

# Bimodal Functionalized Silica Nanoparticle/Epoxy Composites with Improved Dielectric Breakdown Strength

Timothy M. Krentz  
Graduate Student

*Department of Materials Science and Engineering  
Rensselaer Polytechnic Institute, Troy, NY, USA*

Dr. Linda Schadler and Dr. Keith Nelson

Dr. Brian Benicewicz, Dr. Henrik Hillborg and Dr. Su Zhou

ABB

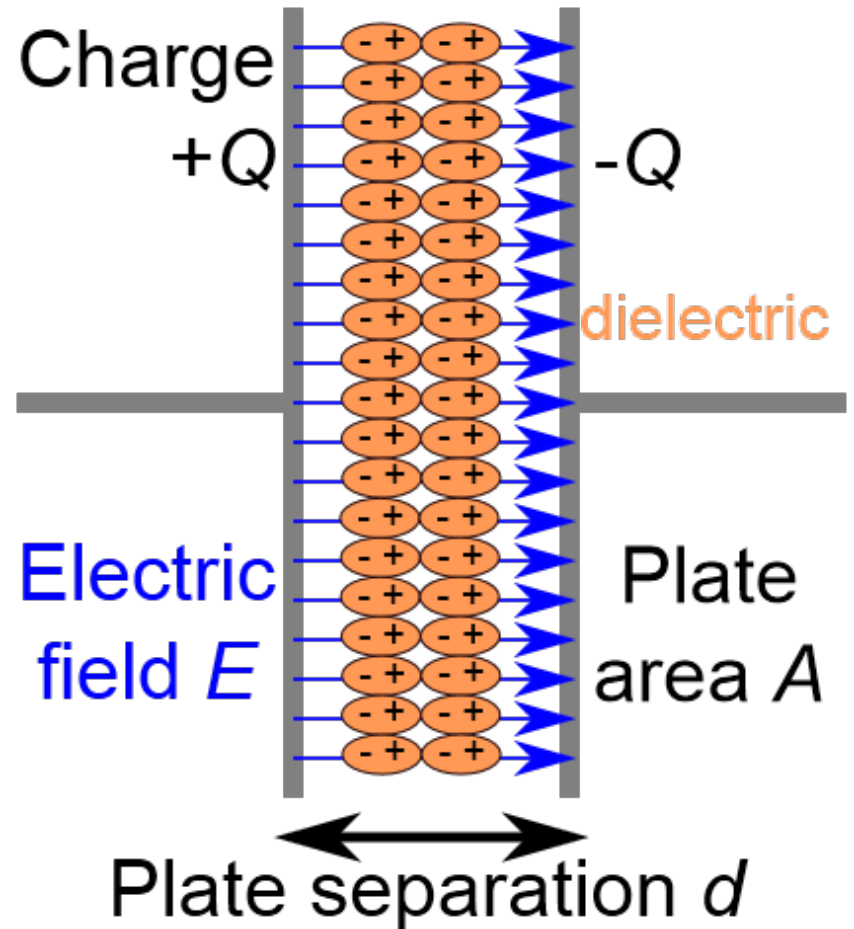


**Rensselaer**

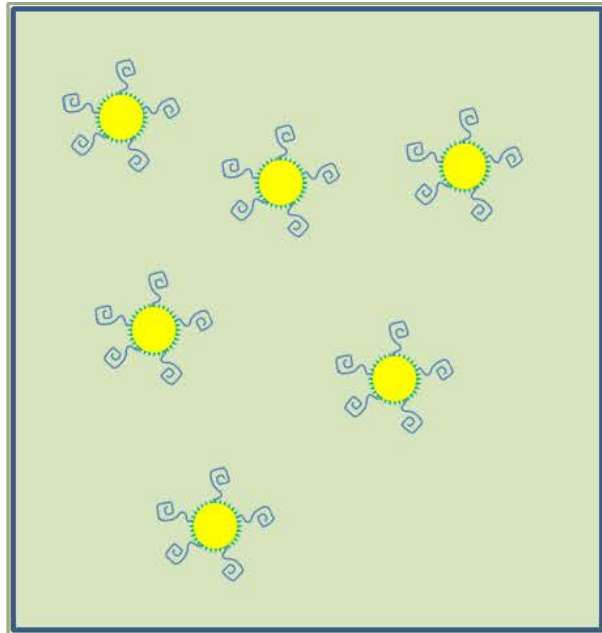
2013 Rensselaer Nanotechnology Center Research Symposium  
Wednesday, November 6, 2013

