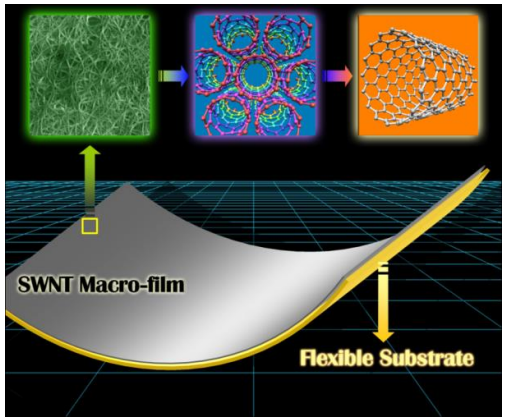
Nanotechnology Research

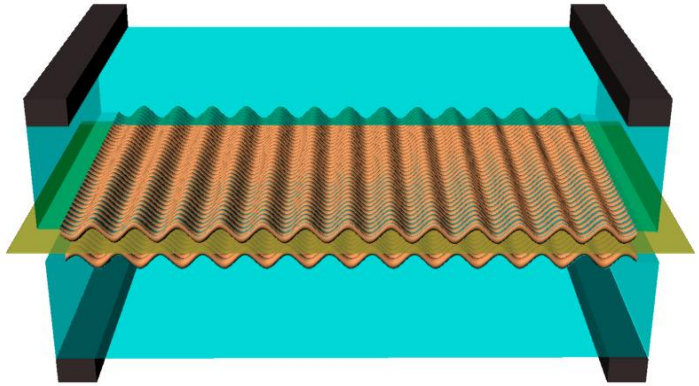
Mechanical Engineering
University of Delaware

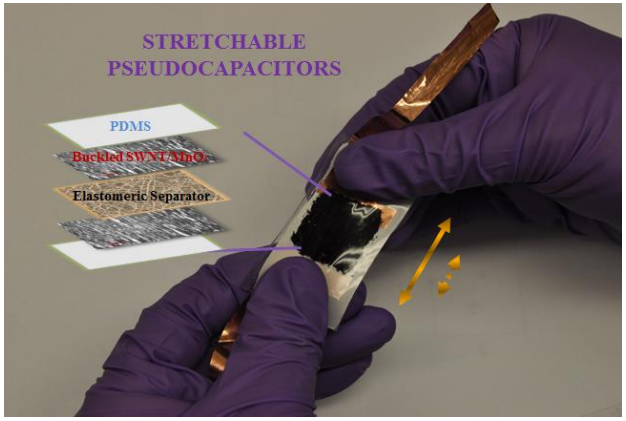
Nanomaterial-Enabled Flexible/Stretchable Energy Storage Devices

- Flexible and Stretchable Double-layered Supercapacitors
- Stretchable and Bendable Pseudocapacitors
- Stable, Repeatable, Static and Dynamic Bending and Stretching

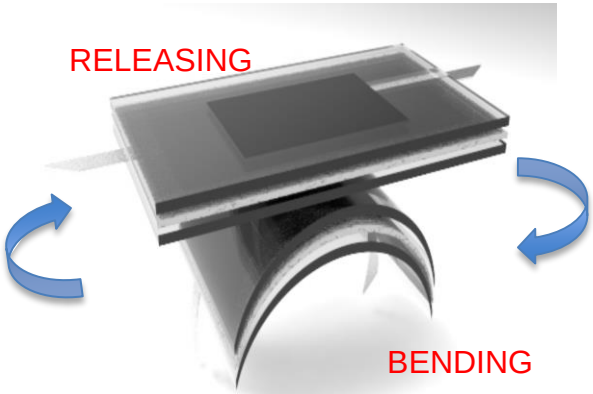
Statically and Dynamically Stretchable Double-layered Supercapacitors from CNTs

