Composite Materials Research

Mechanical Engineering
University of Delaware

Center for Composite Materials (CCM)

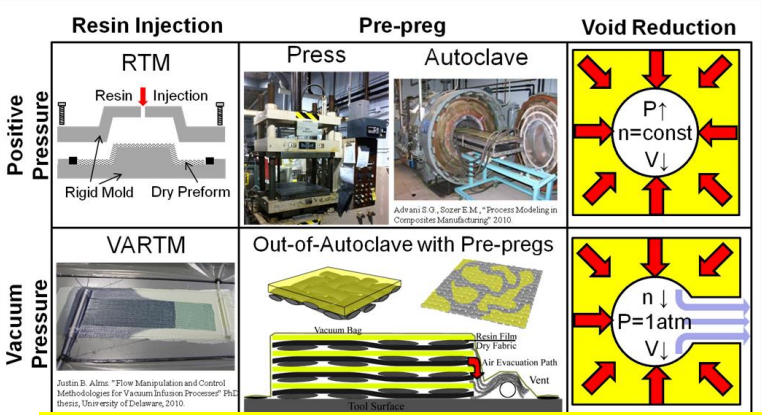
- Founded in 1974, CCM is an internationally recognized interdisciplinary center of excellence for composites education and research
- Three-Part Mission
  - Educate scientists and engineers
  - Conduct basic and applied research
  - Transition technology to industry
- Host to 7 NSF/DoD Centers of Excellence since 1986
- University/industry consortium – more than 3500 small, medium and large companies have benefited from partnerships with CCM

UNIVERSITY of DELAWARE

Composites Manufacturing Science for Reliability and Automation

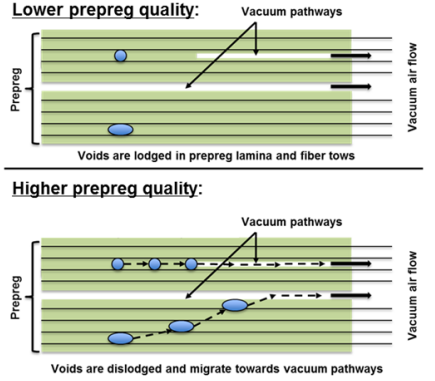
Suresh Advani

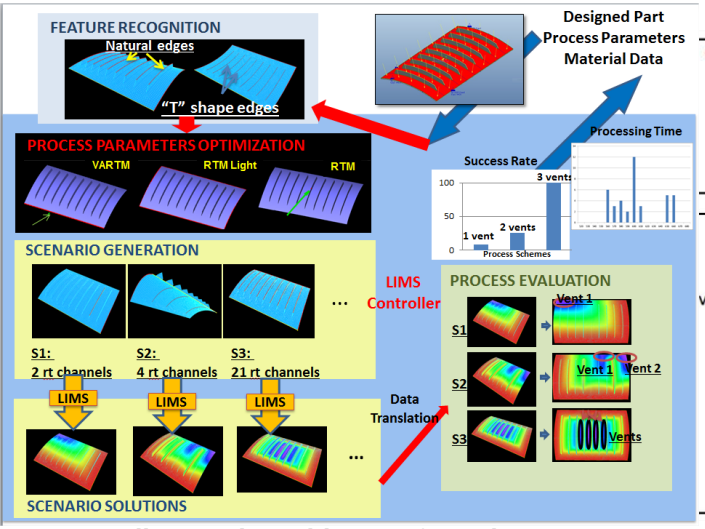
- Manufacturing simulations are developed to fabricate void free composites to improve yield, and introduce reliability and automation
- Simulations are coupled with Design and Optimization Methodologies for Tailored and Lean Manufacturing



Modeling and Simulation of out of Autoclave Processing

How to get resin and voids into flow pathways to reduce the porosity?

