

**HARVEY  
MUDD  
COLLEGE**

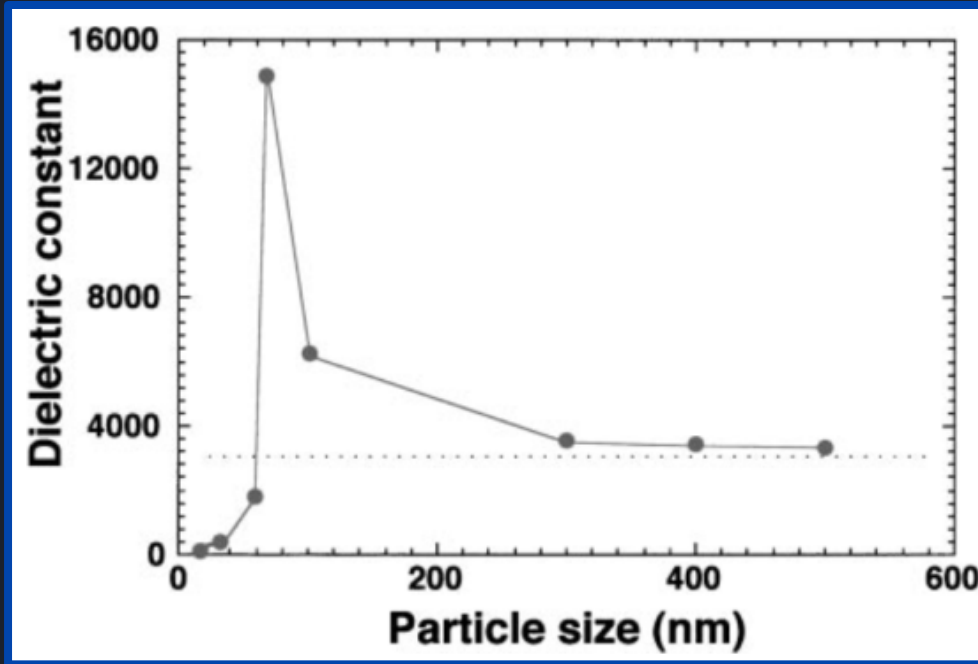


# Measuring the Permittivity of Ferroelectric Nanoparticles in an Epoxy Composite

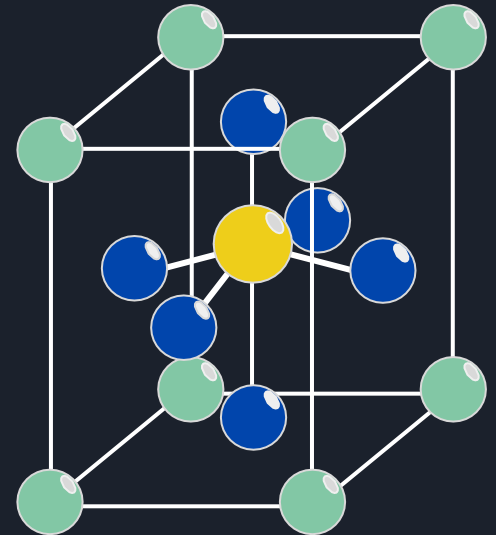
[Presenter name(s), credit collaborators]