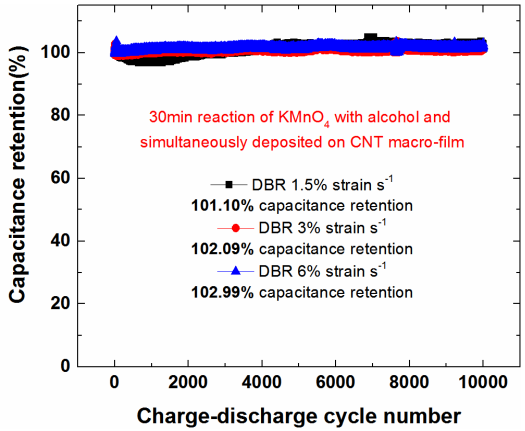






Stretchable pseudocapacitors based on buckled SWNT/MnO_2 hybrid films

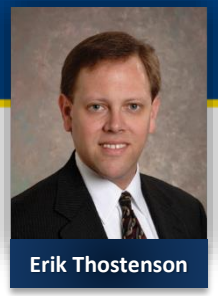


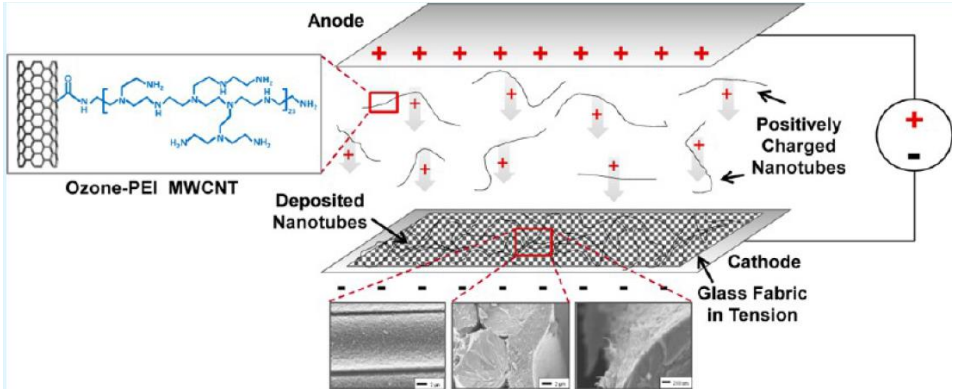


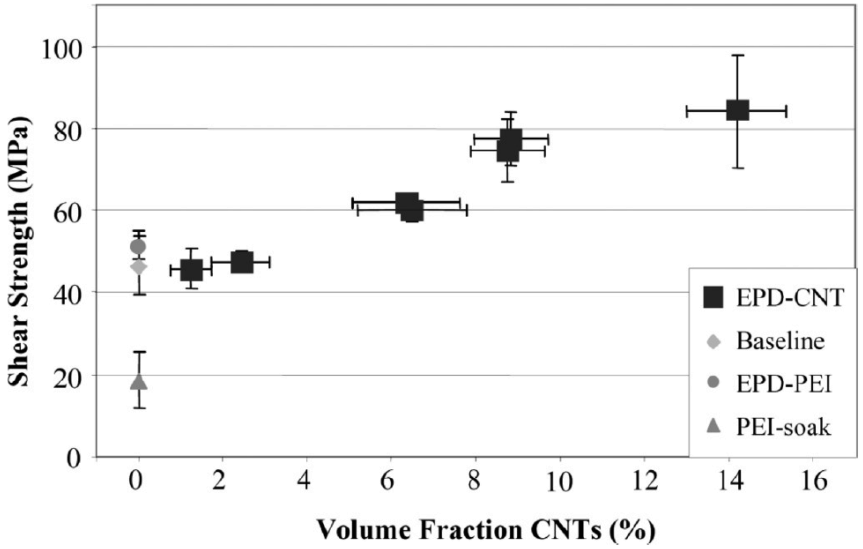
Dynamic Bending/Releasing (DBR) Charge/Discharge Retention

