Nanofibers and Nanocomposites for aerospace applications

Prof. Yuntian Zhu
Dept. of Materials Science and Engineering
Nano for Safety and Environment

- Nanofiber Filtration: Clean Water and Air
  - Nanofibers for air, water filtration devices
  - Reduce energy consumption
  - “Smart Filters” – Integrated sensor devices

- Protection
  - Fire, Chemicals
  - Particulates, Toxins

Behnam Pourdeyhimi
Nonwovens Institute
Currently, the most commonly-used method for producing nanofibers is electrospinning (90% publications on nanofibers are based on electrospinning). However, the mass production of nanofibers by electrospinning is limited by its low production rate (<100 mg per hour), poor safety, and high cost. More importantly, electrospun nanofibers are mechanically weak due to the lack of molecular orientation, and they are not suitable for composite applications.
Our Approach: Centrifugal Spinning

• Our approach is to use the centrifugal spinning technique to produce ultra-strong nanofibers for composite applications at high speed, high safety, and low cost

• Our preliminary results demonstrated that the production rate of the centrifugal spinning process is 600 times greater than that of typical single-syringe electrospinning

• More importantly, the stretching of jets during centrifugal spinning results in a high degree of molecular orientation, thereby leading to excellent mechanical properties that cannot be obtained by other methods
Four key factors for the best properties in CNT composites

1. **Straight, non-waviness**: To make all CNTs carry the load simultaneously (unique for CNTs)

2. **Good Alignment**: For a CNT to carry load effectively, it has to be aligned in the loading direction

3. **Long individual CNTs**: Long nanotubes are more effective in carrying load

4. **High nanotube volume fraction**: The composite strength increases with increasing nanotube volume fraction
Our New Approach for Fabricating CNT Composites

- Long CNTs
- High volume fraction
- Good alignment
- Good preliminary properties
- Potentially produce the multifunctional CNT composite with
  - Strength much higher than current carbon fiber composites
  - High electrical conductivity
  - High thermal conductivity
Spray Winding CNT Composites

Conducive to low-cost, large scale production
High strength, stiffness, electrical conductivity, and thermal conductivity
Polymer Infiltration and Pyrolysis: PAN

- CNT/PAN composite precursor (dip winding)
- Stabilization at 250 °C for 2hrs, 320°C for 25 min (under tension)
- Carbonization at 1300 °C (under compression)
- Graphitization at 2150 °C

Resultant CNT-carbon composites:
- Relatively high carbon yield from PAN (50-55%)
- Long, aligned CNT structure with weight fraction of 5~20%
- Providing scaffold for PAN graphitization, enhance thermal stability of composites, which in turn strengthen the CNTs

40-60 walls
Diameter: 35-60 nm
Length: 900 µm

1, 2, 5% PAN in DMF were used
Good infiltration obtained
Mechanical and electrical properties

**Graphs:**
- Stress (MPa) vs. Strain (%)
- Electrical Conductivity (S/cm) vs. Sample Group

**Images:**
- Precursor
- After Carbonization

**Legend:**
- 1% precursor
- 1% carbonized composites
- 2% precursor
- 2% carbonized composites