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$$\epsilon_{BTO}(r) = ?$$

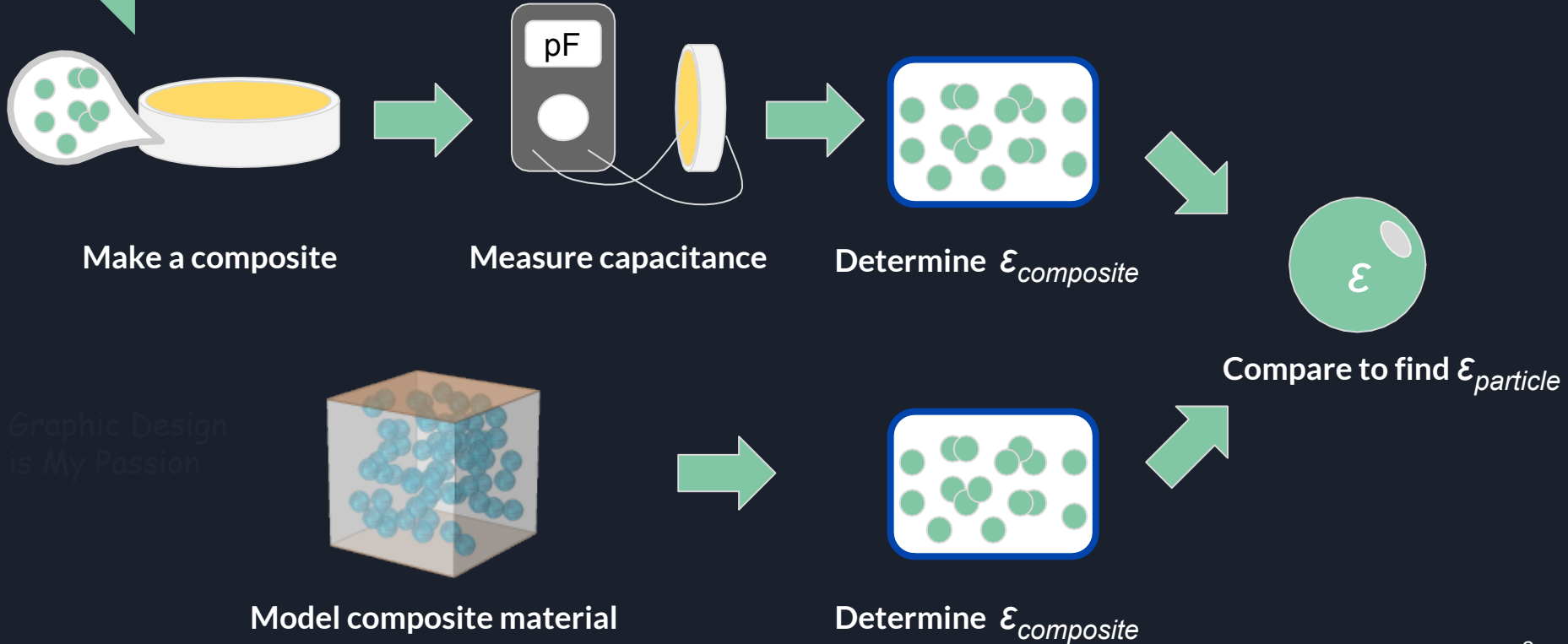


Satoshi Wada et al 2003 Jpn. J. Appl. Phys. 42 6188

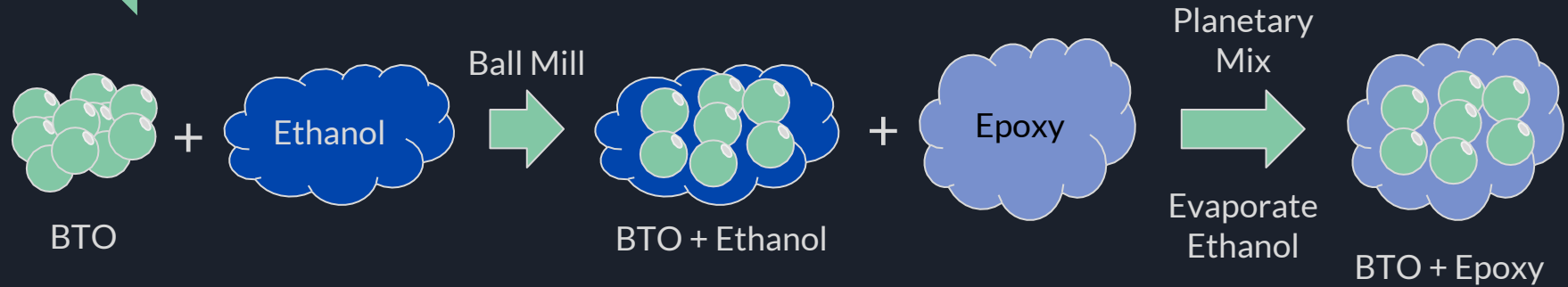


-  Barium
-  Titanium
-  Oxygen