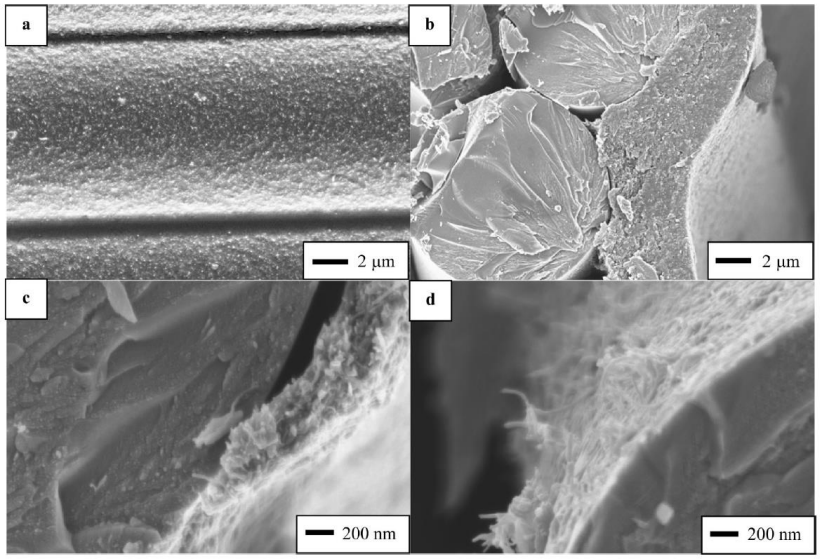
Yu, C., Wei, B. Q. *et al. Adv. Materials* (2009). Li. X. Gu, T. Wei, B. Q. *Nano Letters* (2012)
Gu, T. Wei, B. Q. *Submitted* (2014)

Processing of Multifunctional Nanostructured Composites









- Electrochemical assembly
- Novel AC approach for nanotube integration
- Demonstrated for the first time on glass
- Formation of stiff and strong interphase

Funding: NSF CAREER

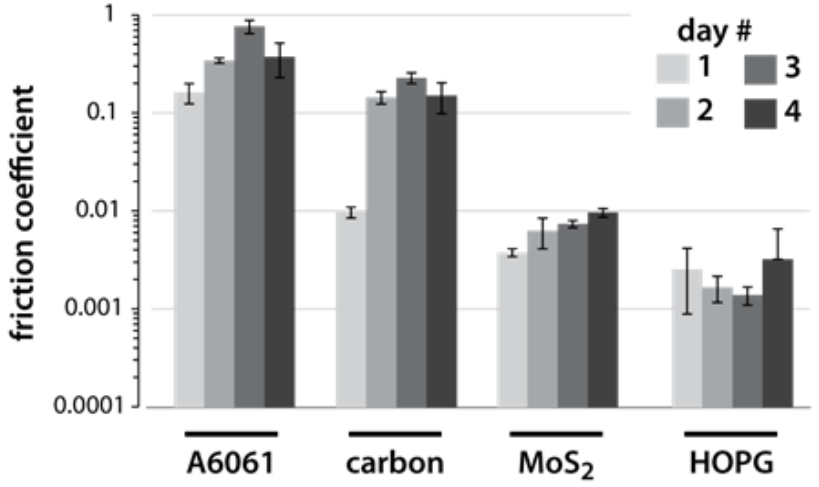
An, Rider and Thostenson, *Carbon* ***(2012)***

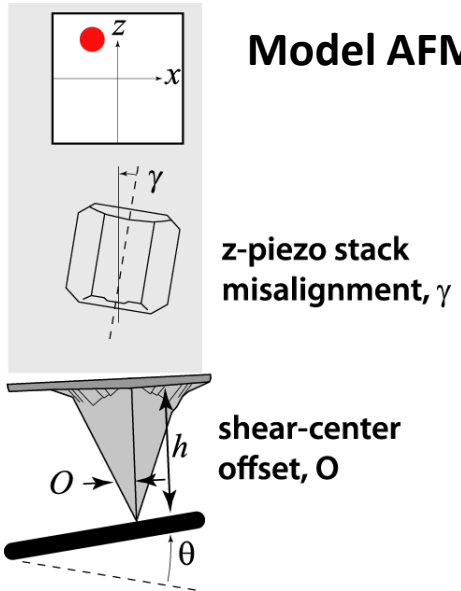
An, Rider and Thostenson, *ACS Applied Materials and Interfaces* ***(2013)***

Quantifying Friction at the Nanoscale

Motivation

- Macroscale friction is due to an ensemble of fundamental frictional interactions
- AFM: probes fundamental interactions, calibration is difficult, setup adjustments can change calibration constants
- Khare and Burris, *RSI* 2013: Developed '***extended wedge method***' to calibrate AFM voltage signals ***during*** measurement

