Synthesis and Characterization of FeZnO Microparticles As a Platform for Investigation of Antibacterial Mechanisms

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Introduction

- Iron doped Zinc Oxide (FeZnO) **stabilizes** the surfaces of the hexagonal wurtzite structure of pure Zinc Oxide (ZnO)
- Iron doped Zinc Oxide has many potential electronic and biomedical **applications** due to its physicochemical and optoelectronic characteristics
- **Hydrothermal synthesis** offers a safe and affordable method that allows for size and shape control

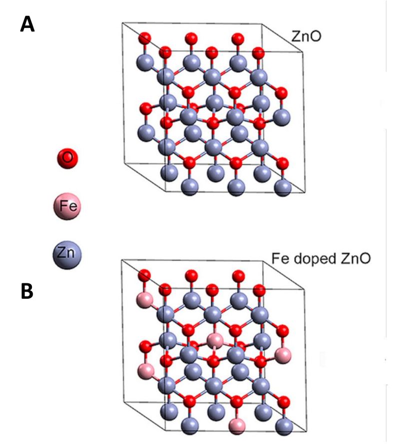
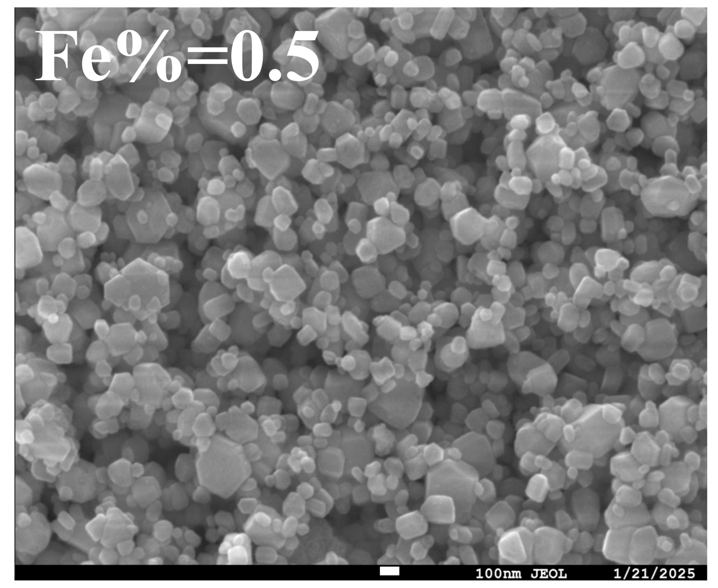


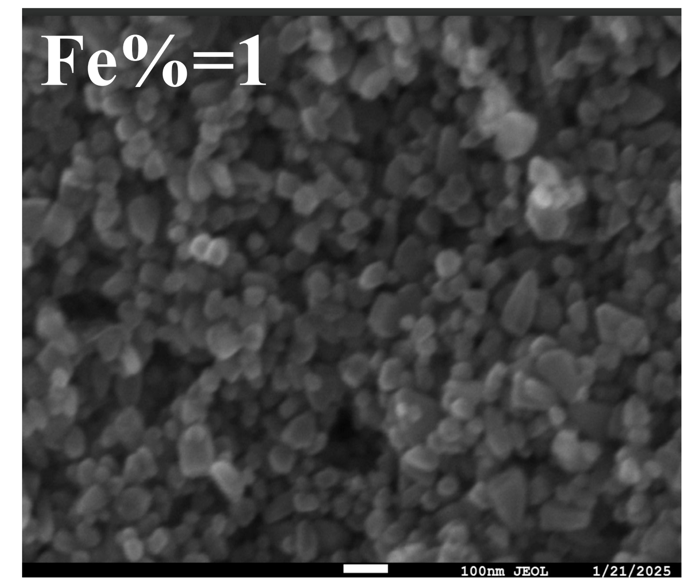
Fig. 1: A) Structure of Zinc Oxide
B) Structure of Iron Doped Zinc Oxide. (1)

