Does surface polarity of micro- and nano-scale ZnO particles contribute to antibacterial action?

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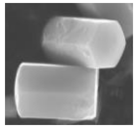
Abstract

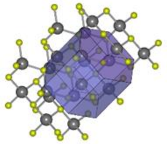
Antimicrobial action of micro- and nanoscale ZnO particles has been documented, but the fundamental physical mechanisms driving this action are still not identified. We hypothesize that one of the key mechanisms behind the antibacterial action of ZnO is rooted in interactions between ZnO surfaces and extracellular material. Crystalline structure of ZnO results in two distinct types of crystallographic surfaces: polar (charged) and non-polar (neutral). The excess charge and electronic states at the polar surfaces of micro- and nano-scale ZnO particles may affect interfacial phenomena with surrounding media. Therefore, it is feasible that the relative abundance of such polar surfaces could significantly influence their antibacterial action. In this study we use a hydrothermal growth method established in our lab to synthesize ZnO crystals with different controllable surface morphologies. We study the effects of relative abundance of polar surfaces on antibacterial action. These experiments performed in conjunction with optoelectronic studies of ZnO crystals yield information regarding the fundamental nature of their antibacterial action.

Introduction

- Fundamental mechanisms driving antibacterial action for ZnO is still unknown.
- Nanoparticles can infiltrate into and kill cells.
- Antimicrobial behavior of ZnO is initiated by interactions of surfaces
- ZnO has uniquely stable polar and nonpolar surfaces
- This polarity is believed to influence antibacterial behavior

Zinc Oxide Crystal Structure

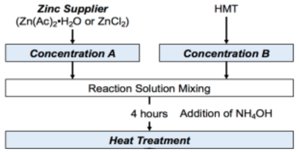




- ZnO has Hexagonal structure composed of alternating layers of Zn^{2+} and O^{2-} ions
- Structure yields net charge at hexagonal (polar) faces and neutral charge on rectangular (non-polar) sides
- Nature of these crystallographic faces (neutral, negative, positive) could be very different.

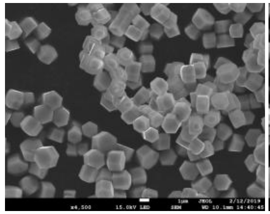
Controlling growth of ZnO structures

- Hydrothermal chemical method allows us to grow specific ZnO micro-crystals
- Necessary for studying specific crystallographic faces



Optoelectronic effects of surface characteristics

- Different surfaces, sizes, and shapes influence bandgap energies for ZnO
- This could be related to defect states and confinement effects



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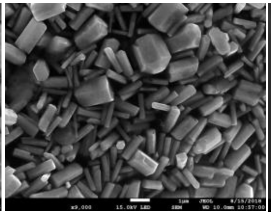

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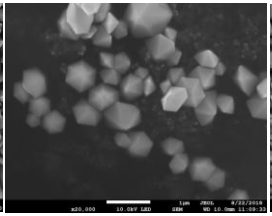

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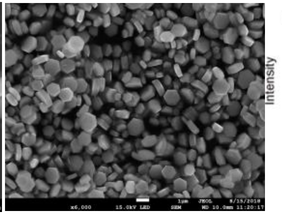

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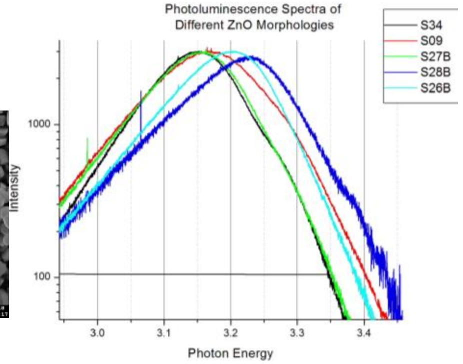
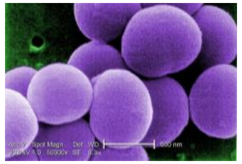
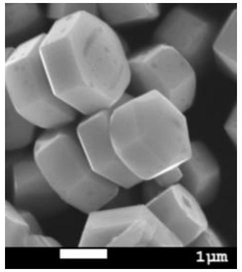


Dimensions of Zinc Oxide Microcrystals and Bacteria

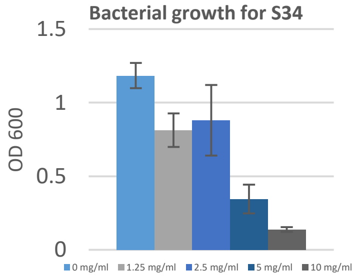
- Particles too large to be internalized

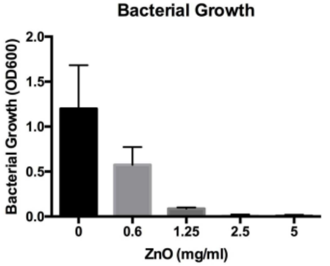




Bacterial Growth Inhibition

- Zinc Oxide nanoparticles and microcrystals inhibit bacterial growth
- Internalization is not necessary for growth inhibition
- ZnO surfaces are hostile environment for bacteria





**Courtesy of Dr. Shauna McGillivray

Conclusions

- Initial antimicrobial assay trials confirm hypothesis that interactions between ZnO and bacterial surfaces drive this action
- Photoluminescence studies of various particles reflect changing optoelectronic behavior with surface morphology and particle dimensions

Future Directions

- Investigate near surface optoelectronic phenomena (surface photovoltage experiments)
- Correlate antibacterial activity to surface type
- Investigate antibacterial action and optoelectronics of other ZnO micro- and nano-structures