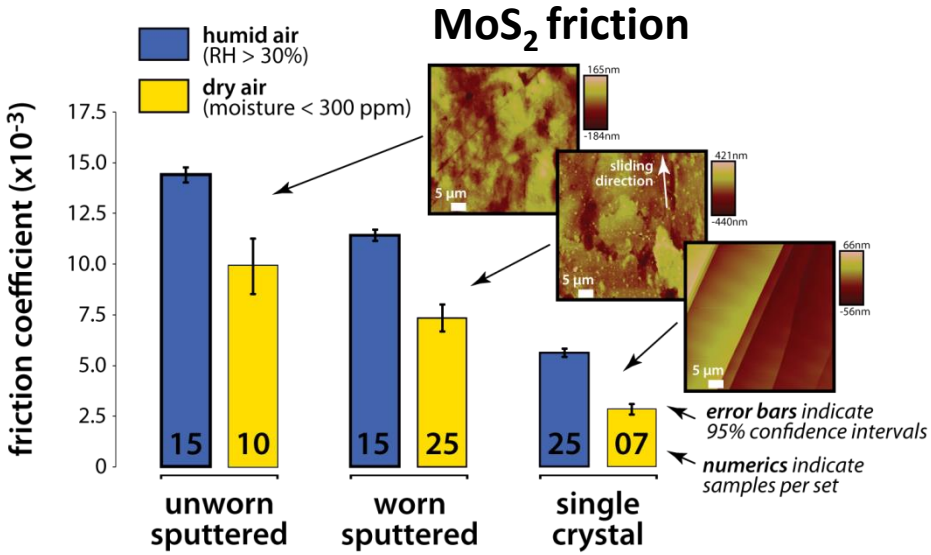




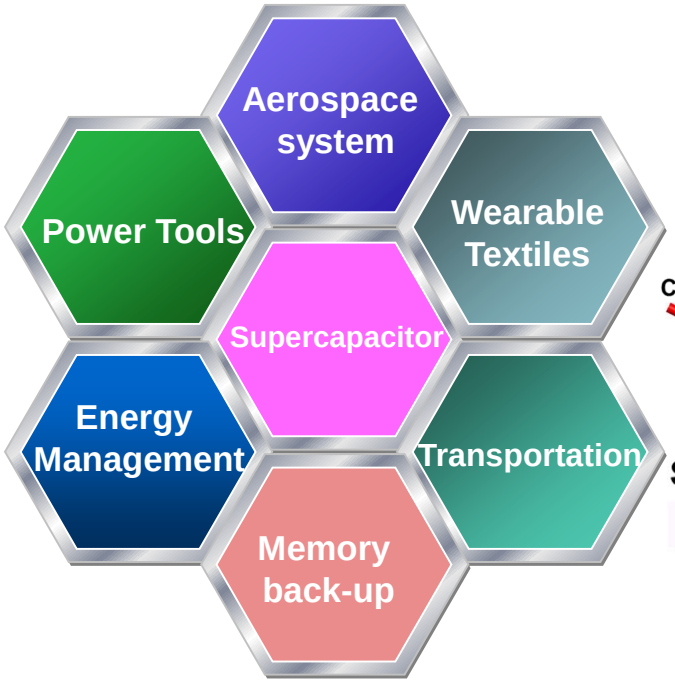
Model AFM

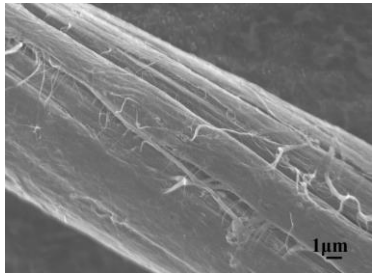
z-piezo stack misalignment, γ

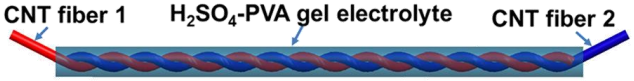
shear-center offset, O

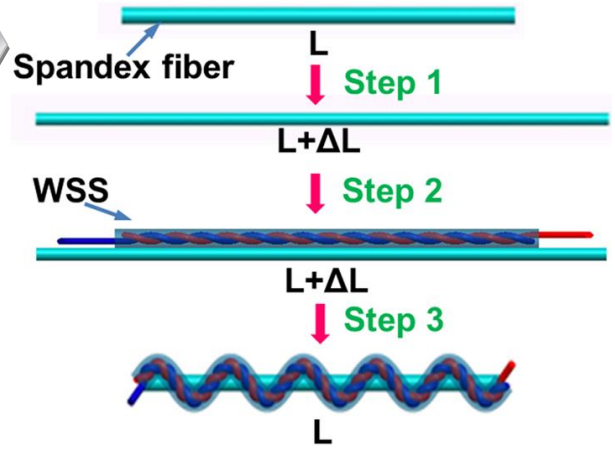


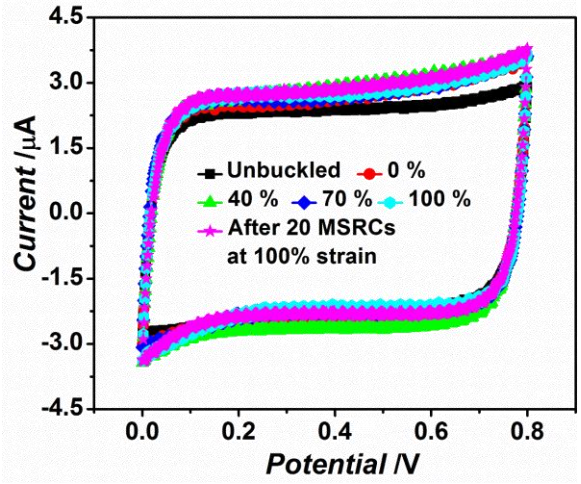
Nanomaterials for Energy Storage Devices Wire-shaped Supercapacitor