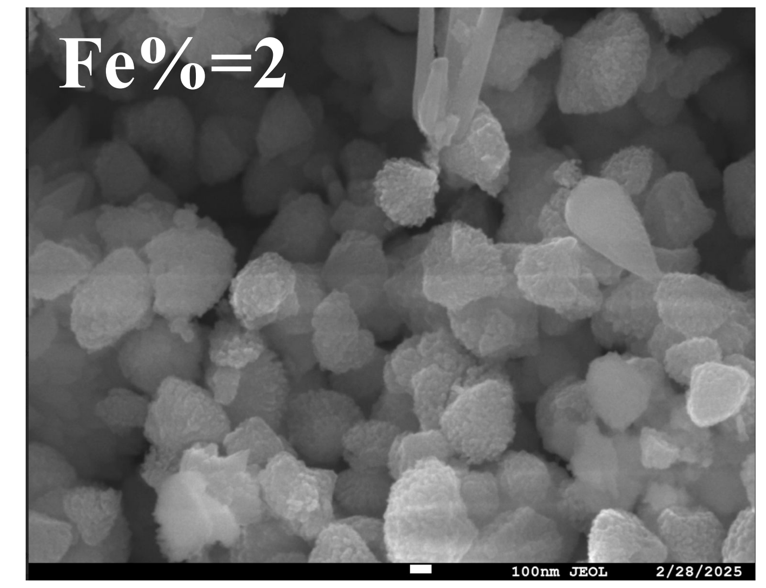
Methodology

- Zinc Acetate ($Zn(Ac)_2 \cdot 2H_2O$) and Iron Nitrate ($Fe(III)(NO_3)_3 \cdot 9H_2O$) are added in varying amounts corresponding to theoretical doping percentage and mixed in 100mL DI water.
- We maintain the Zinc Acetate ($Zn(Ac)_2 \cdot 2H_2O$) of the solution to be 0.05M
- Sodium hydroxide (NaOH) is added in various amounts to **control pH**
- Solution heated in an oven 180°C for 24 hours
- **Iron Doped Zinc Oxide** crystals were washed in DI water and Methanol, and dried at 60 °C for 6 hours

