Methods for the Characterization of Porphyrin thin film dielectrics

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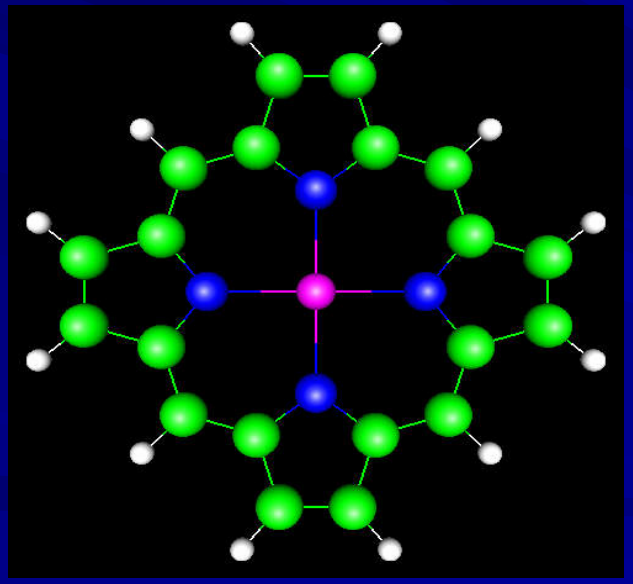


Picture from: http://altair.physics.ncsu.edu/research.htm

Background

- What are Dielectrics?

  Dielectrics are non-conducting material that have the ability to prevent electrical conduction, and at the same time are capable of absorbing electric charge.

- Different Categories of Dielectrics

  - Linear Dielectrics - $\mathbf{P}=\varepsilon_o\chi_e\mathbf{E}$
  - Non – Linear dielectrics

Motivation

- Dielectrics are used to create capacitors which in turn tend to be very important voltage/energy sources
- Equation for Capacitance

$$C = \epsilon_r \epsilon_o S/d$$

- High Energy Capacitors are implemented in the following
  - Pulse Powered Applications
  - Electrical vehicles, aircraft, and ships
  - Future Military Equipment

Research Goal

- Create different mixtures of ferroelectric particles with porphyrin to create high energy capacitors.

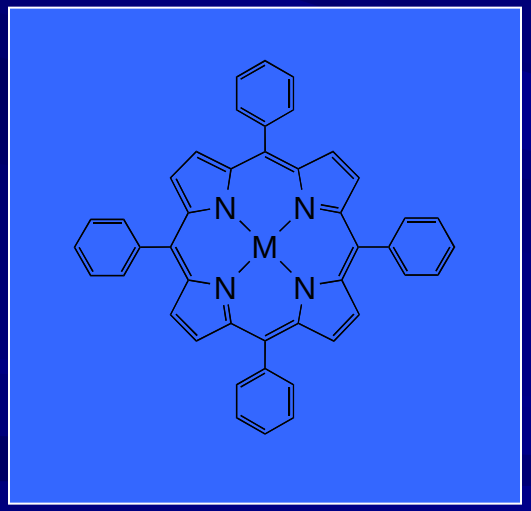
Project goals

- Discover potential methods in characterizing porphyrin thin films

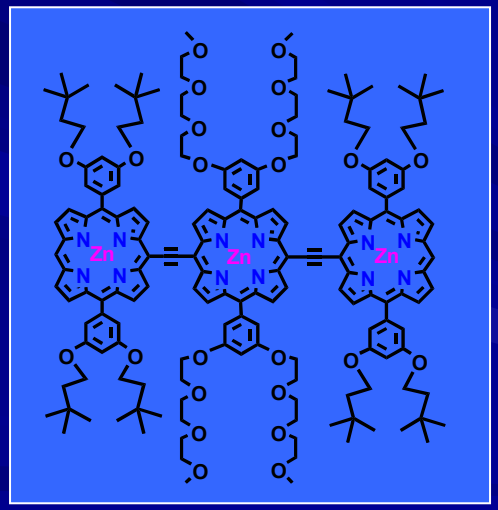
- Measure dielectric response of different samples of porphyrin

Porphyrin

- Organic Compounds that occur widely in nature
- Contain a central Metal Atom
- Exhibit high dielectric strengths, and are highly polarizable



Tetraphenyporphyrin (TPP)