# Capacitor Films

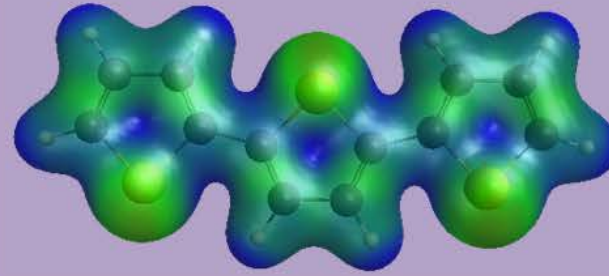
$$\text{Energy} = \frac{1}{2} \epsilon A d V^2$$



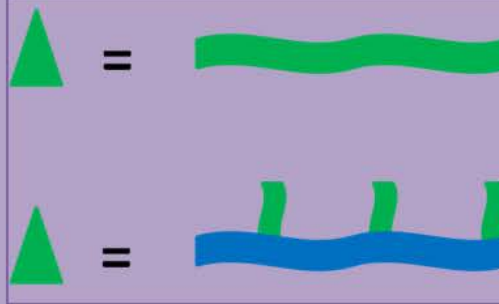
# Bimodal Brush Nanoparticles



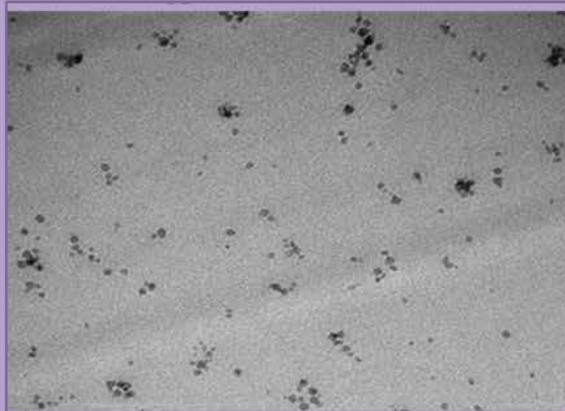
Dielectric Nanocomposite



Electronic Character of Brush

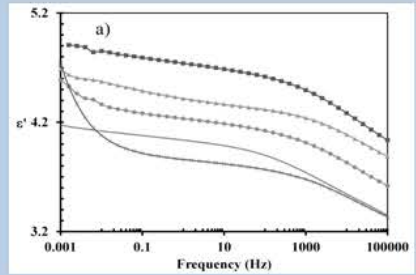
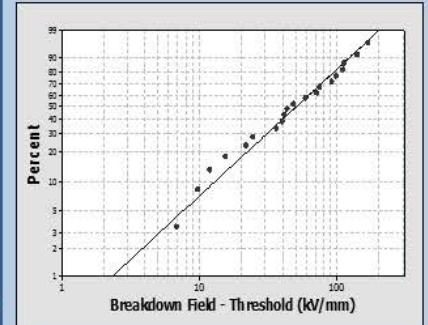