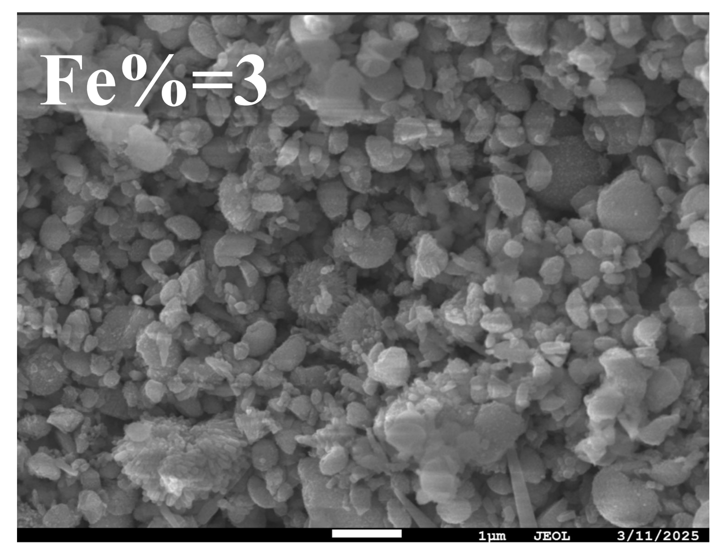
SEM Images of FeZnO

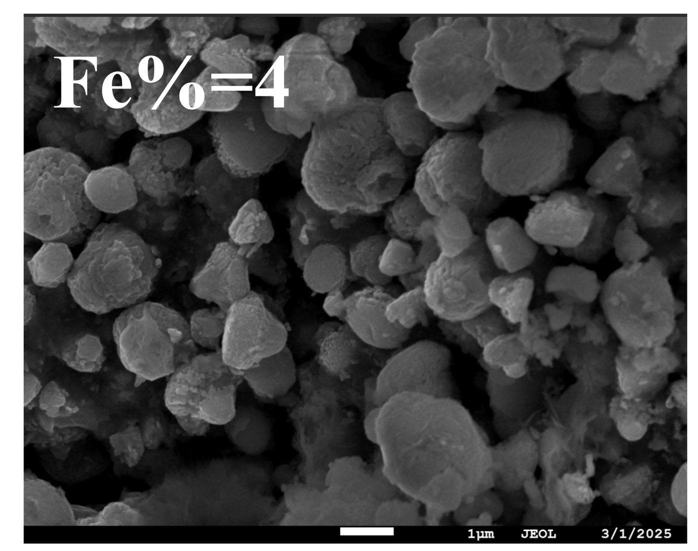


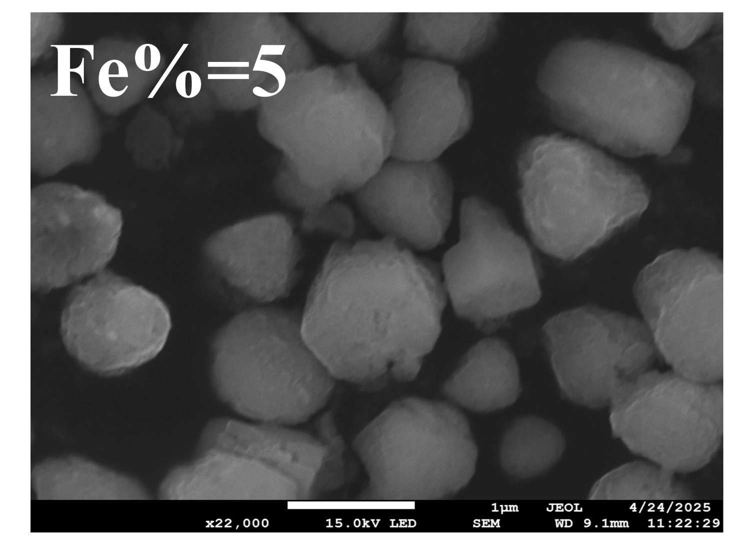


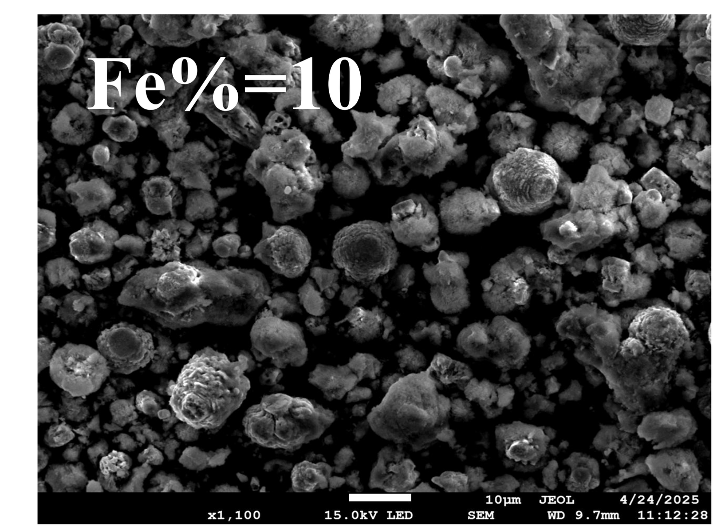


- No clear change in the morphological features of Zinc acetate as we increase levels of iron relative to zinc in the material.
- This suggests no significant distortions accompanied by incorporation of low levels of Fe into the ZnO lattice.









Antibacterial Activity

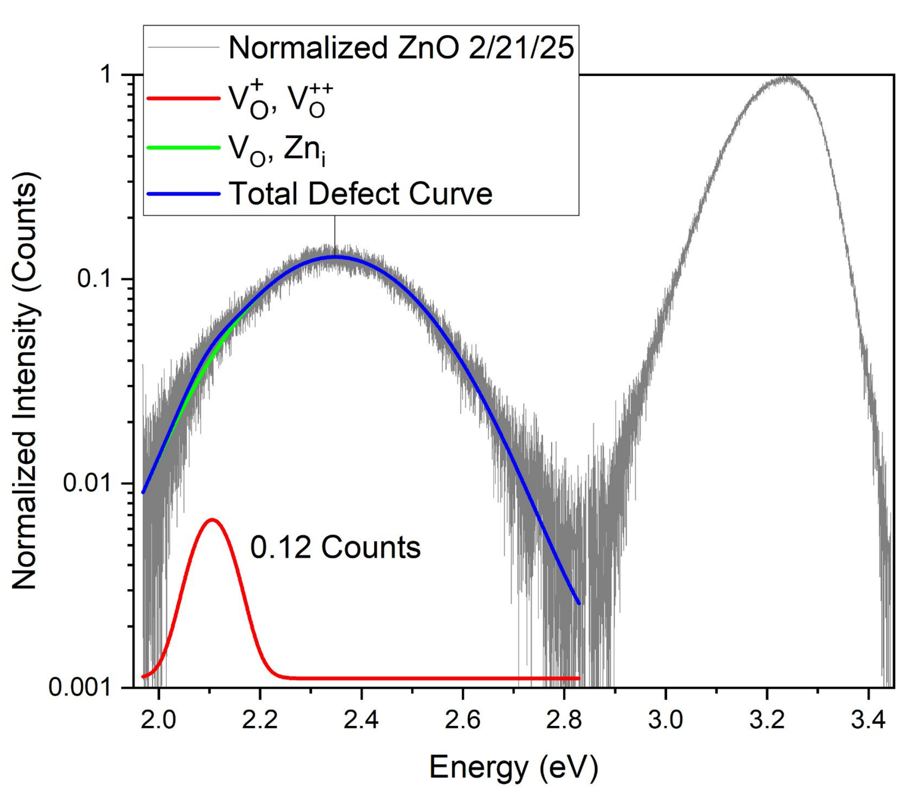
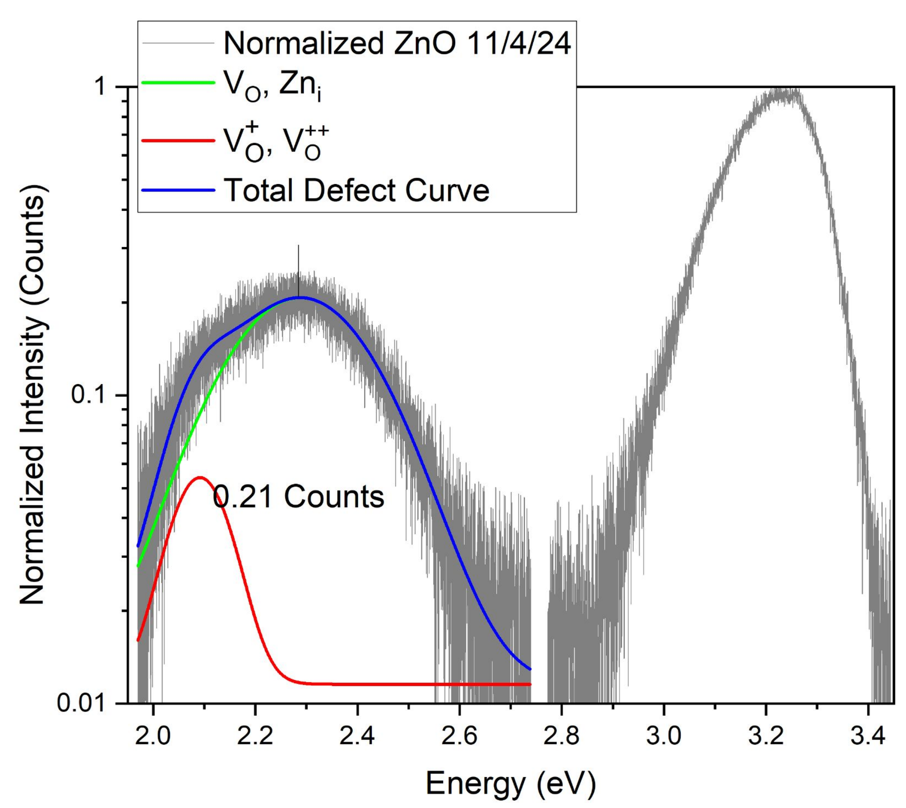


