Surface Cleanliness of Hydrothermally Grown Zinc Oxide Microparticles for Antibacterial Usage

Vivek Athipatla

Dustin Johnson and Dr. Yuri M. Strzhemechny

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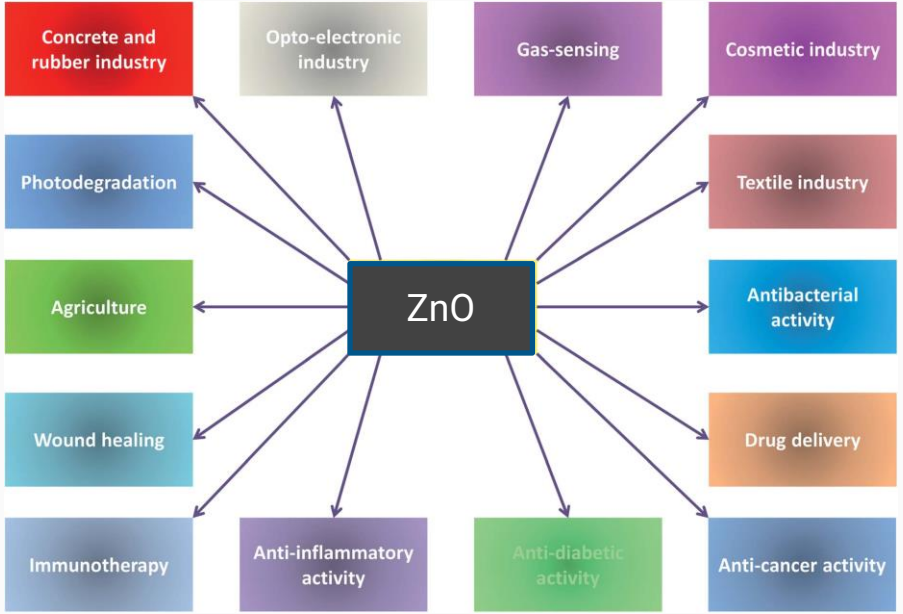
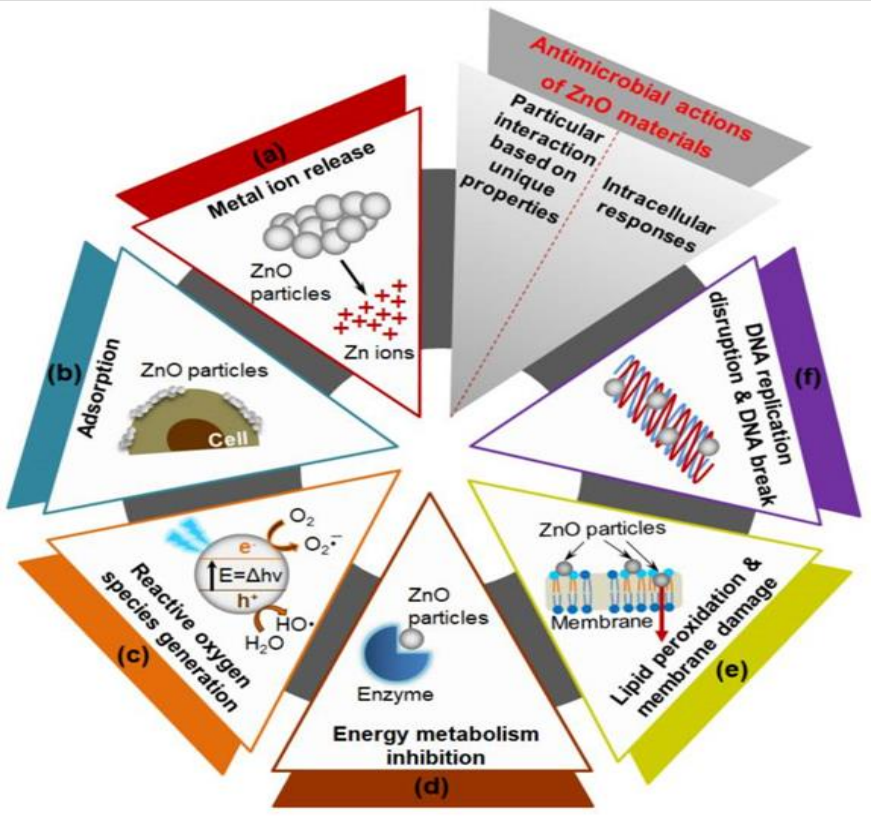
Zinc Oxide – Properties

- Zinc oxide (ZnO) is an important multifunctional material with broad applications in many fields.
- ZnO possesses many excellent properties, and its synthesis is simple.
- Furthermore, zinc is a necessary element of our health and has high biocompatibility with human cells, low toxicity, and good antimicrobial activity.
- All these properties allow for the usage of ZnO materials in medicine as biomarkers, drug carriers, and therapeutic.



