Nanoscale ZnO with Controllable Crystal Morphology as a Platform to Investigate Mechanisms of Antibacterial Action

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Abstract

Nanoscale zinc oxide (ZnO) is an inexpensive, widely accessible material used in numerous well-established and emerging applications due to the unique optoelectronic, structural and chemical properties as well as the variety of synthesis methods. One of these emerging applications of ZnO nanostructures is in the field of antibacterial tools. The antibacterial nature of this material is being actively investigated, yet the mechanisms behind remain largely unknown. Some studies indicate that there is an influence of the polarity of exposed ZnO surfaces on their antibacterial action. Crystalline ZnO forms hexagonal prisms due to an anisotropic hexagonal lattice, which in turn produces three primary surface types: Zn-polar, O-polar and nonpolar. The hexagonal faces of these prism-shaped crystals are polar while the rectangular surfaces are nonpolar. In this study we employ a hydrothermal chemical method for growing ZnO nanocrystals having tunable morphology with the aim of obtaining a reliable control of the predominant polarity of the exposed nanocrystalline surfaces. This in turn can serve as a platform to investigate mechanisms of antibacterial action. Using Scanning Electron Microscopy as a probe of the microcystal morphology we demonstrate that the predominant ZnO surface polarity can be affected through the variations in the chemical precursors of the hydrothermal process. The ability to control the morphology and prominent surface polarity of ZnO nanocrystals would allow us to investigate fundamental phenomena governing antibacterial characteristics of nanoscale ZnO.

Summary

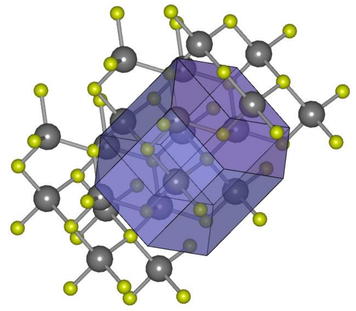
- Nanoscale zinc oxide (ZnO) is emerging as a candidate for use in medicine as an antibacterial agent. Antibacterial nature is established, but not well understood. Studies indicate that polarity of exposed surfaces influences antibacterial action.
- Since polarity of the surface is related to which crystal plane is exposed, we employ a hydrothermal chemical method to grow crystalline ZnO structures with tunable morphology.
- Using Scanning Electron Microscopy we demonstrate the predominant surface polarity can be affected by varying chemical precursors of the hydrothermal process.
- Photoluminescence reveals changes in charge dynamics due to surface morphology and polarity

Surface Polarity

- Hexagonal faces of the surface are composed of Zn or O atoms which leaves a net surface charge because ZnO is an ionic crystal.
- Rectangular faces have equal number of Zn and O atoms so there no net charge
- Surface polarity affects charge dynamics at and around the surface of ZnO.
- Connecting antibacterial action with surface polarity allows us to investigate optoelectronic properties and charge dynamics contributing to antibacterial activity

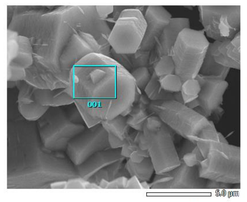
ZnO Crystal Structure

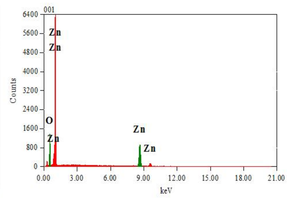
Anisotropic hexagonal lattice of ZnO crystal



Hydrothermal Crystal Growth

- EDX shows crystals grown with this method are pure ZnO





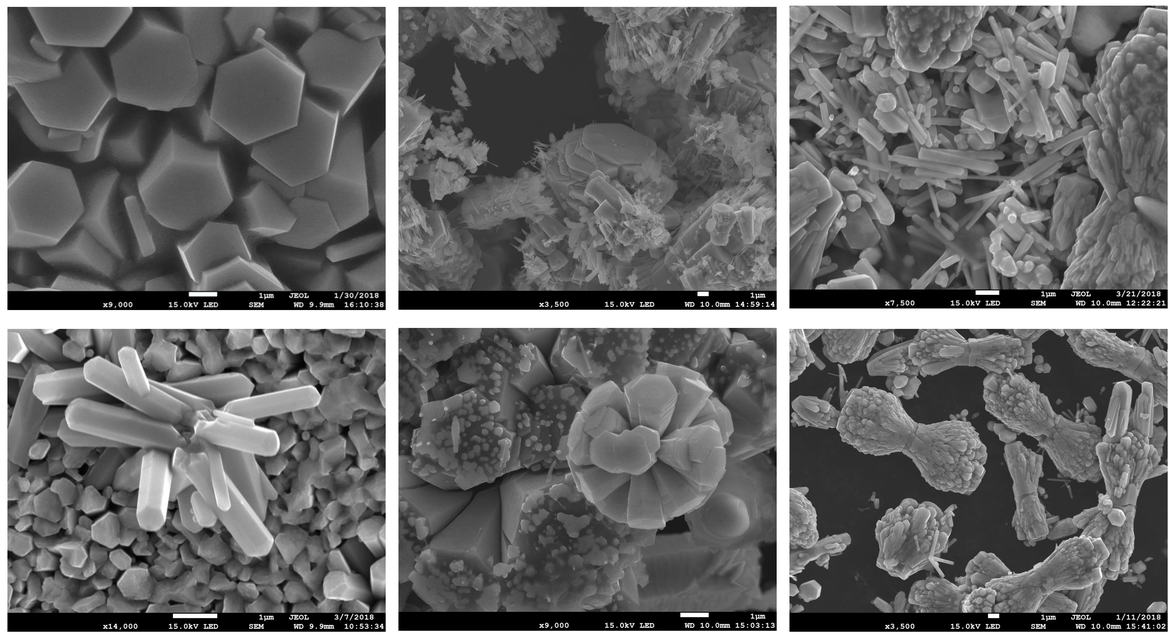
ZAF Method Standardless Quantitative Analysis

Fitting Coefficient : 0.0488

Element	(keV)	Mass%	Sigma	Atom%	Compound	Mass%	Cation	K
O K	0.525	38.25	0.40	71.68				46.0405
Zn K	8.630	61.75	0.74	28.32				53.9595

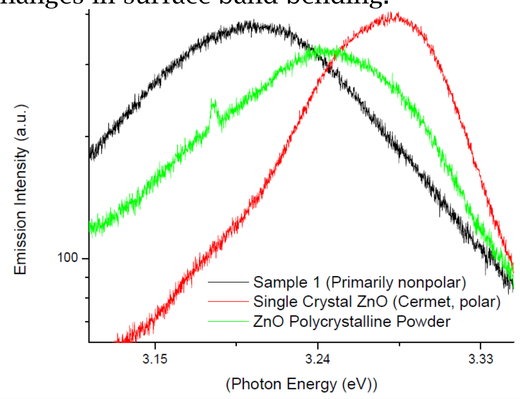
Tunable Morphology

Different Surface morphology with different precursors



Photoluminescence of ZnO Structures

Photoluminescence of different morphologies and surface polarity reveals a shift in the emission energies with the presence of exposed polar and nonpolar faces. This is a result of energy band-gap changes due to changes in surface band bending.



Future Directions

- Now that controllable morphology is established, we will study the antibacterial action of different surface morphologies against antibiotic-resistant strains of bacteria.
- We will continue to study optoelectronic properties at the surface of different morphologies and surface polarities of ZnO to better understand fundamental mechanisms and charge dynamics at the surface.
- Studying charge dynamics at the surface may uncover the fundamental mechanisms driving the interaction of nano-scale ZnO and bacteria based on environment.