# The Plan

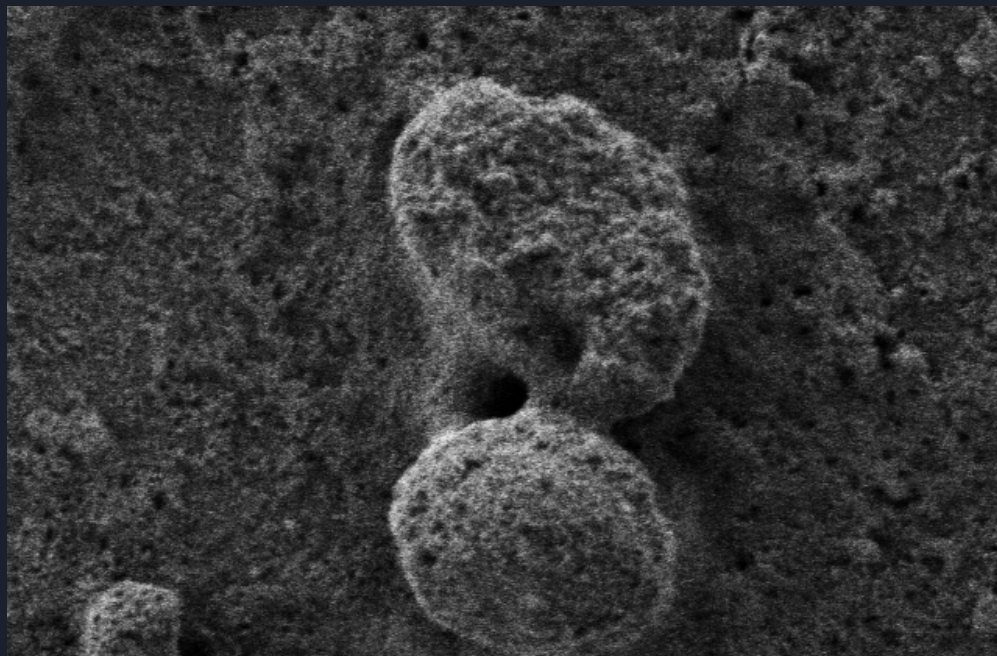


# Preparing Composite Sample



# Particles as Received

Donated by  
Sakai Chemical



500  $\mu\text{m}$



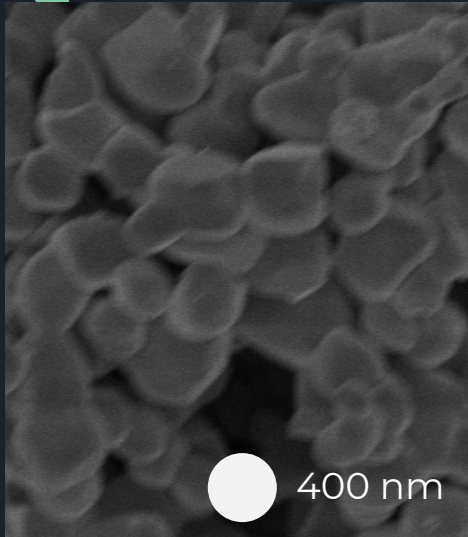
# Ball Mill Breaks Agglomerates

Contact:

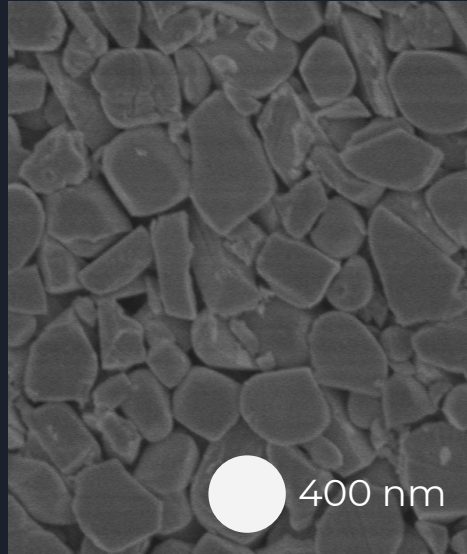
Grinding Ball Movements



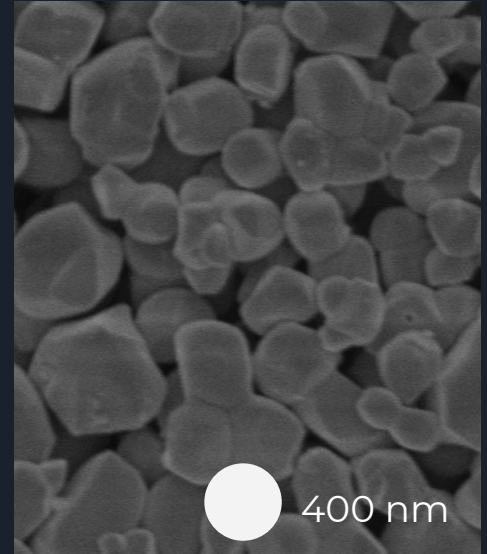
# Before and After Ball Milling



As received



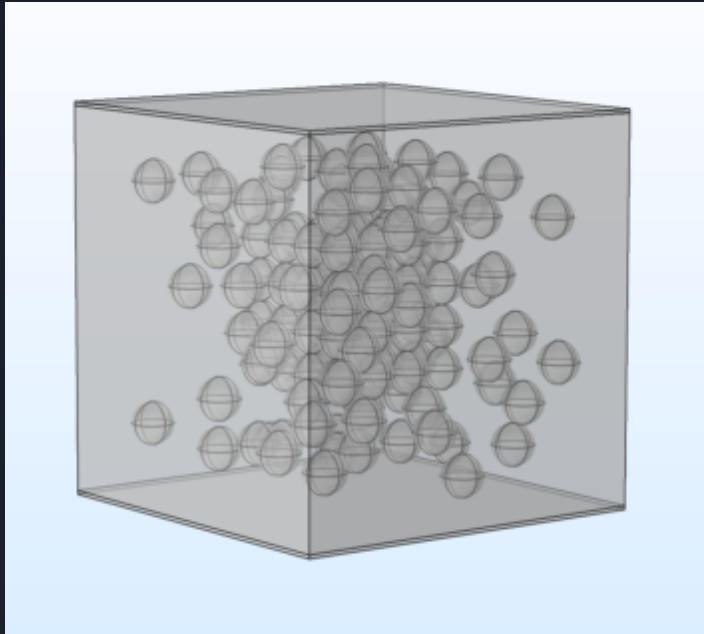
300 RPM  
75 minutes



150 RPM  
90 minutes



# Modeling BTO Composites

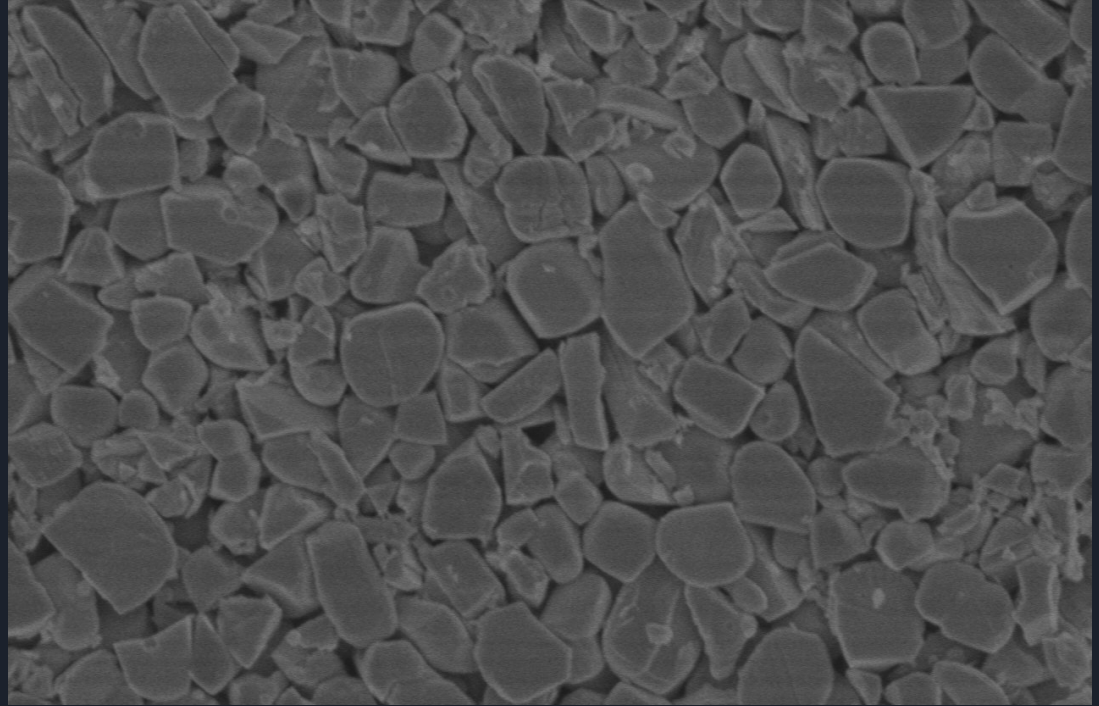
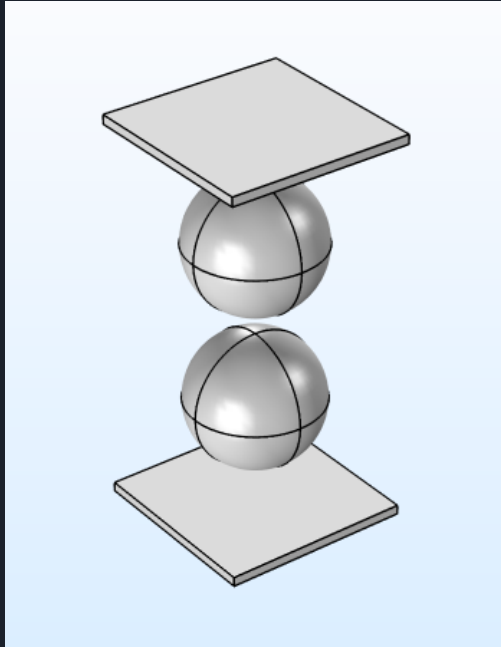