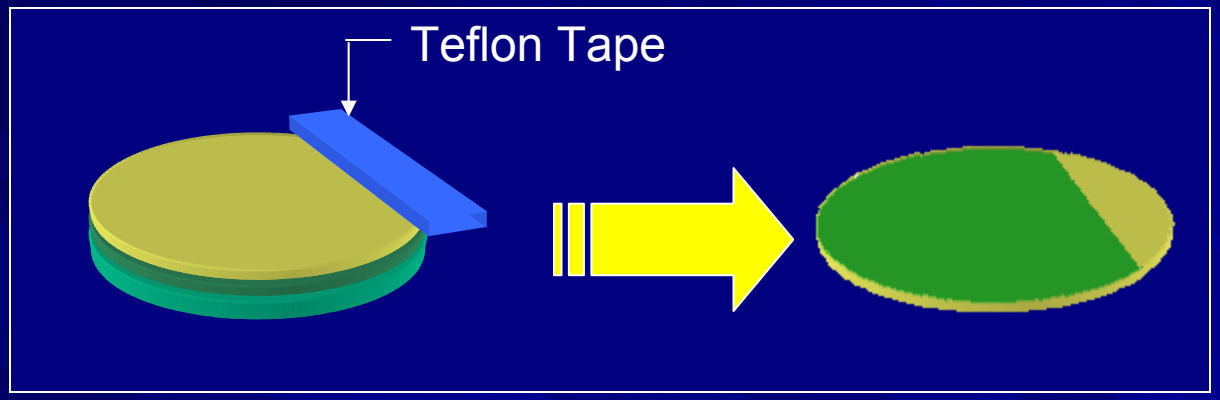
Ethyne-Bridged Porphyrin Oligomers (DDD)

Methods

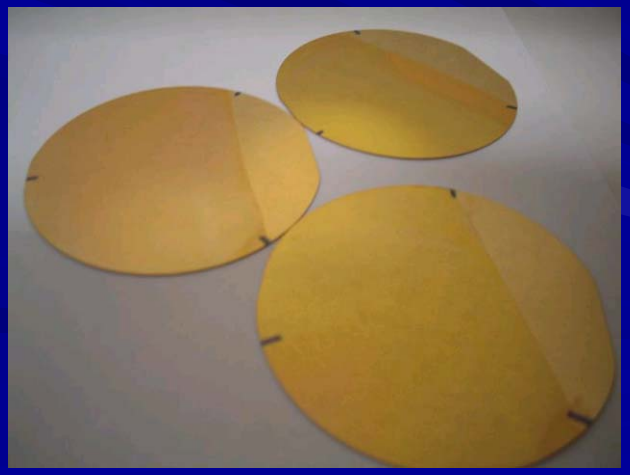
- Spin Coating, Capacitance device
- Indium Tin Oxide (ITO) Sandwich Cells, e-beam evaporation
- Photolithography

Spin Coating

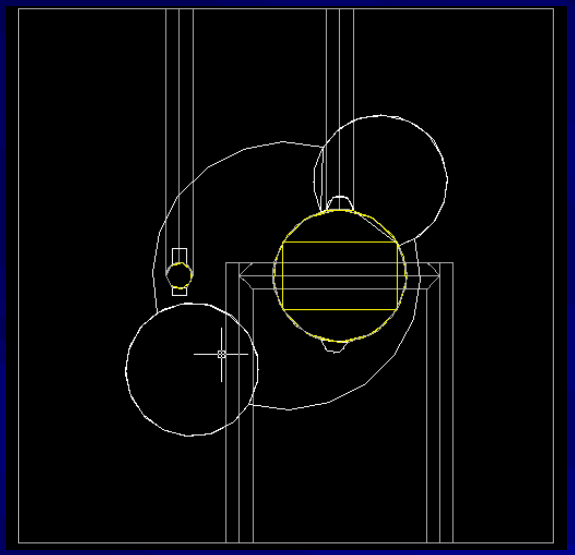
- Wafer Process Flow (Spin Coating)