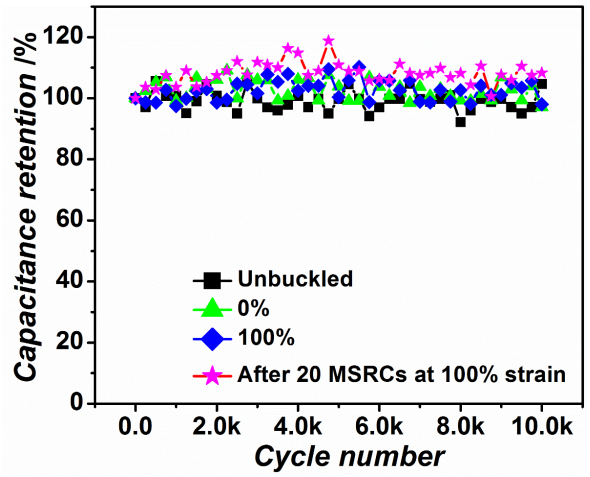








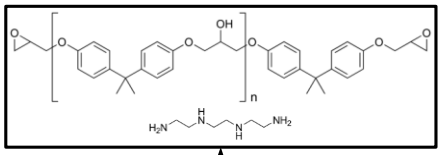




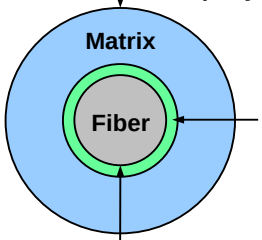
Xu, P., Wei, B. Q. , Chou, T.-W. *et al., Adv. Energy Mater.* (2013).

Molecular Dynamics Modeling of Interphase Formation

Molecular Dynamics LAMMPS → Coarse Graining LAMMPS/ Peridynamics → Micro-Meso Scale Peridynamics / LS-DYNA