Brush Structure



Dispersion State

## Breakdown Strength



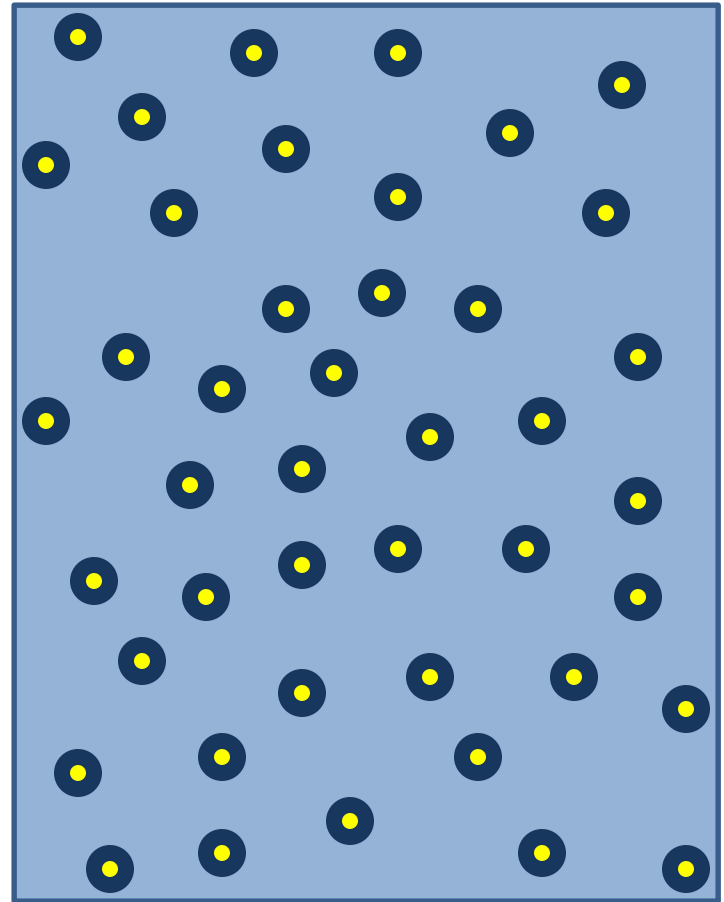
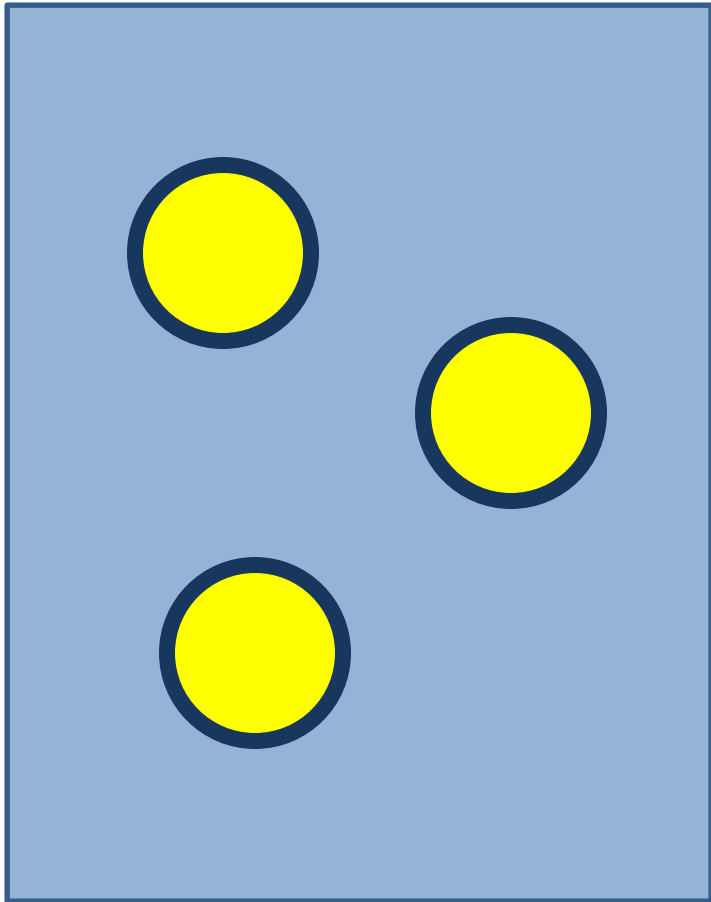
Permittivity