Fig. 2: A) Zinc oxide sample synthesized February 21st and when immersed in antibacterial environment it does not kill in antibacterial environment. The time between post material growth and when we started cleaning our material is 2 days.

Fig. 2: B) Zinc oxide sample synthesized November 4th and when immersed in antibacterial environment it kills the bacteria. The time between the post material growth and when we started cleaning our material is 4 days.



- Inconsistent antibacterial results for ZnO behavior in antibacterial environments atem from differences of time between synthesis and the time in which we started the cleaning process of the material
- Sampled left for 48 hrs exhibited no antibacterial efficacy whereas samples left for 96 hrs exhibited notable efficacy against *S. aureus* bacteria
- This correlates with differences in optical active defect abundances
- Specifically there exists an order of magnitude increase in the luminescence peak associated with charged oxygen vacancies in the more effective material

Further Studies

- We are planning to do a further analysis of the antibacterial activity in relevant bacterial environments. Specifically examining how the defects of our material enable the material to kill the bacteria
- Further investigation of the correlations between the relationship between pH, alkali rate, temperature, and time with their impact on the morphology of iron doped zinc oxide
- We continue fine tuning systematic methodology of synthesizing FeZnO due to inconsistent results
- Finally use of computational methods for easier quantification of varied morphologies of iron doped zinc oxide
- Also, eventually we plan on completing our theoretical model of ZnO by examining CuZnO and how is it able to kill more bacteria by destabilizing ZnO surface defects

Conclusions

- Positive results for methodology in synthesizing ZnO and FeZnO to examine the antibacterial properties of the material
- No significance difference in the morphological features of FeZnO as we increase the iron to zinc ratio
- Surface defect abundance, specifically charged oxygen vacancies, are highly influential in antibacterial action

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Zinc oxide is currently used in industry, specifically as a component of food storage, transportation, water treatment, and in the medical field to treat or prevent mild skin irritations. Currently, there is promising research showing the cytotoxicity of zinc oxide in common bacterial environments. However, the physical mechanisms describing the antibacterial action behavior of zinc oxide are still unknown. This is why our lab is focusing on examining iron-doped zinc oxide's theoretically stabilizing effect on the hexagonal wurtzite structure of zinc oxide. To confirm this, we performed comparative studies of increasing ratios of iron to zinc oxide.