- Vary degree of agglomeration and number of dispersed particles
- Attempt to match measured dielectric constant

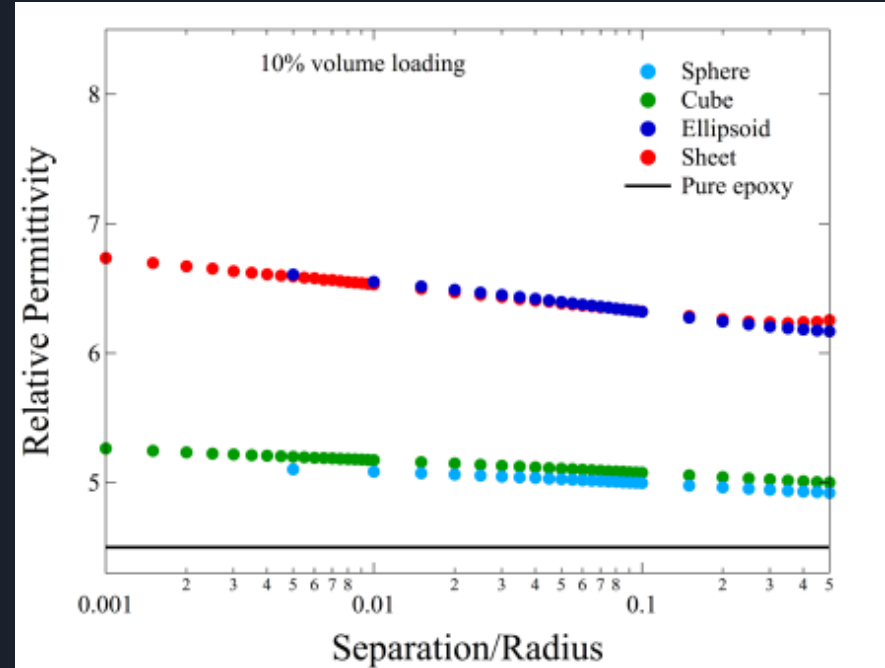
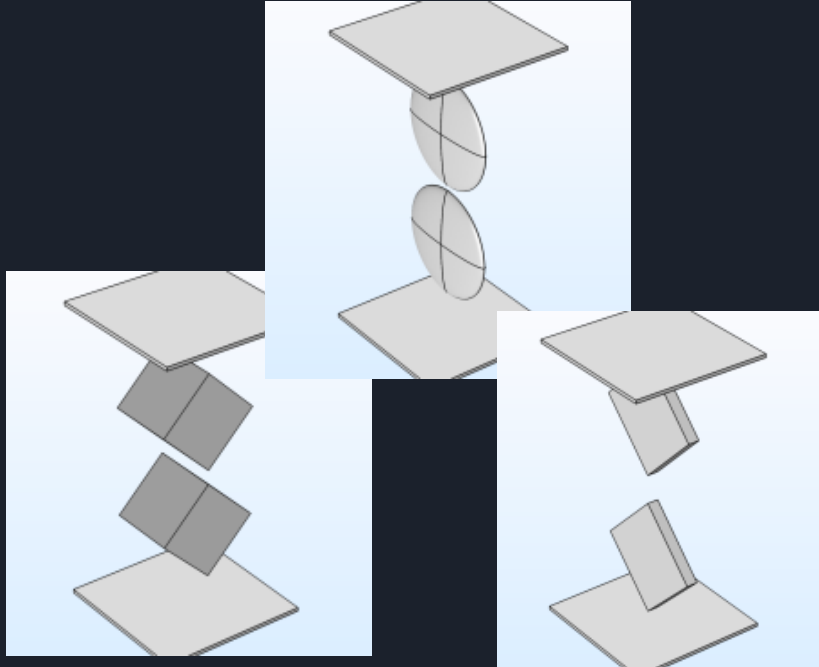




