Dielectric Properties

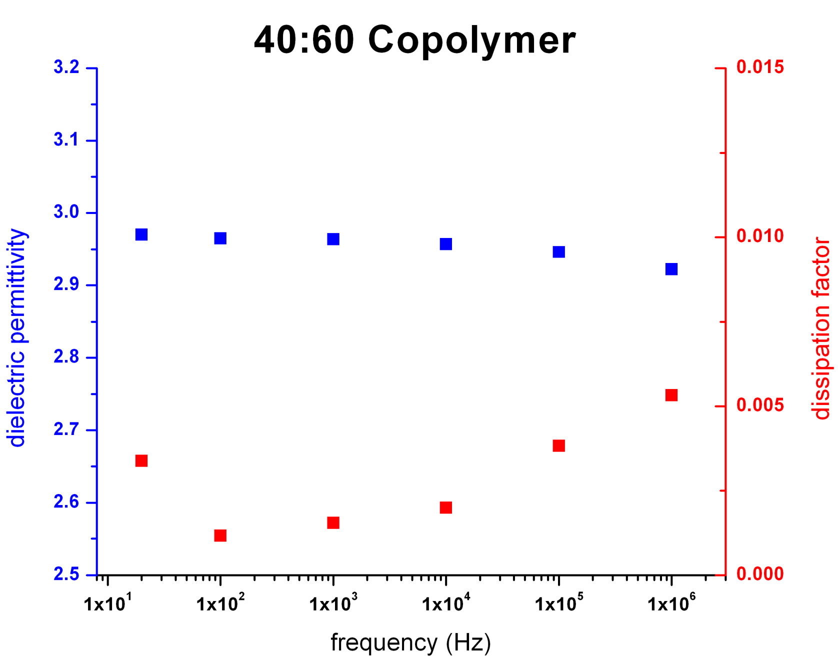
SAND2011-2854C

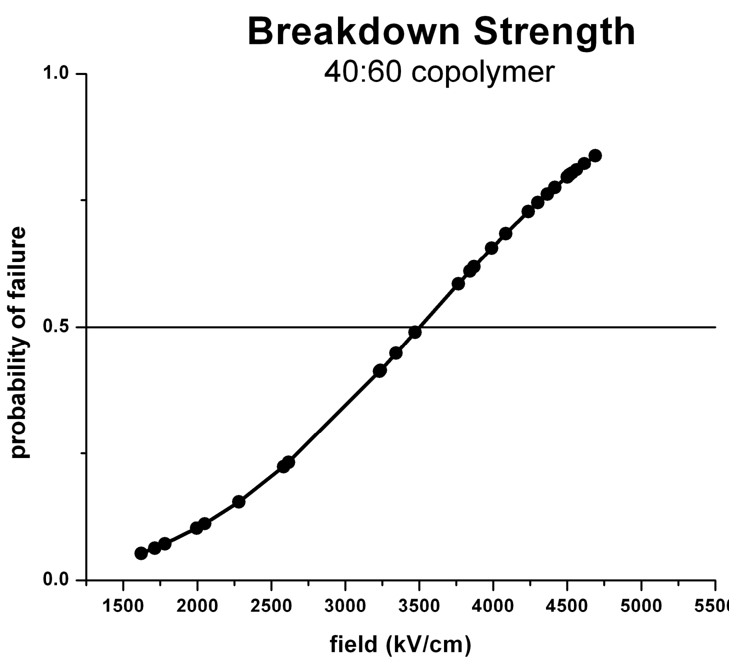
high κ: high energy density capacitors
low κ: high performance integrated circuits

relative permittivity (ε_r or κ)
breakdown strength (E_b)
dissipation factor (Df)

energy density $U_e = ½\, \varepsilon_r \varepsilon_o E_b^2$

- mechanical properties
- failure mode
- temperature stability
- processing
- cost





Polymer Dielectrics

Sandia National Laboratories

Advantages of Polymer Dielectrics

- high breakdown strengths
- soft failure
- cost
- flexibility
- ease of processing
- control of properties

but…

high- κ

- low relative permittivities
- low energy densities
- small range of operating T
- high performance polymers expensive

low- κ

- high relative permittivities (<2)
- thermal stability
- mechanical properties

Polymer Composite Dielectrics

- control of permittivity

- lower breakdown strengths
- polymer/additive incompatibility
- poor dispersion
- field inhomogeneity

Improve Compatibility

- organic functionalization
- covalent particle integration
- polymer/insulator coating
- MOFs?

