Influence of Pore Size on Dielectric Breakdown in Plasma-polymerized Films

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Introduction

Phenomena involved in dielectric breakdown in solids:

- **Electron injection by Fowler-Nordheim field emission**
- **Gas state partial discharge (electron avalanches) in gas-filled pores**
- **Solid state electron avalanches**
- **Bond scission**
- **Charge migration by hopping**
- **Light emission (solid state electroluminescence and plasma state light emission)**

Background

Pore size is expected to influence dielectric breakdown in plasma-polymerized films since it influences:

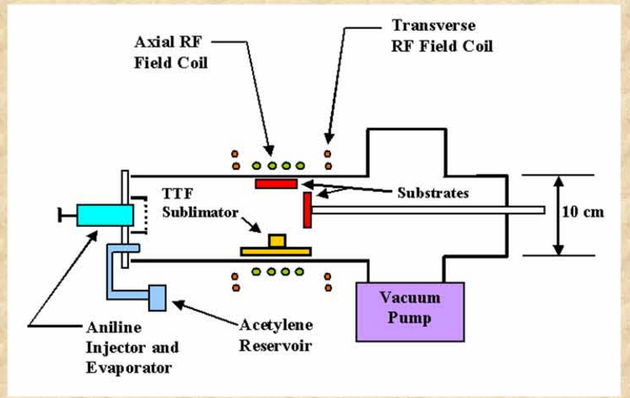
- ➢ **Partial discharge**
- ➢ **Hopping**
- ➢ **Bond scission**
- ➢ **Electric field enhancement inside the pore**

Other models that might be pertinent in this study are:

- ❖ **electroluminescence in porous silicon**
- ❖ **quantum confinement as found in carbon nanotubes, quantum dots and quantum wires**

Setup

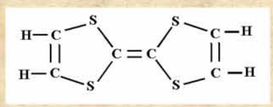
Plasma-polymerization:



Precursor Molecules:

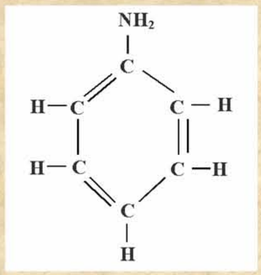
Acetylene, C_2H_2

State at STP is Gas



Tetrathiafulvalene, $C_6H_4S_4$

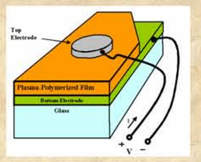
State at STP is Solid



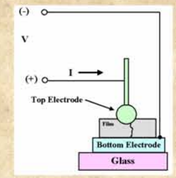
Aniline, C_6H_7N

State at STP is Liquid

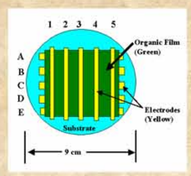
Electrode Assemblies:



Electrode Type: Conducting Epoxy
Primary Use: Impedance Spectroscopy



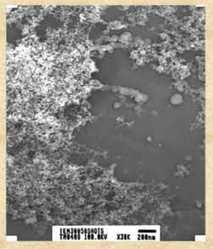
Electrode Type: Pressure
Primary Use: Dielectric Breakdown



Electrode Type: Matrix
Primary Use: VI Characteristics

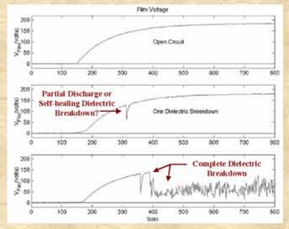
Results

Plasma-polymerized Aniline On Indium Tin Oxide (ITO)

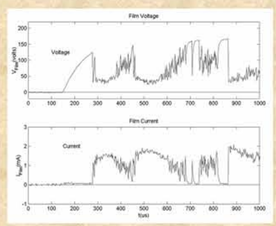


Transmission Electron Microscopy Plasma-polymerized Aniline

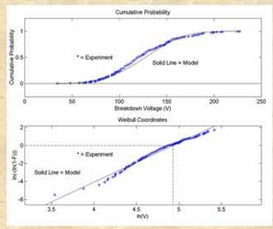
Results from Pressure Contact:



Voltage Oscillograms



Voltage and Current Oscillograms

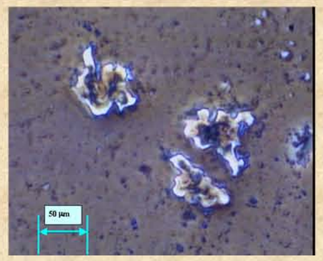


Distribution of "First Breakdown Events"

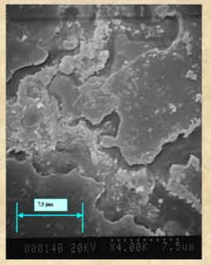
$$f_W(V) = \frac{bV^{b-1}}{V_{CH}^{\,b}} \exp\left(-\frac{V^b}{V_{CH}^{\,b}}\right)$$

$$F_W(V) = \int_0^V f_W(x)dx = \left[1 - \exp\left(-\frac{V^b}{V_{CH}^{\,b}}\right)\right]$$

Weibull Distribution



Optical Microscope Image of Dielectric Breakdown Sites (Aniline)



SEM Micrograph of Dielectric Breakdown Sites (Aniline)

Conclusions

- **Distribution of dielectric breakdown voltages for sub-micron plasma-polymerized aniline films can be accurately modeled with the Weibull distribution.**
- **Damage due to dielectric breakdown occupied sites with scale lengths of about 50 µm.**
- **Characteristic breakdown voltage was 139 volts for film thickness of about 300 nm ($E_{CH} \approx 4.6 \times 10^8$ V/m).**

Future Work

- **Characterize porosity in plasma-polymerized acetylene, aniline and tetrathiafulvalene films.**
- **Apply physical gas adsorption (BET) to characterize pores.**
- **Make electrical measurements of each film type and correlate with porosity properties.**
- **Characterize light emission associated with precursor events leading to dielectric breakdown.**

ACKNOWLEDGEMENT

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