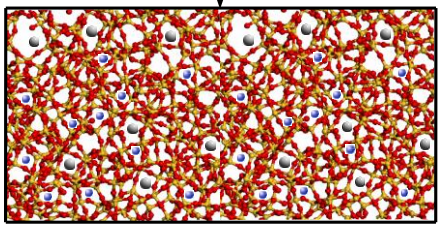


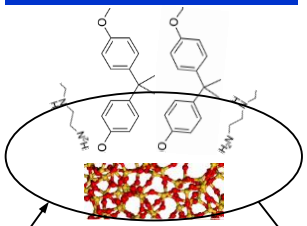
Epoxy-Amine



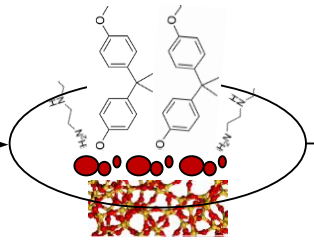
Interphase

Glass

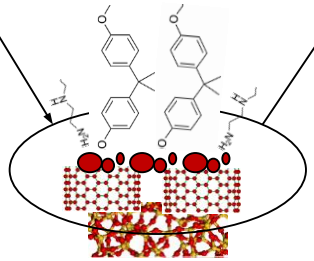




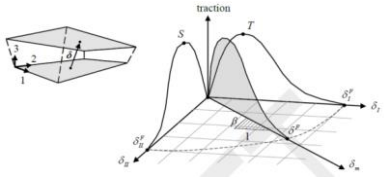
Simple Glass/Epoxy Interphase



Glass/Silane/Epoxy Interphase

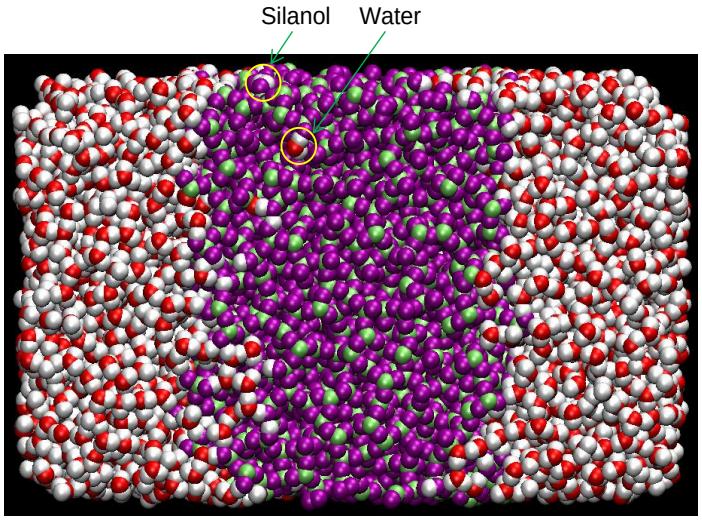


Glass/CNT/Silane/Epoxy Interphase

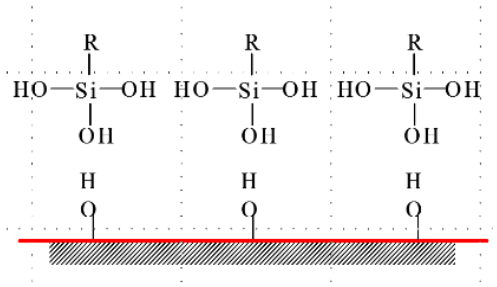


Cohesive Properties of Interphase

Molecular Dynamics Modeling of Interphase Formation