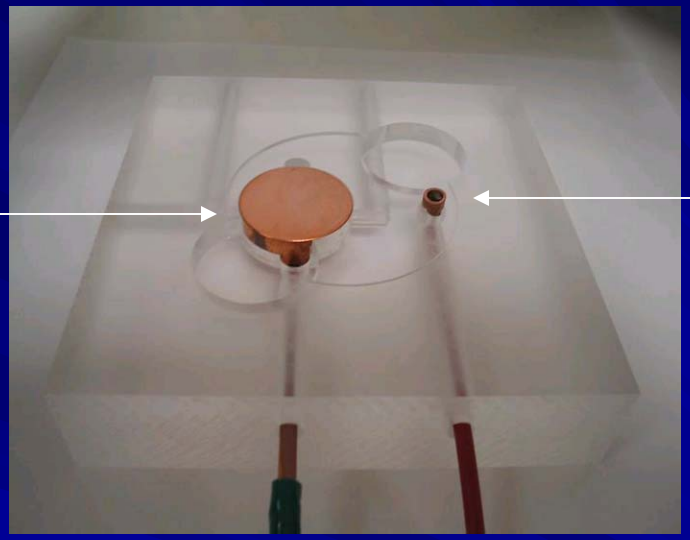


- Silicon substrate
- Silicon oxide
- Au (Gold)
- ZnTPP/ ZnDPP polypropylene mixture



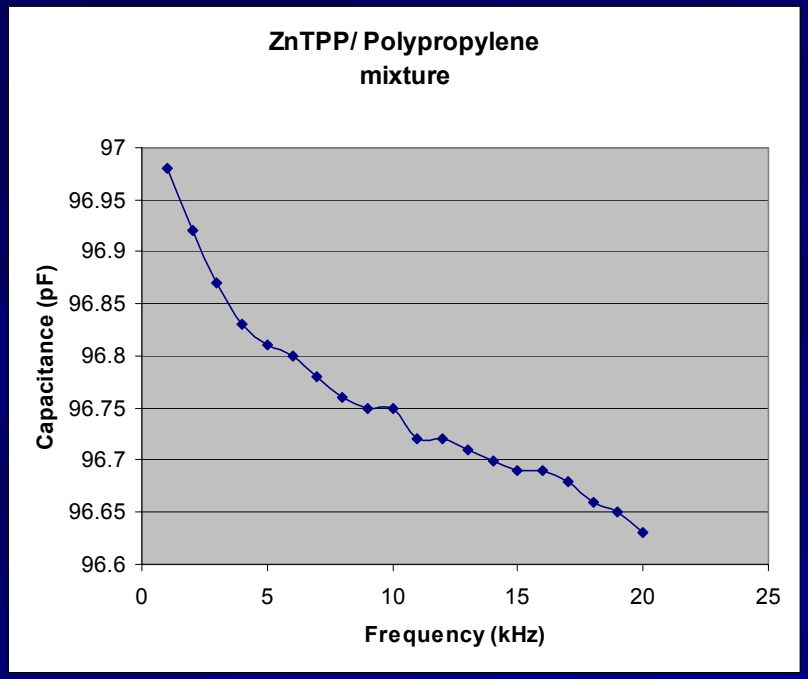
Capacitance Device

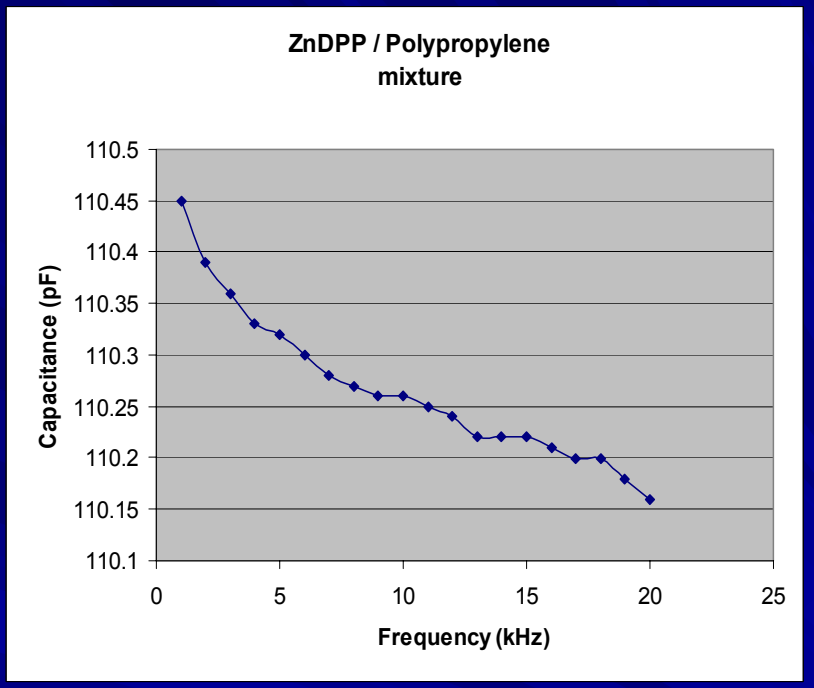




- Wafer is placed face down onto capacitance device
- Foam cushion is placed on back of wafer and a 100g weight establishes pressure