Raha S et al, *Nanoscale Adv.*, **2022**

Zinc Oxide – Antibacterial Pathways



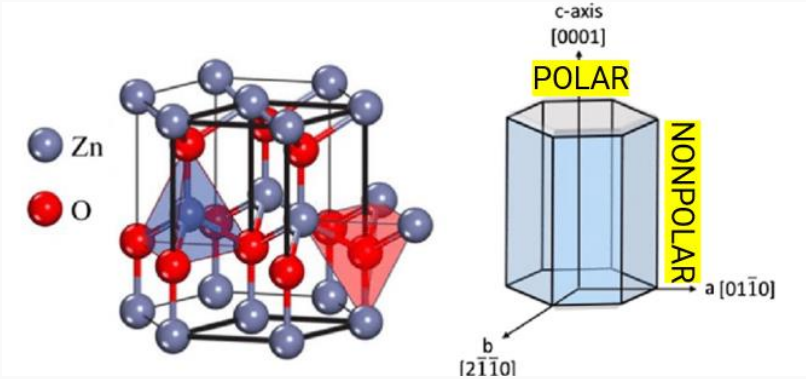
Jin, S. E. et al, *Nanomaterials*, **2021**

Unmet Needs

- Despite the promise of ZnO nanoparticles, it is currently used only as barrier creams (diaper rash) and sunscreens
- One hindrance to wider adoption is that most fundamental physical and chemical mechanisms driving growth inhibition are not well understood
- Nature of interactions between ZnO surfaces and extracellular material is not clear
- Hence, deeper investigations hold important theoretical and practical value.

Zinc Oxide – Microparticles vs Nanoparticles

- We focus on two forms of ZnO: Microparticles and Nanoparticles - Both have comparable antibacterial properties
- However, microparticles are preferred due to their larger size and distinct surface types
- Surface cleanliness is also very influential for antibacterial interactions.
- The goal of this research is to discover if there are significant differences in surface cleanliness between ZnO micro-scale particles and commercial ZnO nano-scale particles that are causing imperfections in the research process.



Samadi M et al, *Research on Chemical Intermediates*, **2022**

Purpose and Hypothesis

Purpose

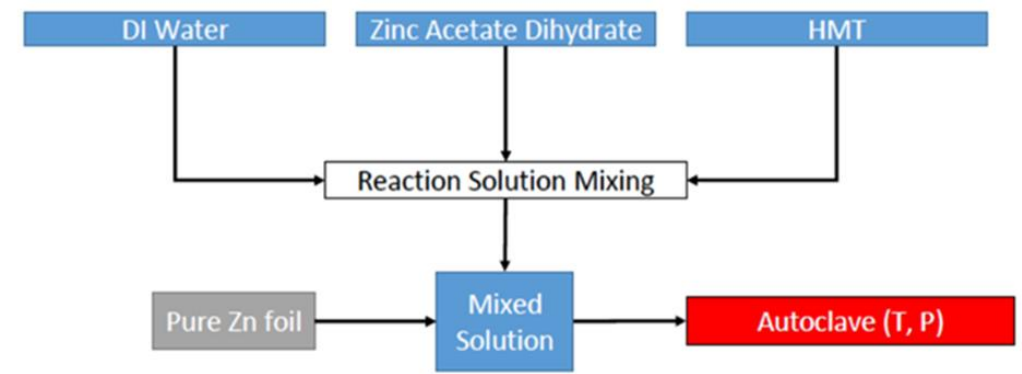
Examine the surface cleanliness of ZnO microparticles vs commercial nanoparticles utilizing Scanning Electron Microscopy (SEM) and Fourier Transform Infrared Spectroscopy (FTIR)

Hypothesis

There are no significant differences in the surface cleanliness of the microparticles compared to nanoparticles