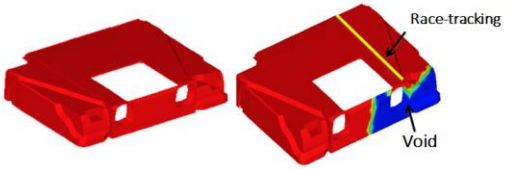


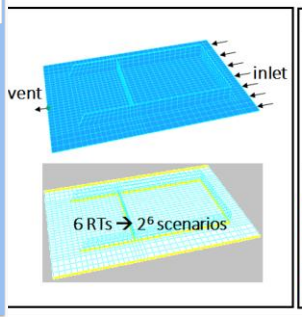


Coupling Design with Manufacturing

Find the permeability distribution that will always fill the given mold cavity, despite:

ALL possible disturbances – such as race-tracking effect around the edges





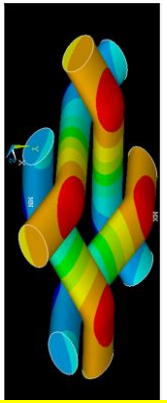
Average fill data for 64 scenarios

Average fill factor	Frequency (element-wise)
0.5	0
0.6	1
0.7	58
0.8	205
0.9	685
1	485

Distribution media (DM) lay-out design valid for ALL 2^6 scenarios

- DM: highly permeable fibrous layers to increase the preform permeability as placed on top of the preform