# Dielectric Breakdown

- A field is applied to an insulator
- Sufficiently high fields will provoke a large increase in current
- Lightning is the classic example
- In solids, permanent damage is caused

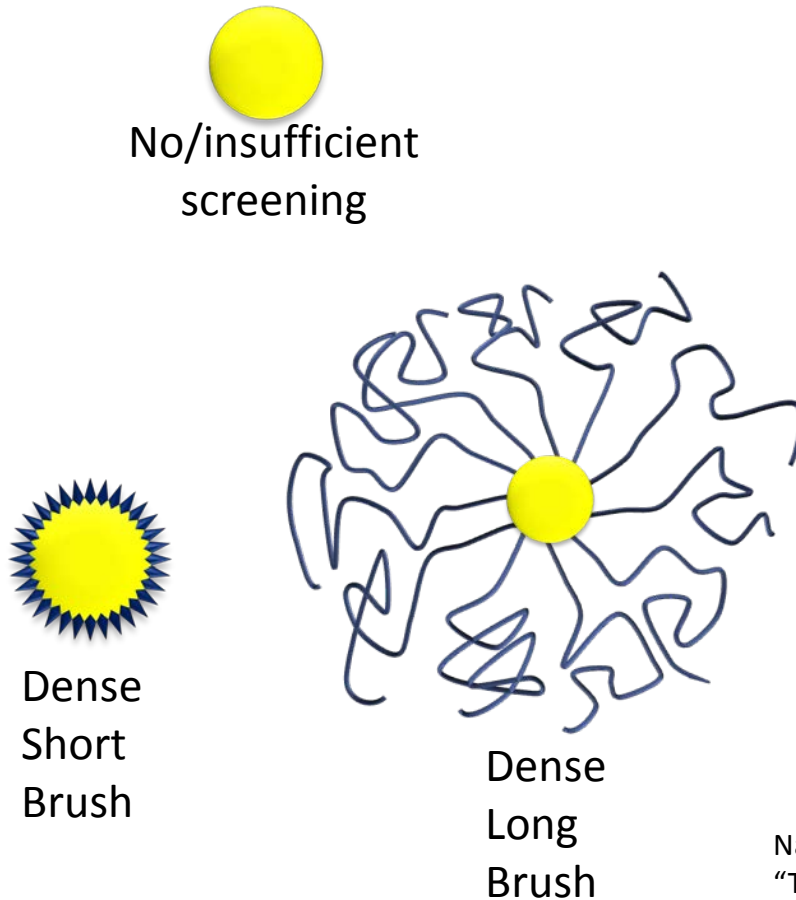