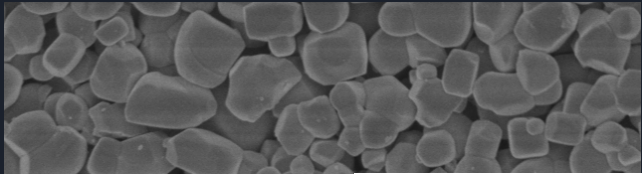
# Two Particle Model



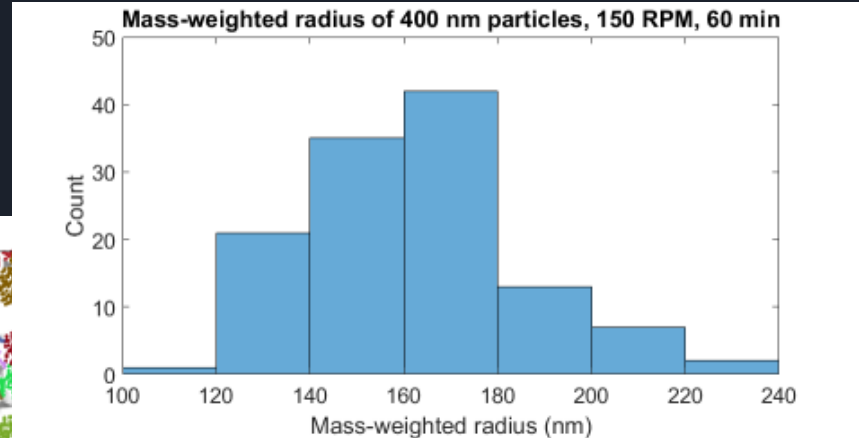
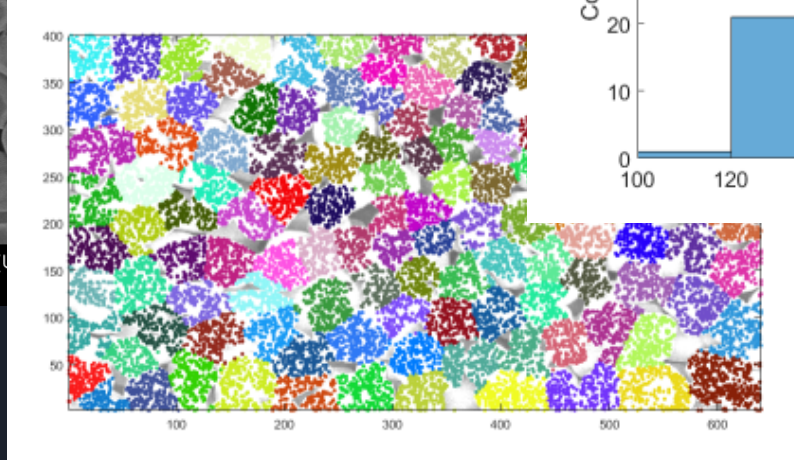
# Relative Dimensions Matter More Than Edges