SILANOL FORMATION



$$H_2O \longrightarrow H^+ + OH^-$$

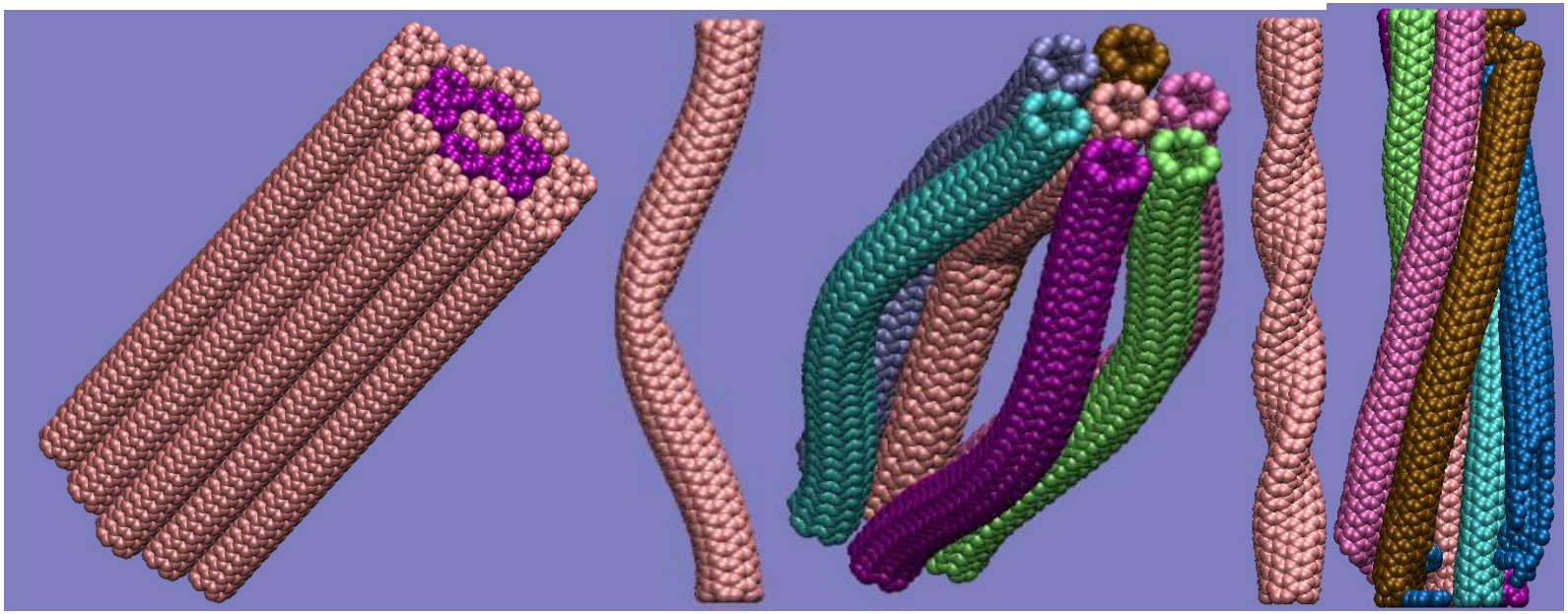
$$H^+ + SiO^- \longrightarrow SiOH$$

$$OH^- + Si^+ \longrightarrow SiOH$$

REACTIONS

- MD modeling of interphase formation during processing
- MD prediction of Mixed-Mode Traction Laws Based on Bond Breakage (strength and energy absorption)
- Bridge length scales using Peridynamics

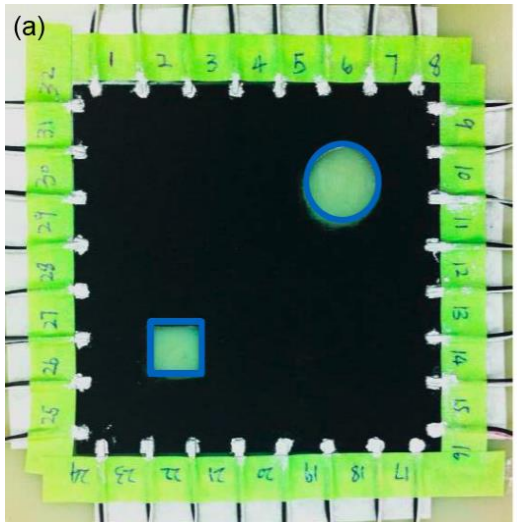
Molecular Dynamics Modeling of Nanotube Bundles