# Nanocomposite Dielectrics

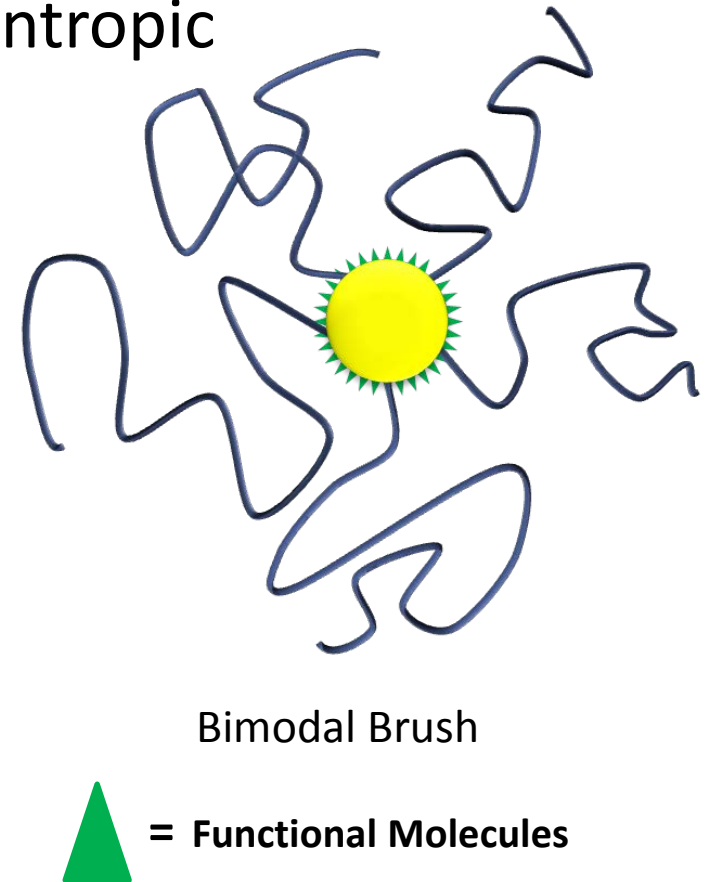


# Nanocomposite Dielectrics

- Enthalpic



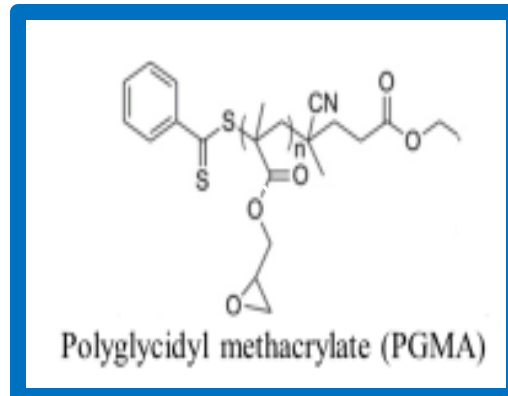
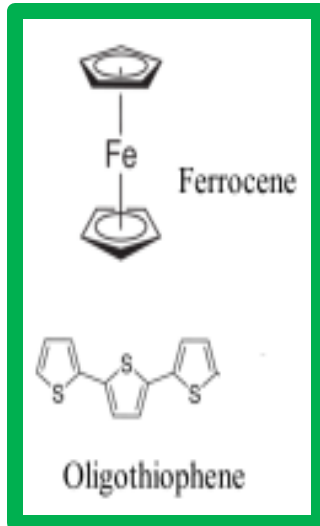
- Entropic