Metal-Organic Frameworks

MOF-Polymer Composites

- intrinsic organic functionality to improve dispersion and polymer compatibility

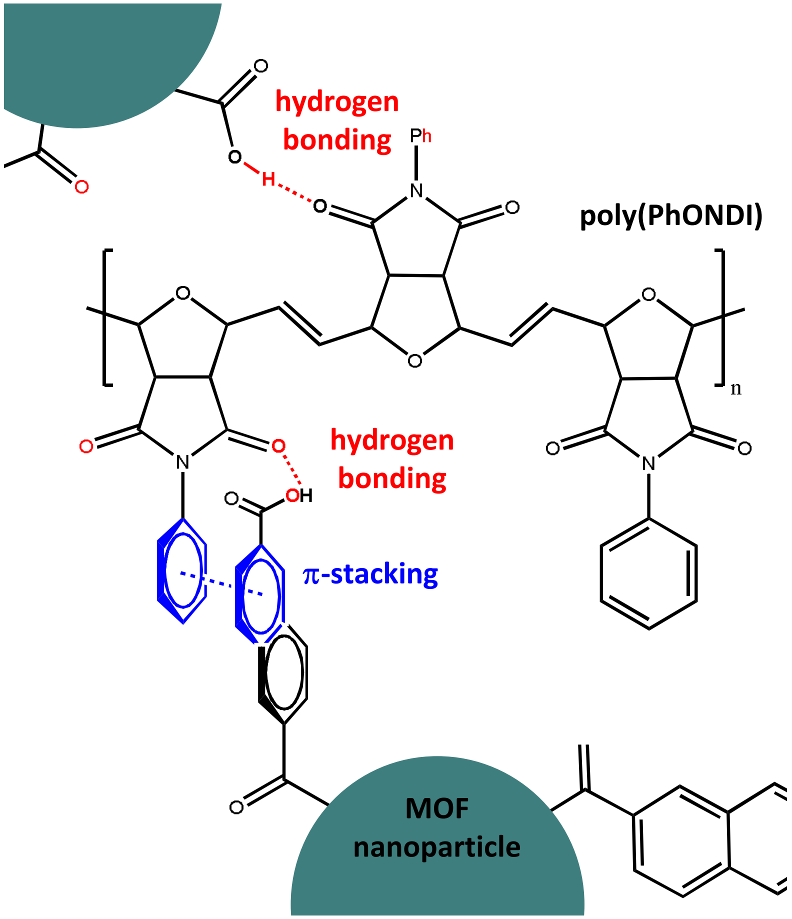
- modify/control properties by appropriate selection of metal and ligand (chiral/polar, porous)

- postsynthetic modification to improve/alter compatibility or covalently integrate into polymer

- high dielectric permittivity materials/high porosity materials

- wealth of new materials with unique properties

- applications in membranes, sensors, etc.



Summary and Future Work

- **ZIF-8 composites have superior dielectric characteristics compared to inorganic (TiO_2) composites.**
- ZIF-8 composites have higher permittivities than the copolymer alone, but lower breakdown strengths, resulting in similar energy densities.
- Dispersibility is more important than intrinsic particle size but both play a role in determining electrical properties.

- Improve particle dispersion in solution prior to polymer addition.
- Examine large particle sizes (>1μm) (not agglomerated).
- Alternative high ε_r MOFs (dense, polar structures) for high-κ applications.
- Explore particle size/dispersion effects at low loadings on lowering permittivity for low-κ applications.
- 'Polymer matching' post-synthetic modification of MOF surface ligands.