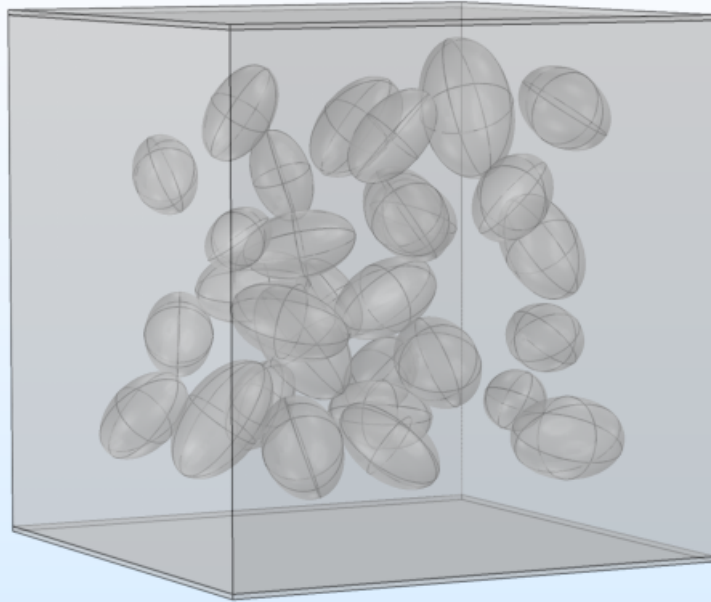
# Extracting Radii From SEM



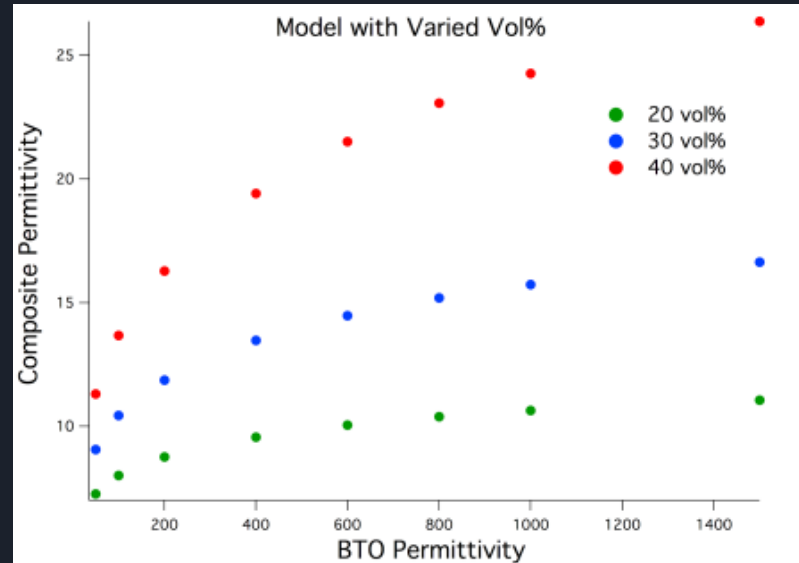
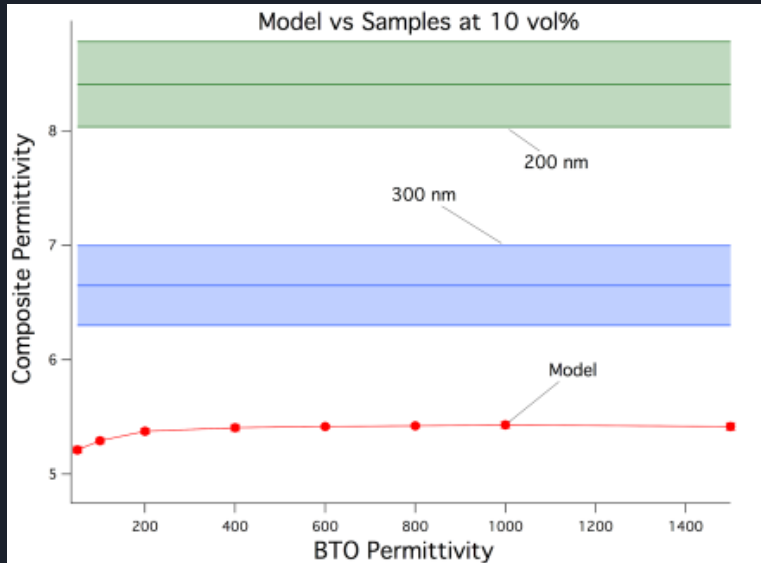
POM/HMC 2.0kV 4.7mm x20.0k SE(U)