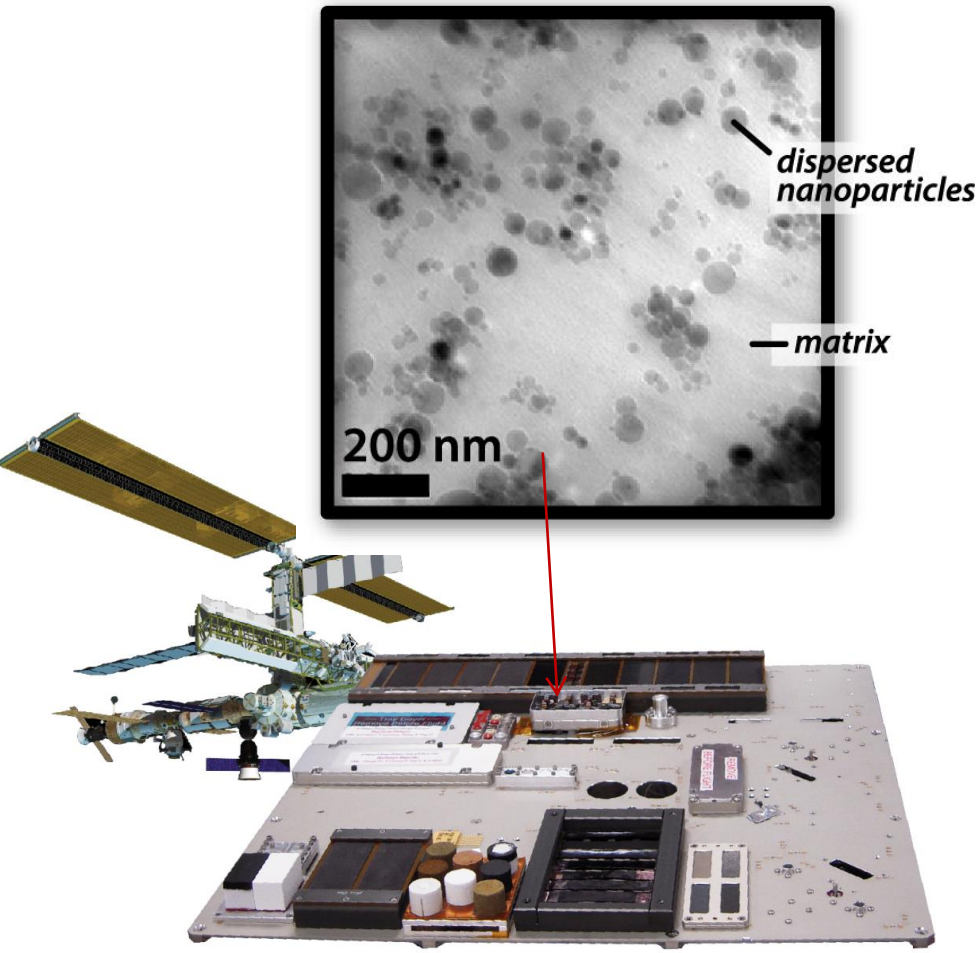
Valid for all possible RTs



Effective thermal conductivity of composites

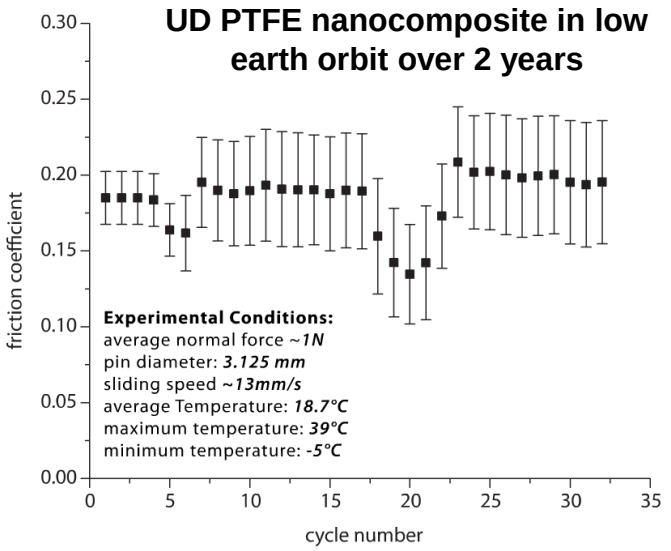
Manufacturing Simulations to Optimize Composite Design

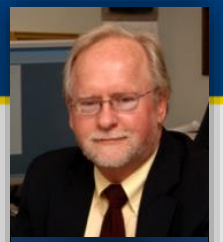
Advanced Nanocomposites for Space Lubrication



MISSE 7: Materials International Space Station Experiments

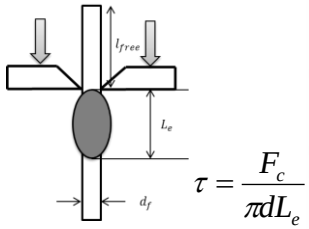
- Current MoS_2 solid lubricants coatings are poisoned by water → seizure
- UD PTFE nanocomposites: environmentally insensitive, 10,000X reduced wear compared to PTFE
- This and 4 other candidate space lubricants tested outside the ISS
- First/only active MISSE experiment



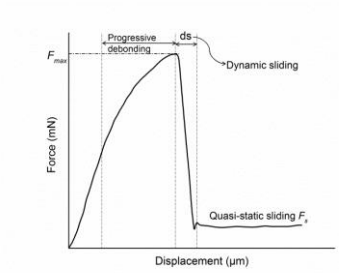


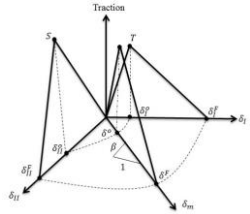
Traction-Separation Behavior of Composite Interfaces

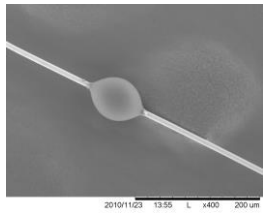
- **Fiber matrix interface – potential source of energy absorbing mechanism**
- **Opportunity to tailor interface to achieve optimum composite structural and ballistic performance**
- **Objective – to develop accurate traction separation behavior of S-glass/epoxy interface at all loading rates at the micromechanical length scale**

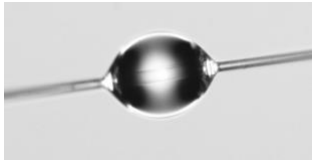


$$\tau = \frac{F_c}{\pi d L_e}$$







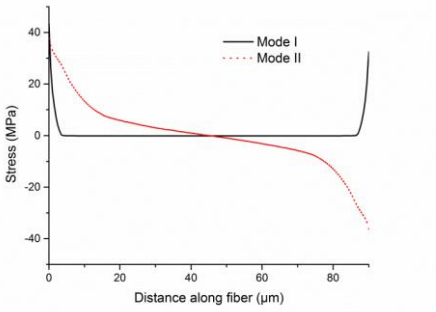


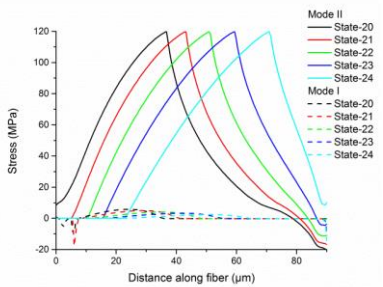
Cohesive zone modeling of the interphase between fiber/matrix