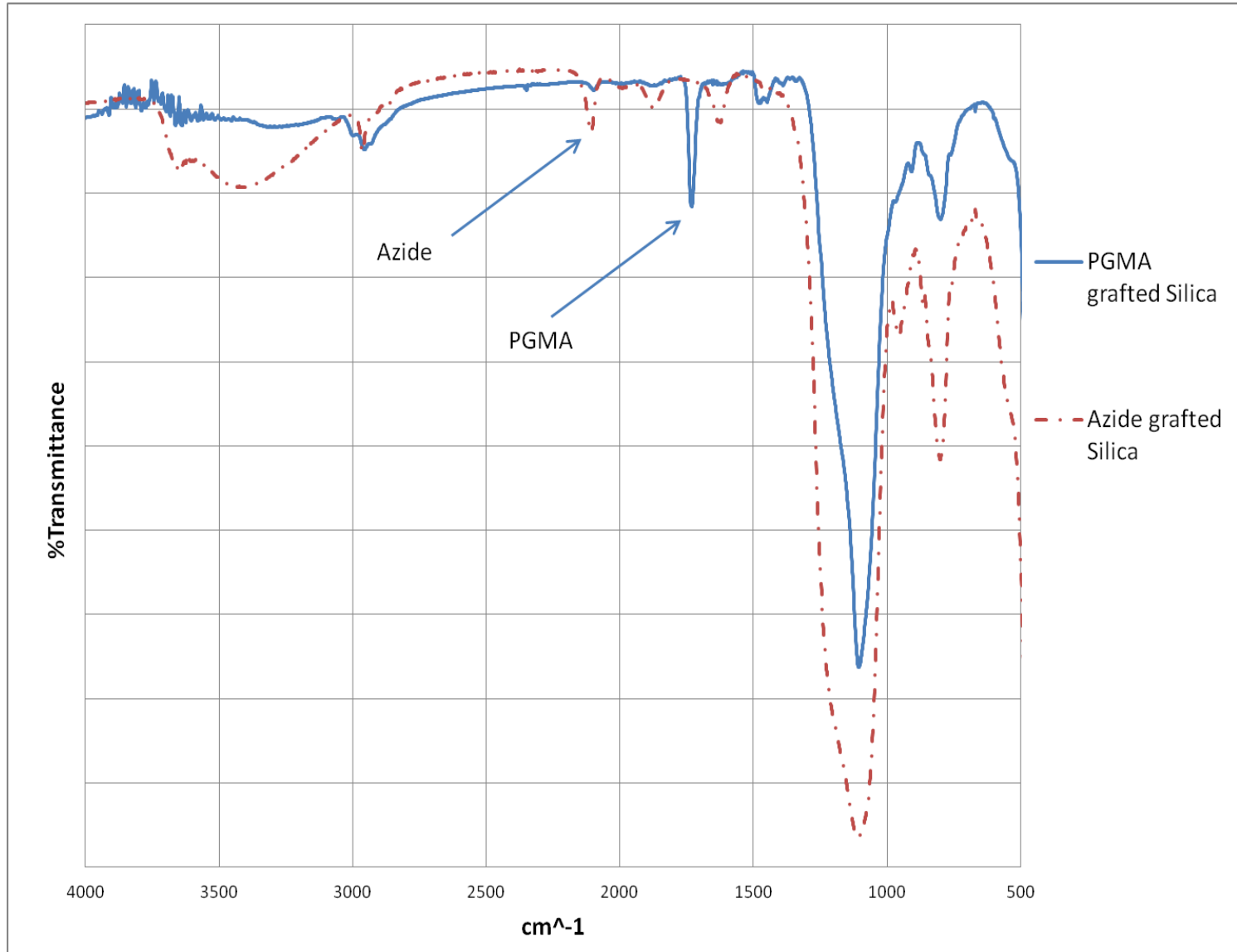
Natarajan, Bharath, Tony Neely, and Atri Rungta. 2013. "Thermomechanical Properties of Bimodal Brush Modified Nanoparticle Composites." *Macromolecules* (46): 4909–4918.

# Filler Design

- Bimodal Brush
  - Short chains for functionality
  - Long chains for matrix compatibility