Discoveries



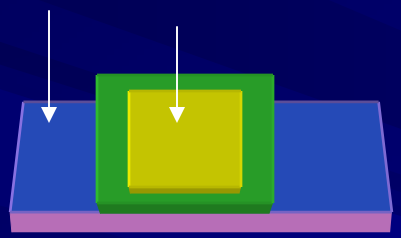


- Very low capacitance due to pressure established contacts
- Thickness not measured due to complications
- Estimate of thickness 800nm~1 micron, $\varepsilon_{mixture}<1$ unlikely

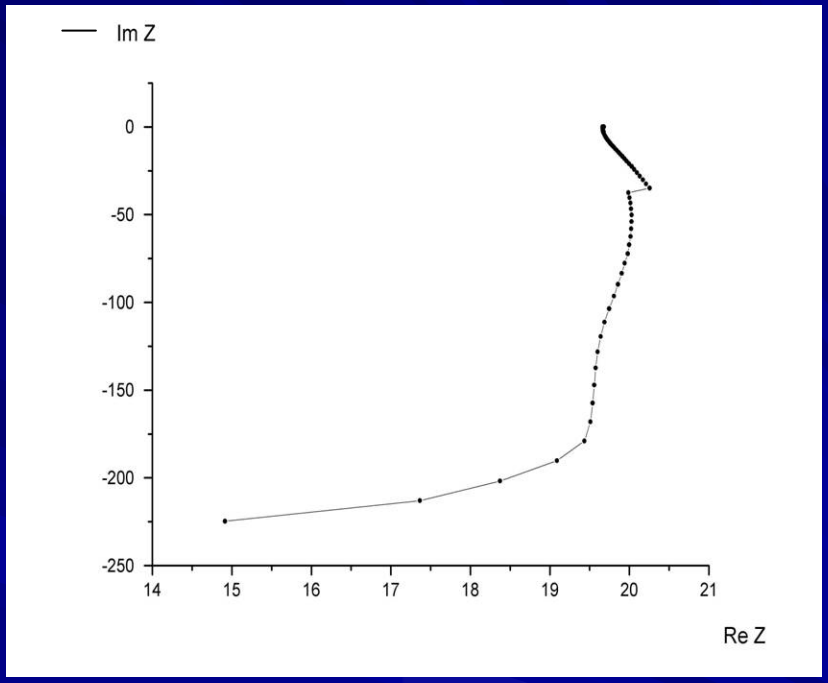
Indium tin oxide substrate

- Indium tin oxide substrate

Contacts

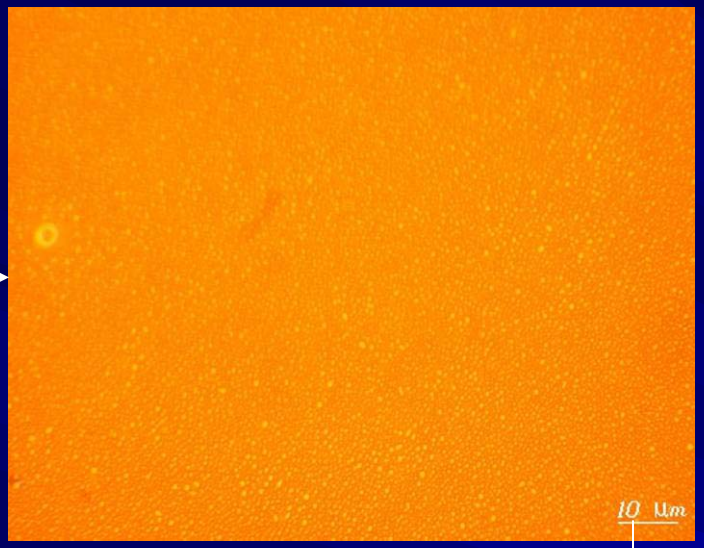


- Indium Tin Oxide Substrate
- Porphyrin (ZnTPP) (spin coating)
- Gold contacts (E-beam Evaporation)