Model processing induced residual stresses

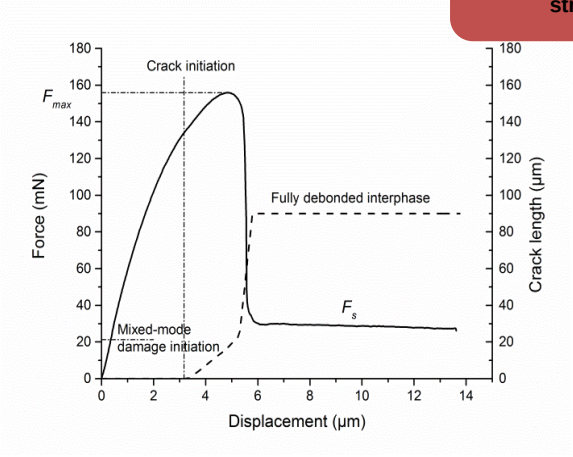
Model progressive debonding with interfacial friction using cohesive zone approach

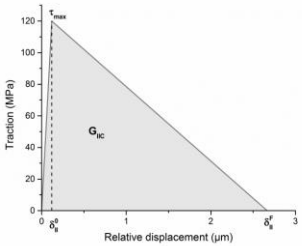
Determination of mode II dominated traction law





Stress state of the interface due to residual thermal stresses and during crack propagation



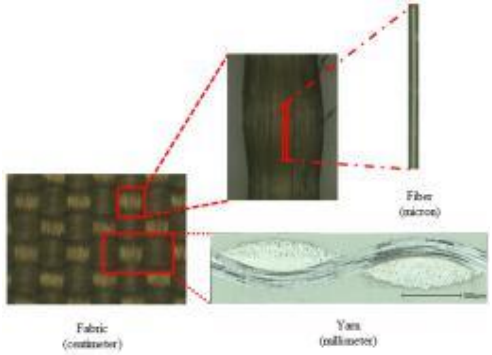


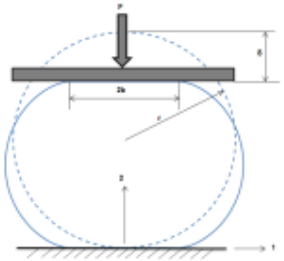

Michael Keefe

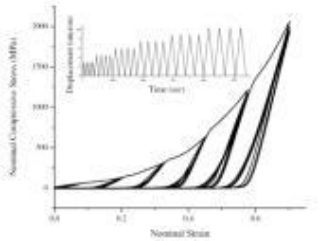

Jack Gillespie

Multi-Scale Modeling of Kevlar KM2 Tows Subjected to Transverse Impact

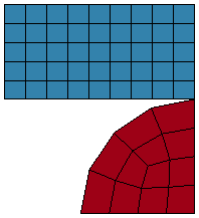
- **Kevlar flexible textile composites in high velocity impact applications**
- **Role of fiber transverse properties during impact not well understood**
- **Objective – to understand fundamental fiber-level mechanisms during impact to establish materials-by-design**