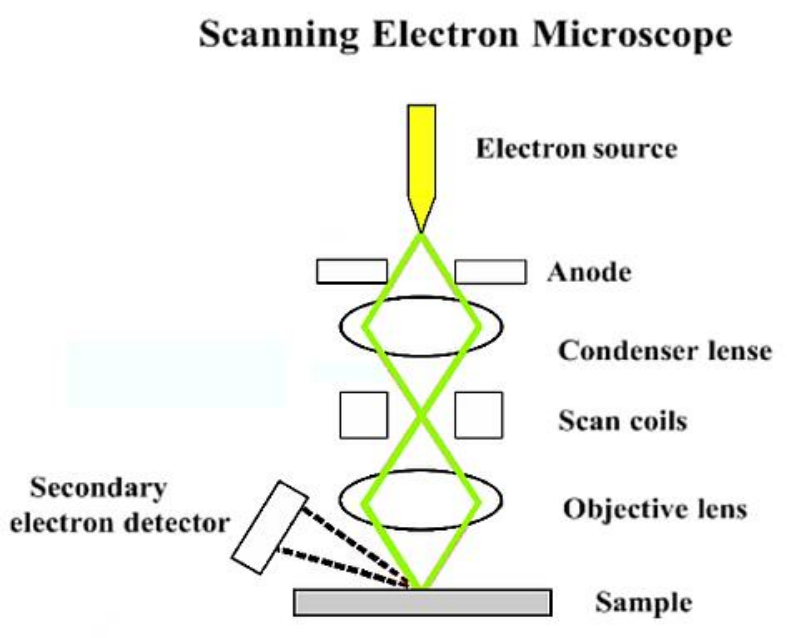
Materials and Methods

- Used both ZnO nanoparticles as well as microparticles
- The nanoparticles were purchased from Sigma Aldrich and ZoChem
- ZnO microparticles were synthesized through a bottom-up, hydrothermal growth method.



Scanning Electron Microscopy (SEM)

- SEM is a type of microscope that produces a magnified image of a sample by using electrons
- These electrons are scattered as they penetrate the surface of the sample
- The energies of these scattered electrons are collected to produce a final image of the sample
- SEM was used to see if there were any glaring surface or structural differences between the nano and microparticles



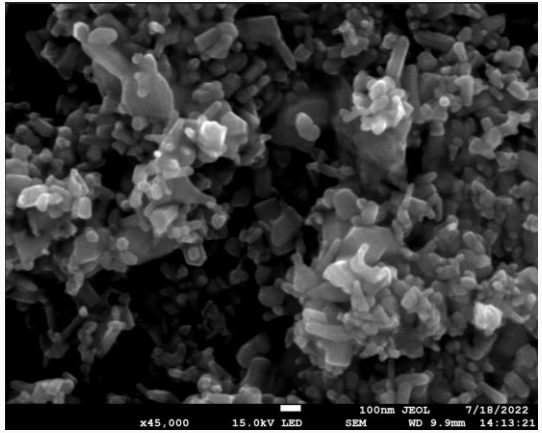
Schematic representation of SEM. ThermoFisher Scientific

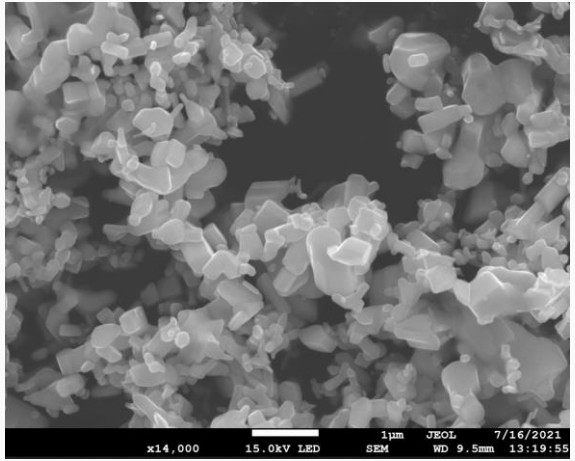
SEM Results

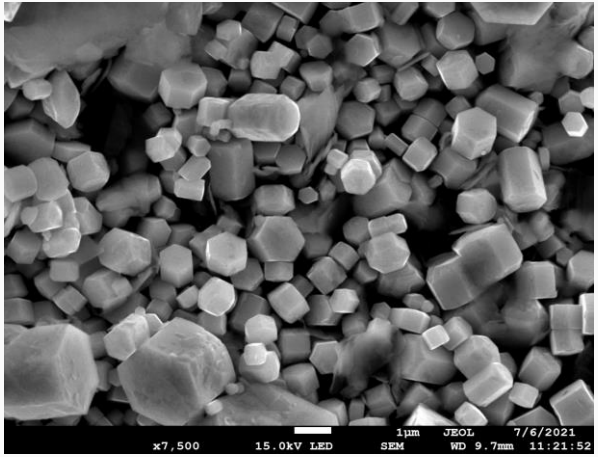
Commercial Nanoparticles

- Homegeneity of the microparticles stands in contrast to the heterogeneity of the nanoparticles in these pictures
- This affirms the current knowledge that microparticles have well-defined polar and nonpolar surfaces and are more useful for conducting antibacterial research

