Methods for the Characterization of Porphyrin thin film dielectrics

Matthew Saucedo
Advisor: Dr. Jorge J. Santiago-Aviles

Picture from: http://altair.physics.ncsu.edu/research.htm
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 - \( P = \varepsilon_0 \chi_e E \)
- Non – Linear dielectrics
Motivation

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

- Equation for Capacitance

\[ C = \varepsilon_r \varepsilon_0 \frac{S}{d} \]

- 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

Tetraphenylporphyrin (TPP)  
Ethyne-Bridged Porphyrin Oligomers (DDD)
Methods

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

- Silicon substrate
- Silicon oxide
- Au (Gold)
- ZnTPP/ ZnDPP polypropylene mixture
- 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, $\varepsilon_{\text{mixture}} < 1$ 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

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Graph showing the relationship between real (Re Z) and imaginary (Im Z) components of impedance.
Discoveries

- Pinholes due to aggregates
- Non-Uniformity

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

Zinc-diphenyl-porphyrin [10 um]

Zn ethyne bridged trimer [10 um]

(DDD)
Photolithography

- UV Light
- 20μm gap
- Mask
- Positive Resist
- Au (Gold)
- Glass Substrate

Dielectric covered substrate (ZnTPP)
Out of range of equipment

Capacitance normalized $\sim 4 \text{pF}$ $\varepsilon_r > 100$ (not likely)

Theoretical calculations, $\varepsilon_r \sim 10 \rightarrow 3.32 \text{fF}$
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
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