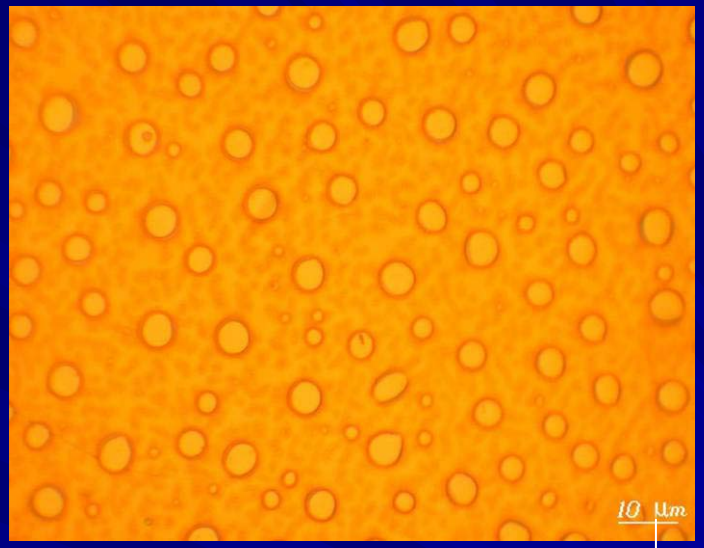


- Shorts across Contacts

Discoveries



Zinc-diphenyl-porphyrin [10 um]



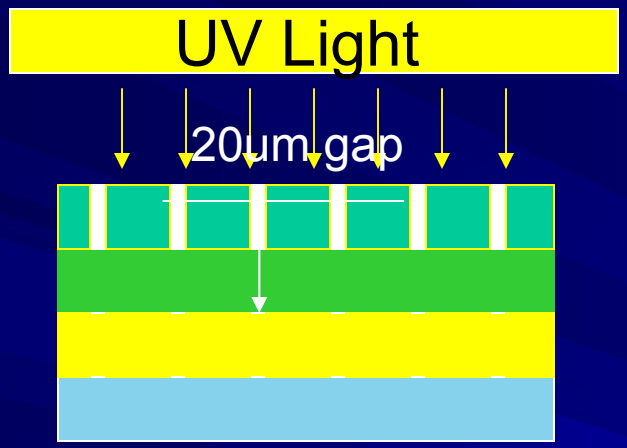
Zn ethyne bridged trimer [10 um]

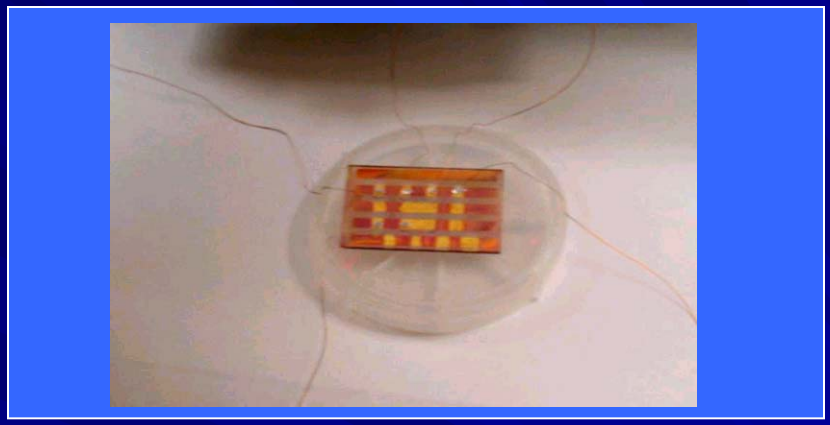
(DDD)

- Pinholes due to aggregates
- Non-Uniformity

- Solutions performed
  - Explore different porphyrin media
  - Explore Self Healing process of porphyrin