# Implementing Randomized Ellipoids



# Model Currently Not Sensitive to Measured Values





# Data so far

● 2016-17 samples

● Matched to simulation

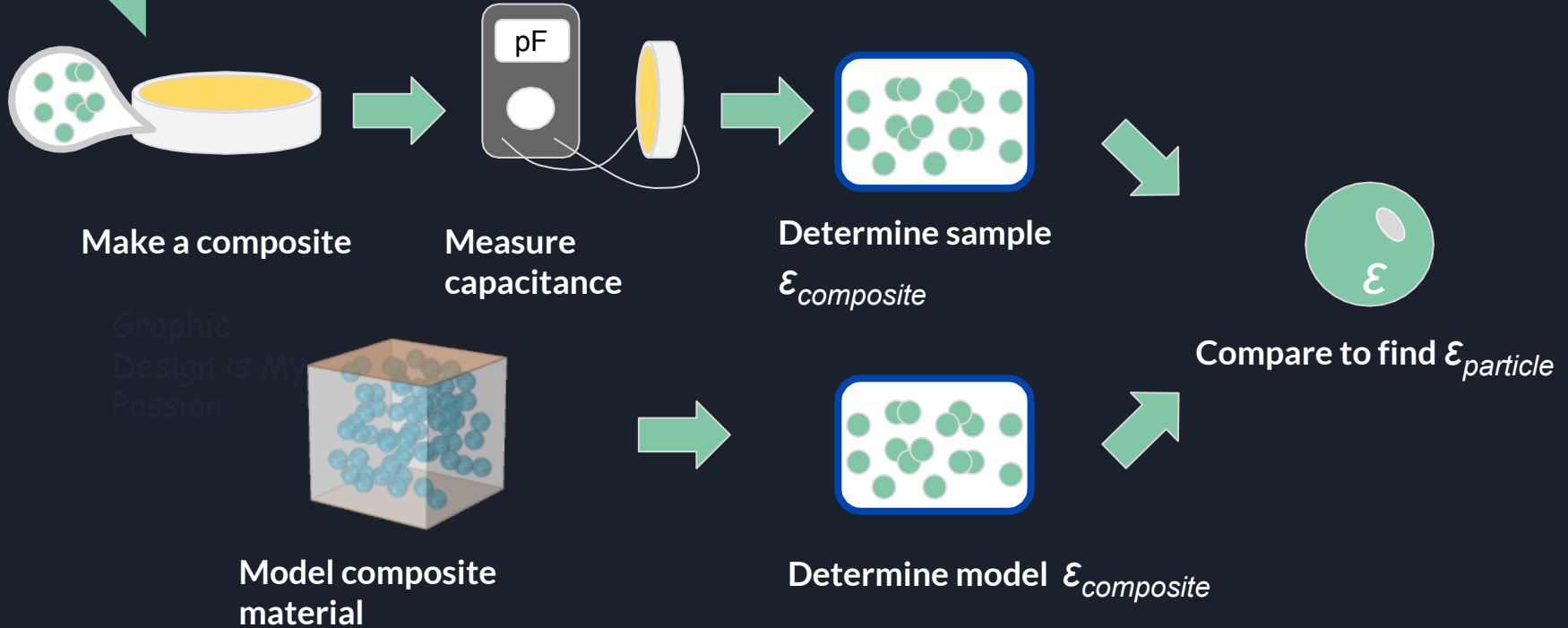
	100 nm	200 nm	300 nm	400 nm	500 nm
10 vol%		7.4 +/- 0.1	7.0 +/- 0.1		6.8 +/- 0.1
20 vol%		10.4 +/- 0.1			8.0 +/- 0.1



# Future work

- Manufacture higher vol% samples
- Improve dispersion during manufacturing
- Limit damage to particles during ball milling
- Extract particle dimensions from SEM images
- Implement particle geometries in full model

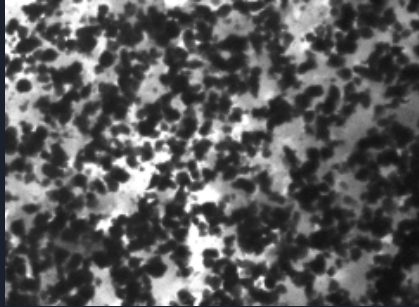
# Questions?



Special thanks: Prof. Van Ryswyk, Prof. Haskell, Dr. Todd Monson, Logan Rubin, and David Vargas

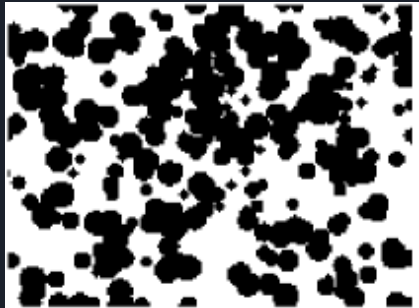


# Reconstructing Samples



Original TEM

—  
1  $\mu\text{m}$



Final Reconstruction