Microparticles

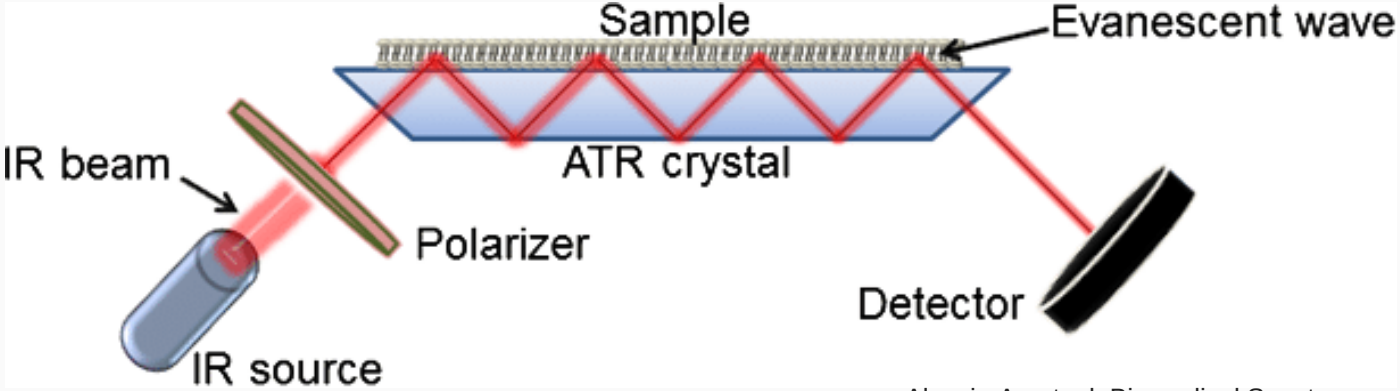






ATR-FTIR Spectroscopy

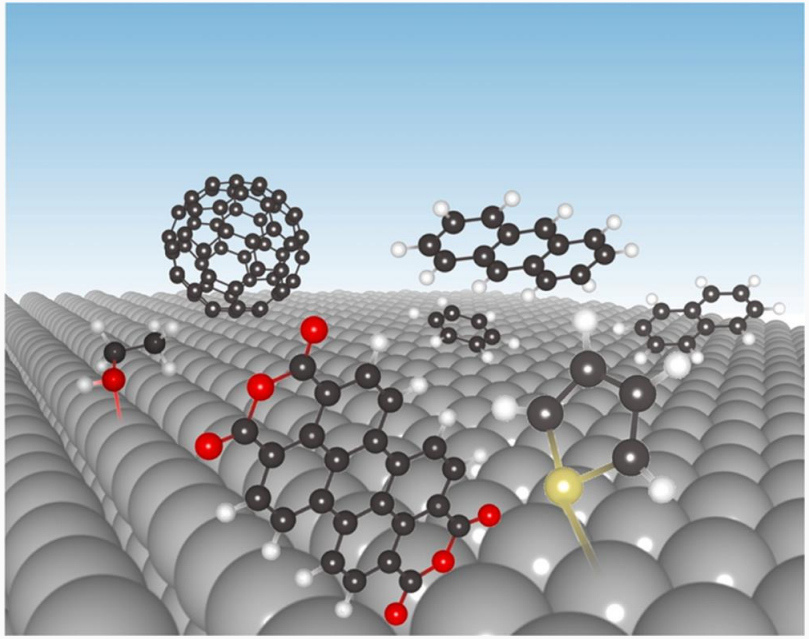
- FTIR spectroscopy is a technique which allows for characterization of functional groups at the material surface
- Attenuated Total Reflection (ATR) is the most widely used form of FTIR
- Infrared (IR) beams send light through the crystal and is attenuated as it penetrates the sample.
- FTIR measures the energy loss at different wavelengths which allows us to dentify the presence of surface functional groups



