reactive oxygen species was 2nd major mechanism in the dark.
- The chemical inactivation by Zn^{2+} ions released from the arrays was insignificant.

GRAPHICAL ABSTRACT



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ABSTRACT

Although zinc oxide nanorod (ZnO NR) arrays are a nanomaterial that offers efficient bactericidal activity, they have not been systematically evaluated to quantitatively investigate their disinfection mechanism under dark conditions. In this study, ZnO NR arrays of different lengths (0.5–4 μm) were uniformly grown via hydrothermal synthesis. The longer arrays exhibited higher *Escherichia coli* (*E. coli*) inactivation efficiency up to 94.2% even under darkness for 30 min. When the NR arrays were coated via Al_2O_3 atomic layer deposition, the inactivation efficiency was decreased to 56.4% because the generation of reactive oxygen species (ROS) and the leaching of Zn^{2+} ions were both hindered by the surficial coverage of defect sites. The morphological effect, i.e., the mechanical rupture of *E. coli* on the surface, contributed 56.4% of the bactericidal efficiency; chemical effects, i.e., ROS formation and zinc ion release, contributed the remaining 37.8% under dark conditions. The bactericidal effect of fabricated ZnO NR arrays was further validated in bottled and pond water spiked with *E. coli*, exhibiting 87.5% and 80.4% inactivation efficiencies, respectively, within 30 min. Understanding these antibacterial mechanisms is not only of significance for research in this and related fields but also beneficial for potential application in various fields, e.g., biomedical and antifouling areas.

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