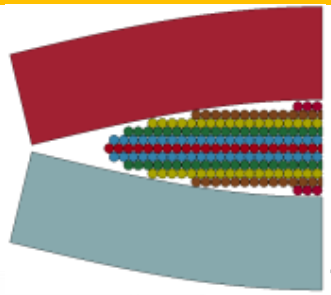


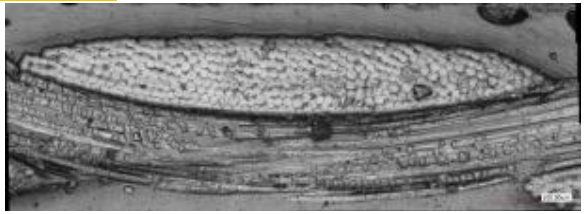


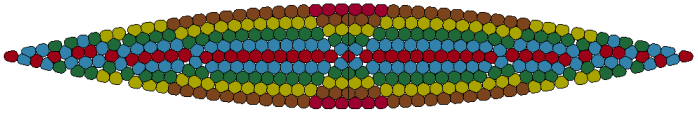


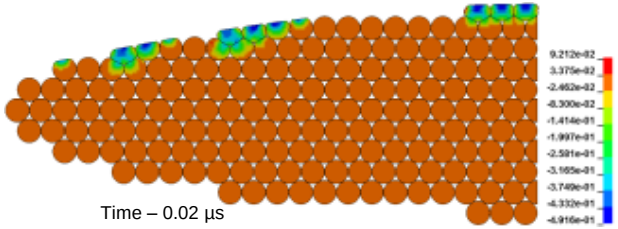
Single fiber transverse compression response – nonlinear and inelastic
Cheng, M. et al., International Journal of Solids and Structures, 2004