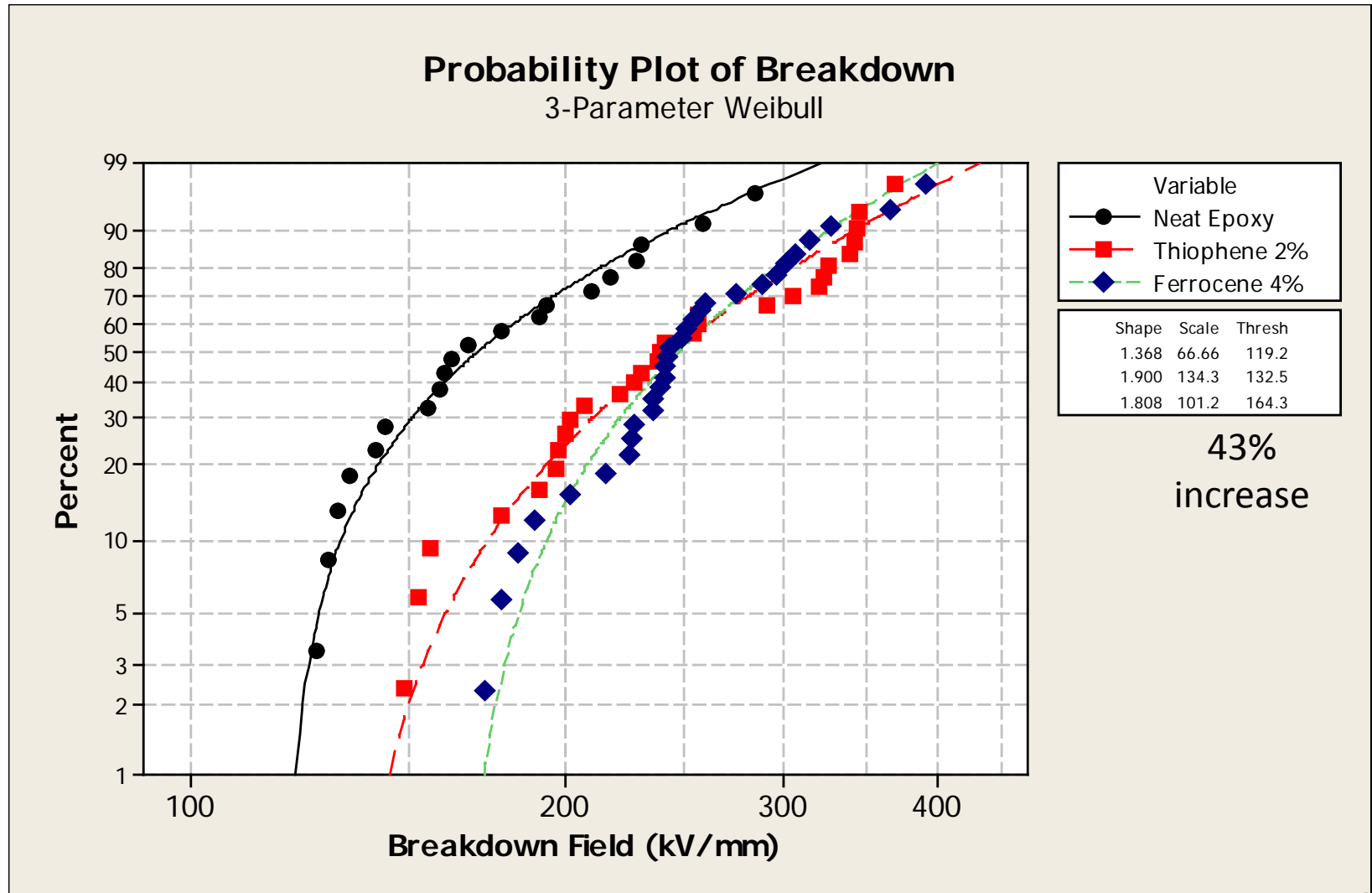


# FTIR– Surface Modification

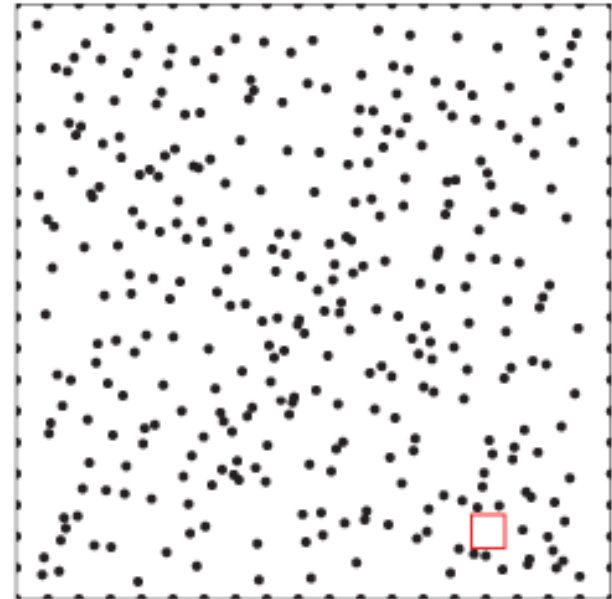
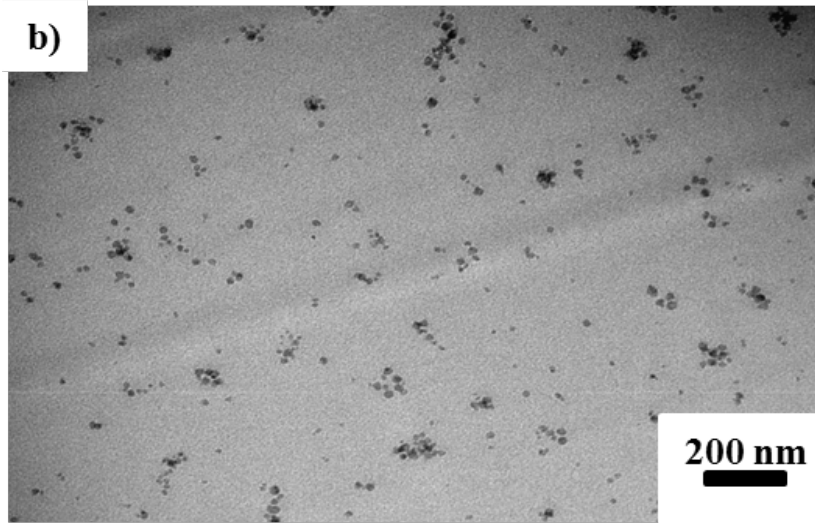




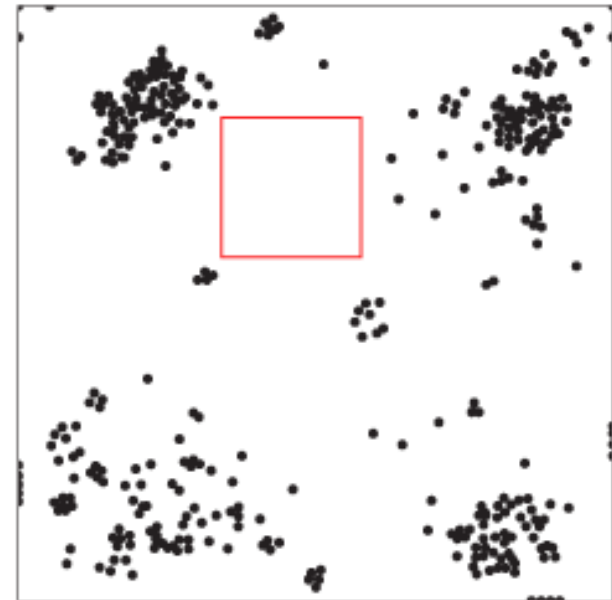
# Effect of Electroactive Short Brush on DBS



# Dispersion



b)  $D = 30$  nm;  $x_f = 6\%$ ;  $L_f = 105$  nm ■ 75 nm



d)  $D = 30$  nm;  $x_f = 6\%$ ;  $L_f = 459$  nm ■ 75 nm

H. S. Khare and D. L. Burris, "A Quantitative Method for Measuring Nanocomposite Dispersion," *Polymer*, vol. 51, pp. 719-729, FEB 5, 2010.

# DBS

Filler	NA	Bare Silica	Silica +PGMA	Silica+PGMA +Thio	Silica+PGMA+Ferro		
<b>Loading</b>	0%	2%	2%	2%	1%	2%	4%
<b>Shape (<i>k</i>)</b>	1.4	1.6	1.4	1.9	1.5	1.4	1.8
<b>DBS (kV/mm)</b>	185	182	213	266	236	235	265
<b>% Change</b>	-	-1%	15%	43%	27%	27%	43%
<b>L<sub>f</sub></b>	NA	900	250	250	-	550	300