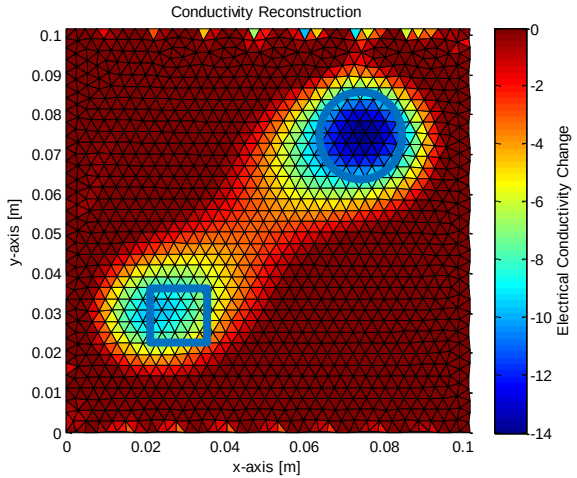


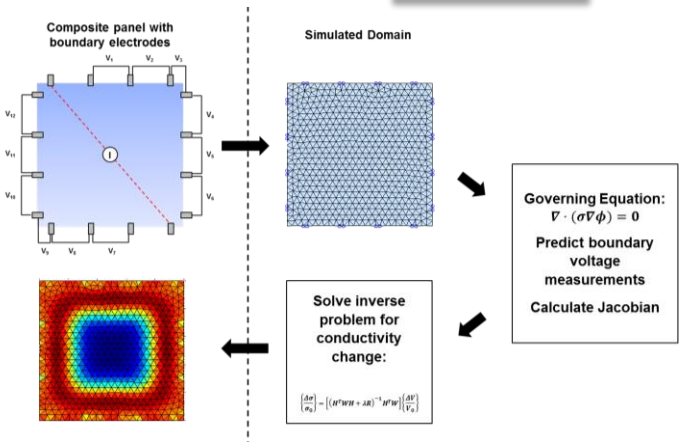
- Carbon nanotubes can form bundle where the axially aligned CNTs are packed closely together to create a larger diameter yarn.
- The inter-tube interaction in the bundle can be non-bonded van der Waals interaction or bonded sp^3 interaction.
- Such bonded and non-bonded inter-tube interaction may change the load carrying capability and damage modes at failure of the bundle as well as individual CNT within the bundle.

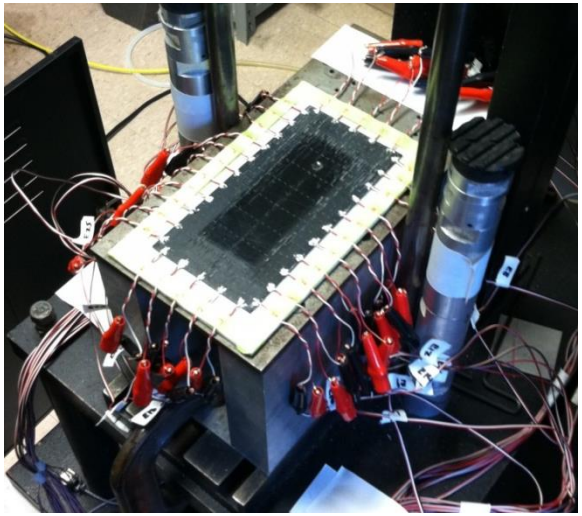
Carbon Nanotubes for *in situ* Sensing of Deformation and Damage

Erik Thostenson

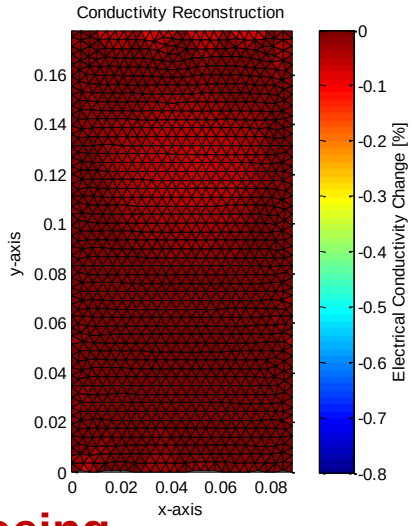




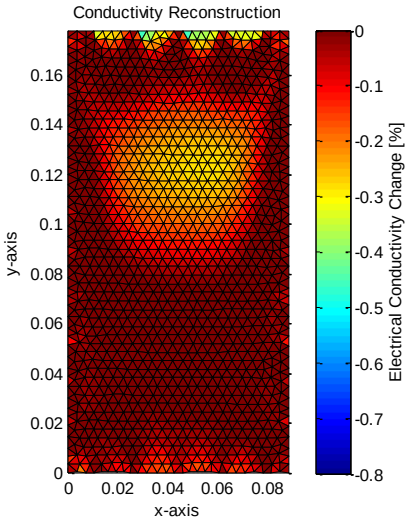




Impact #1



Impact #2



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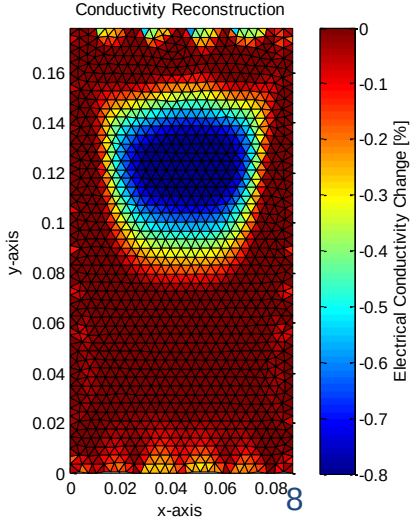

Funding: AFRL/AFOSR, Boeing