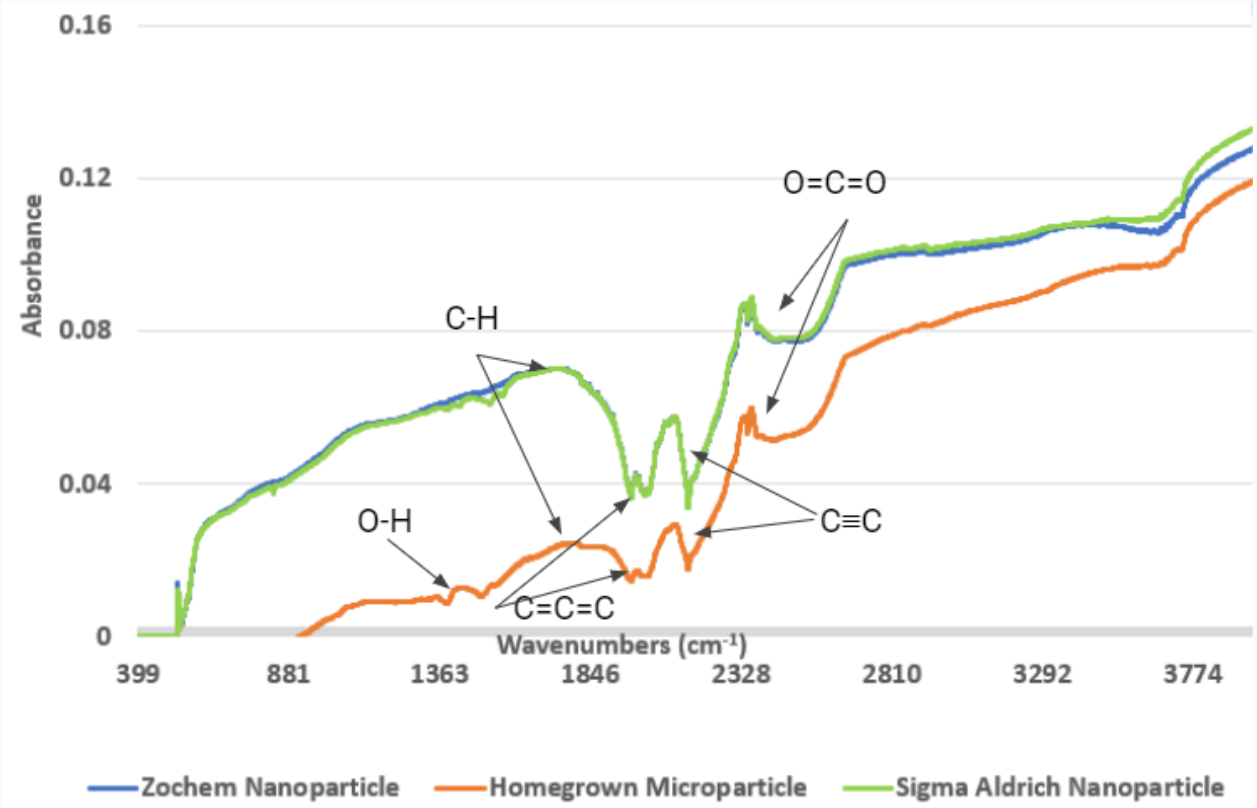
Alessio A., et. al. Biomedical Spectroscopy and Imaging 4 (2015)

Surface Functional Groups

- Functional groups are simply moleules attached to the surface
- FTIR is used to find and discern these functional groups
- Finding these functional groups helps to determine the surface cleanliness of the microparticles which may affect their interactions with bacteria



Composite FTIR Plot Results



- Peaks represent where a specific functional group is located.
- The nanoparticles and microparticles practically have the same FTIR spectrum
- Microparticles exhibit lower absorbance due to their larger size
- Only difference is a benign “O-H Bending” group at the 1400 cm^{-1} region.

Conclusions

- SEM images show that microparticles have much more distinct polar and nonpolar surfaces as well as highly homegenous crystals
- There exist no significant structural differences in the surface contamination between micro and nanoparticles based on FTIR spectra
- Better and more accurate results can be obtained because of the benefits that microparticles provide in comparison to nanoparticles
- Larger sizes of the microparticles as well as distinct polar and nonpolar faces helps in better identifying the point of surface interactions with bacteria

Future Directions

- ZnO microparticles can be the catalyst for massive improvements in antibacterial research and applications

- Plan to continue this work by collaborating with the biology department at Texas Christian University to study ZnO-bacteria interactions at the microparticle surface

Acknowledgements

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Dustin Johnson
Graduate Student
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Texas Christian University

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