Composites and Nano Composites Workshop

Unique Facilities and Strength

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Unique Facilities and Strength

• Nano composite/ multi-component fiber spinning laboratory

• Continuous carbonization laboratory

• Carbon fiber research portfolio

• Functional fibers/materials (thermal, electrical, piezoelectric, superparamagnetic behavior etc…)

• Tailoring the interface in composites and nano composites

• Scalable manufacturing – TRL 4
Schematic description of fiber spinning system

Solution tank A
Solution tank B

Temperature zone 1
Metering pump

Temperature zone 2

Temperature zone 3

Spin-pack
- Filter pack
- Distribution plates
- Spinneret

Coagulation bath 1
Coagulation bath 2
Winder

As spun fiber
Schematic description of fiber drawing system

Unwinding stand

Drawn Fiber

Godets1 (cold)
Godets2 (cold)
Godets3 (heated)
Godets4 (heated)

Guide roller
Guide roller
Guide roller
Guide roller

Glycerol bath 1
Glycerol bath 2
Water rinse bath

Dryer (hot air)

Drawn Fiber
• Line has been tested for continuous carbonization of 100 to 6000 filament tows.
• Stabilization zones: 180 – 300 °C
• LT furnace: up to 1000 °C
• HT furnace: up to 1600 °C
Carbon Fibers

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- **Strength**: After 50 years of development, the strength of the state-of-the-art carbon fibers (5.6 GPa for IM7) is only <10% of the theoretical strength (>60 GPa) of the carbon carbon bond. **Modulus**: High strength carbon fibers have relatively low modulus (276 GPa for IM7 fiber vs 1060 GPa for graphite). Under DARPA funding, gel spinning route has shown significant increase in modulus and potential of increased strength.

- **Electrical and Thermal Conductivity**: State-of-the-art-high strength carbon fibers have relatively low electrical conductivity (~60,000 S/m vs ~1,000,000 S/m for graphite) and low thermal conductivity (<15 W/m/K vs 1000 W/m/K for graphite). Under DARPA/AFOSR sponsorship, PAN/CNT based carbon fibers have been shown to have enhanced conductivity values, as compared to PAN based carbon fibers.

- **Density**: Density of the high strength carbon fibers is ~1.76 g/cm³. It will be desirable to further reduce this density significantly. With funding from Boeing, hollow carbon fibers with density of 1.2 g/cm³ have been processed.

- **Functionality**: High strength carbon fibers are currently passive materials. It will be desirable to introduce additional functionality in these high strength fibers. Super paramagnetic properties is an example of functionality beyond electrical and thermal conductivity, that has been demonstrated under AFOSR sponsorship.

- **Energy**: Approximately 40% cost of the high strength carbon fibers is due to energy used during stabilization and carbonization. It is desirable to reduce this energy significantly. Under AFOSR and DOE funding, progress is made in this area using Joule heating of PAN/CNT fibers.

- **Bio – renewable content**: Carbon fibers are produced from polyacrylonitrile (PAN). PAN is the product of petroleum industry. Currently there is an effort underway to incorporate bio-renewable materials such as lignin and cellulose nano crystals (CNC) in these fibers. Under RBI sponsorship PAN/lignin blend fibers as well as PAN/CNC fibers have been processed using gel spinning, with promising results for enhanced sustainability.
Next generation carbon fiber - High Strength High Modulus Carbon Fiber

30% increase in modulus without reduction in strength.
Working towards 12 GPa/ 420 GPa carbon fiber
Hollow carbon fibers

Small diameter carbon fibers

Carbon Structure thickness ~ 1 µm
Functionality in the fibers including in the carbon fibers can be introduced at the desired location. Using this approach functional fibers can also be made using other nano materials—introducing corresponding functionality in the sheath or in the core. A different nano material and hence a different functionality can be introduced in each component.
Tailored interphase – impact strength of polypropylene

Interphase I – no improvement

Interphase II – 70% increase

Interphase III – 150% increase

% increase in impact strength

Filler concentration (wt. %)

US 20100283174 A1
US 20140329949 A1
US 20100127428 A1
US 8859670 B2
WO 2002004557 A2
CN 103059416 A
Tailored Interphase

Interfacial shear stress

Evidence of ordered PMMA wrapping

A factor of six increase in bucky paper modulus has been achieved using this approach.

35 wt% PMMA wrapped on SWNT

This behavior is expected to provide the breakthrough for narrowing the gap between CNT’s experimentally achieved mechanical properties and their theoretical potential.