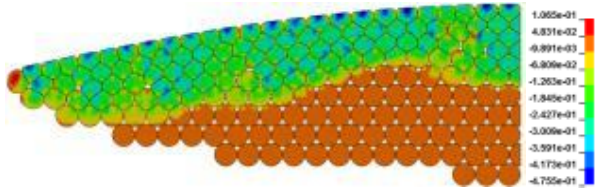




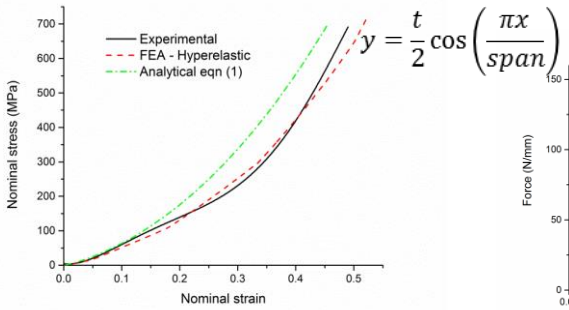


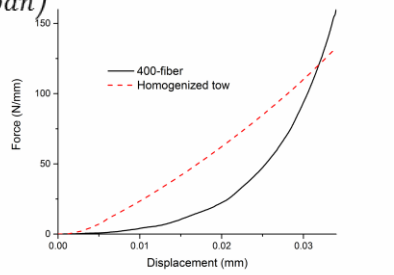


Time – 0.02 μs



Time – 0.07μs



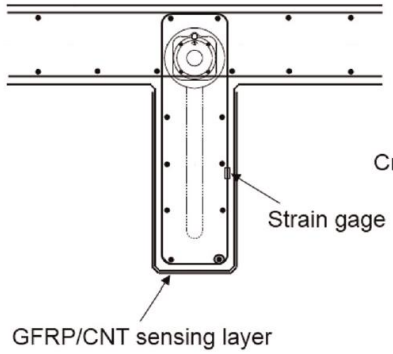


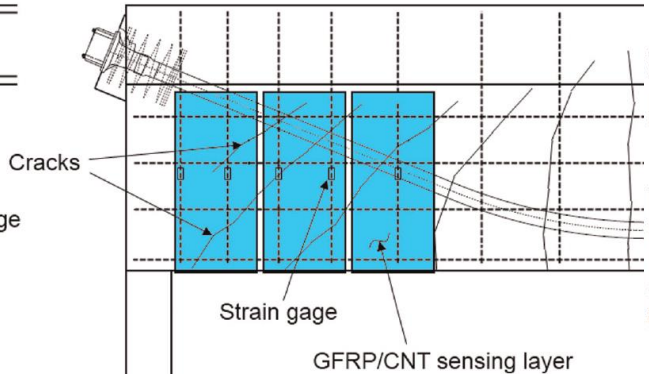
Tow transverse compression response

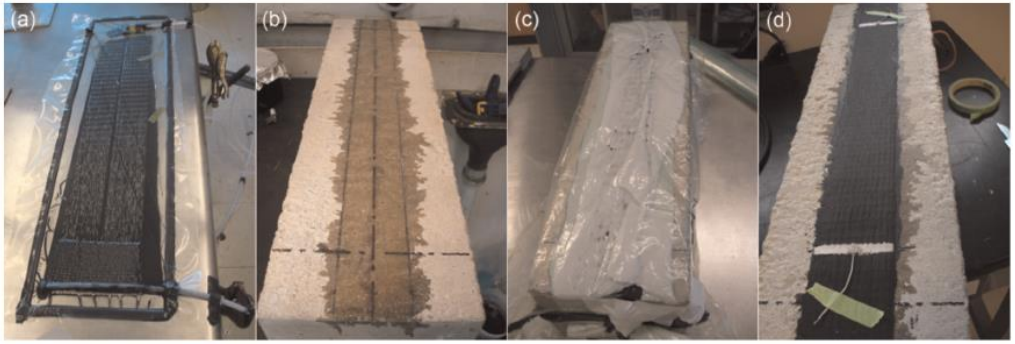
Fiber-fiber contact plays a significant role in the spreading and deformation of individual fibers

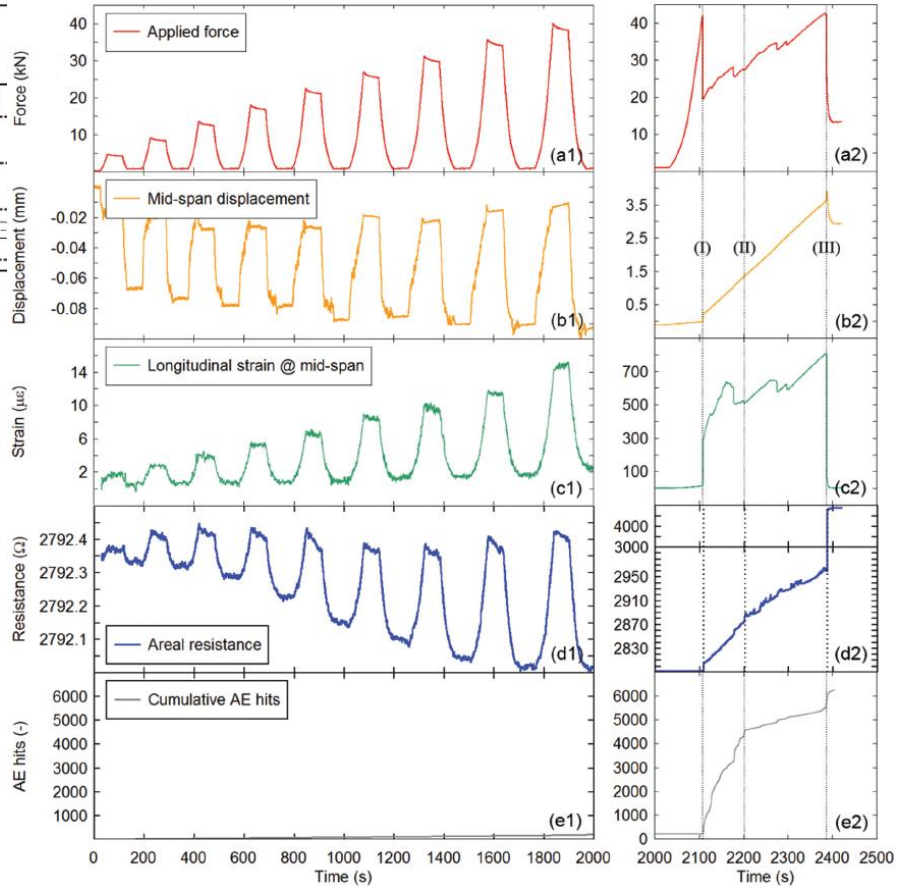
Tow transverse impact short time scale response – significant transverse compressive strains