Photolithography

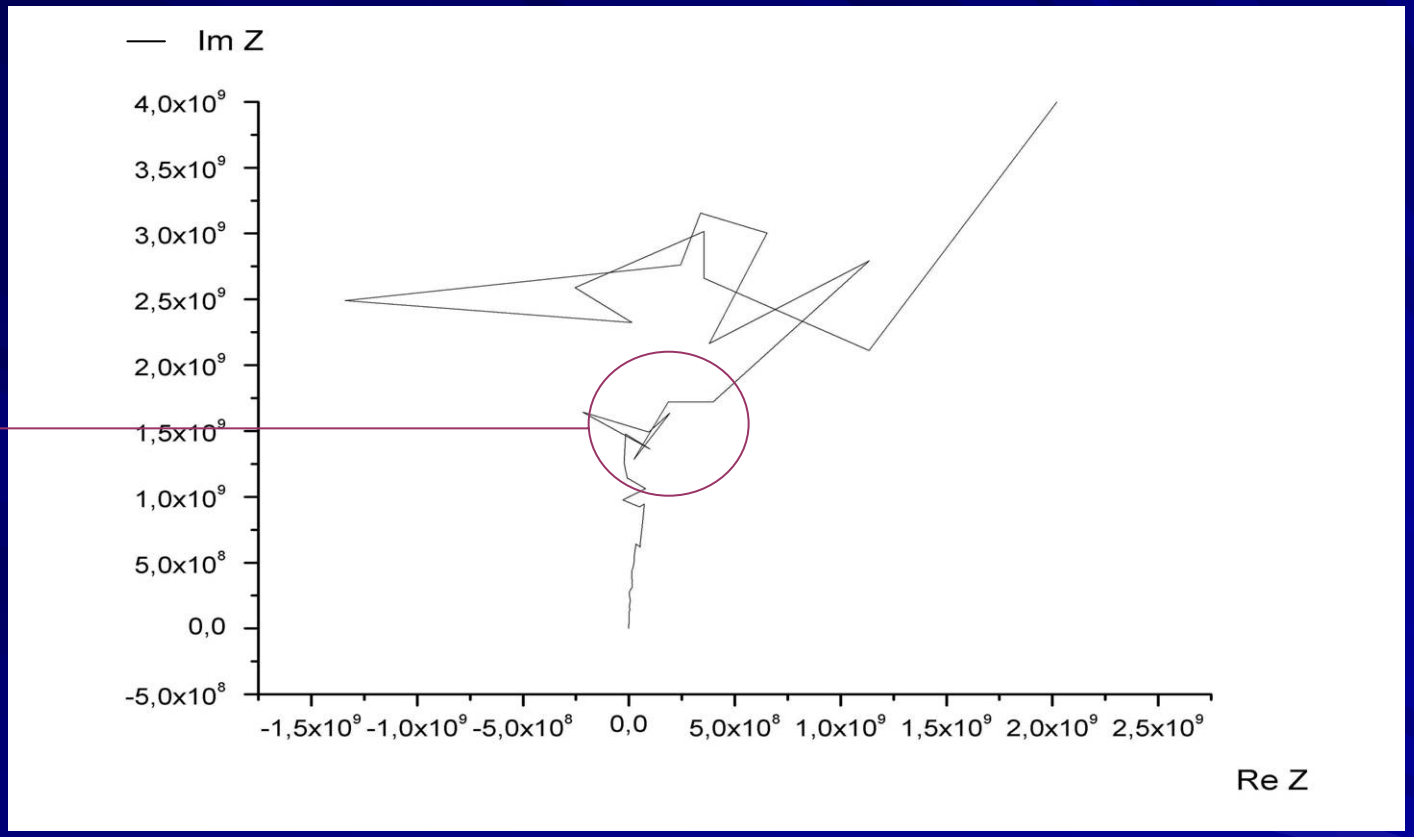




Dielectric covered substrate (ZnTPP)

- Mask
- Positive Resist
- Au (Gold)
- Glass Substrate

Photolithography contd.



- Out of range of equipment
- Capacitance normalized ~ 4pF $\varepsilon_r > 100$ (not likely)
- Theoretical calculations, $\varepsilon_r \sim 10$ ⟶ 3.32fF

The Next Step

- Creating uniform films
  - Explore different solvents
  - Use higher concentrations of porphyrin (Even though it is an expensive process)
  - Strengthen filtering during spin coating
- Future Exploration
  - Create different mixtures of ferroelectric particles with porphyrin

Acknowledgements

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