Nanotube Composites for Infrastructure Health Monitoring







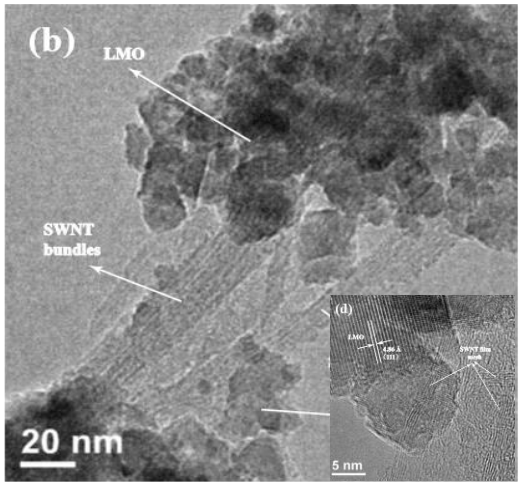


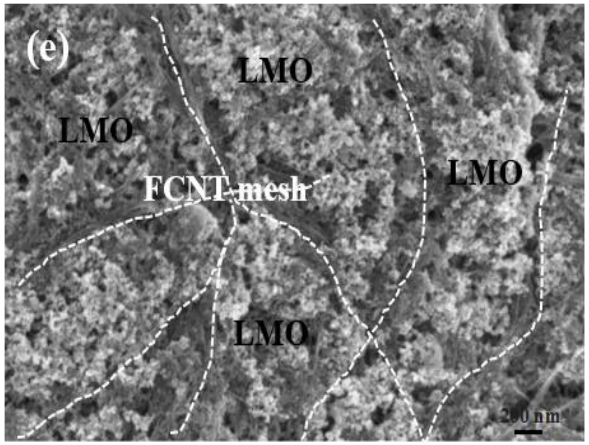
Collaborators: T. Schumacher and J. McConnell (Civil Engineering)

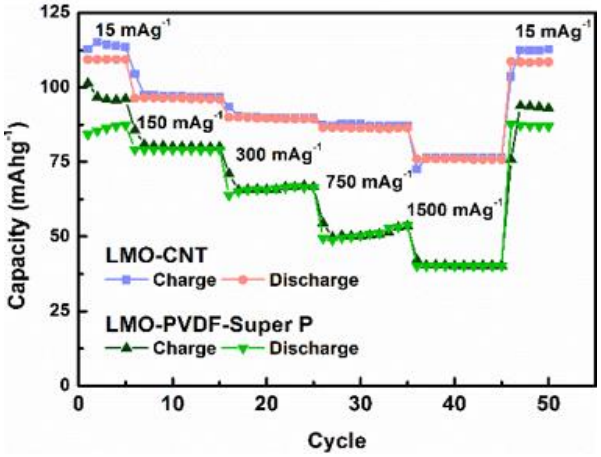
Functional Nanocomposites for Energy Storage

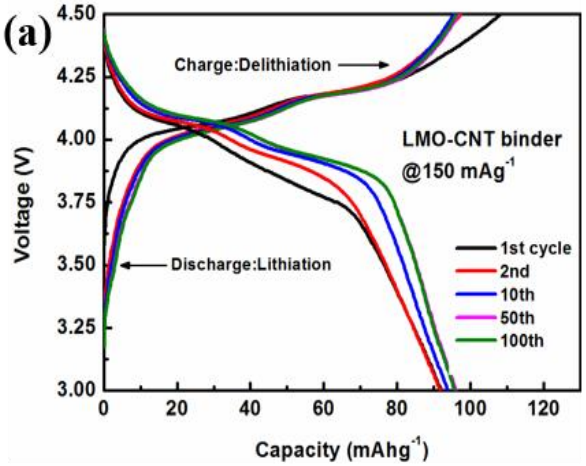
Adhesive Conductors from fragmented CNT macrofilms

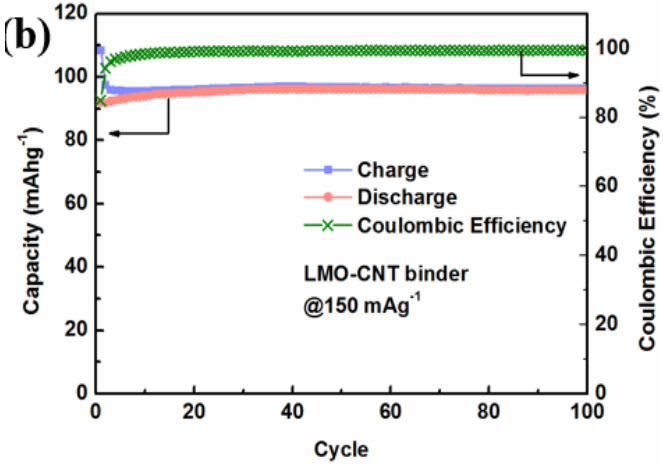
- **Bifunctional adhesive conductor (AC) from CNT film is, for the first time, proposed and demonstrated with a higher adhesive strength than the conventional polymer binder (PVDF)**
- **Nanocomposites coupling AC with active materials, *e.g.* $LiMn_2O_4$ exhibit superior electrochemical performance of the Li-ion Batteries**











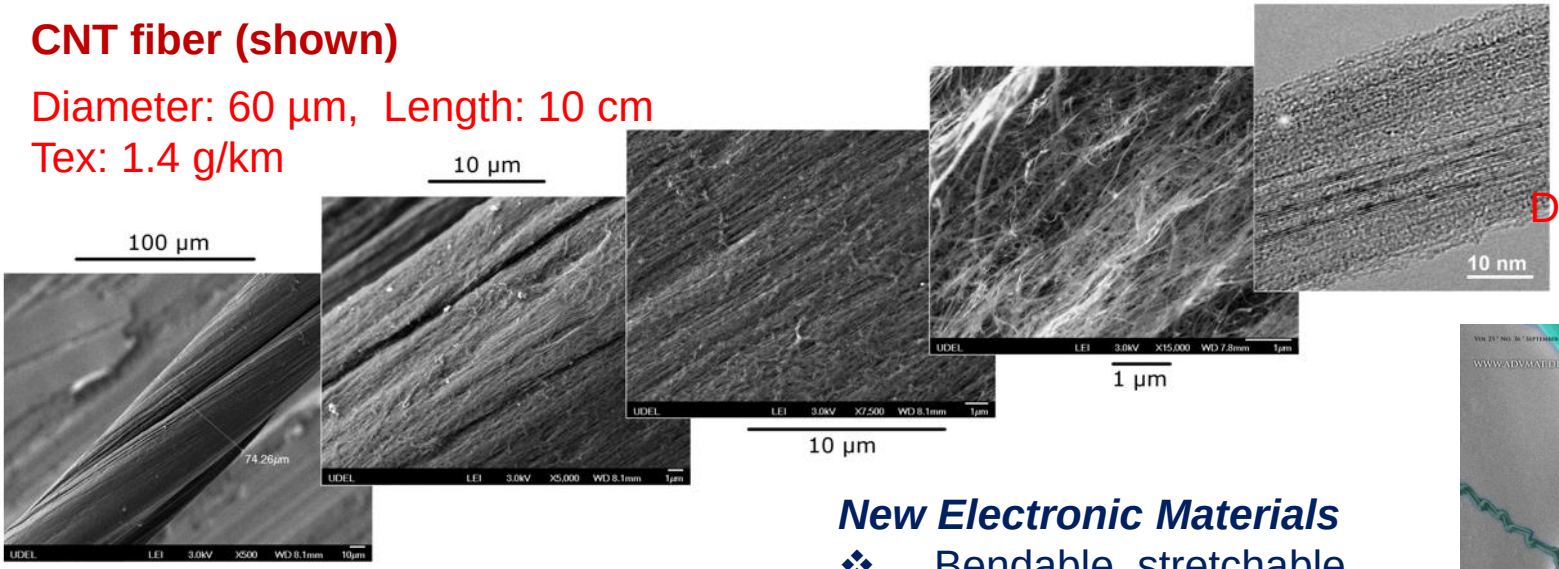
High Strength and Multifunctional Carbon Nanotube Fibers

CNT fiber (shown)

Diameter: 60 μm, Length: 10 cm
Tex: 1.4 g/km

CNTs (SWNT)

Length: 10 μm
Diameter: 1 nm
Density: 1.33 g/cm^3



Fiber Mass: 0.14 mg
Total CNT Volume: 1.05 (10^{-4}) cm^3
Single CNT Volume: 7.85 (10^{-18}) cm^3

# of CNTs in the fiber: ~10^{13}

New Electronic Materials

- Bendable, stretchable, twistable, deformable
- Small resistance change

CNT Fiber Characteristics

- Electrical conductivity
- Flexibility