ELECTROPHORETIC DEPOSITION OF CARBON NANOTUBES ON LONG DISCONTINUOUS CARBON FIBERS

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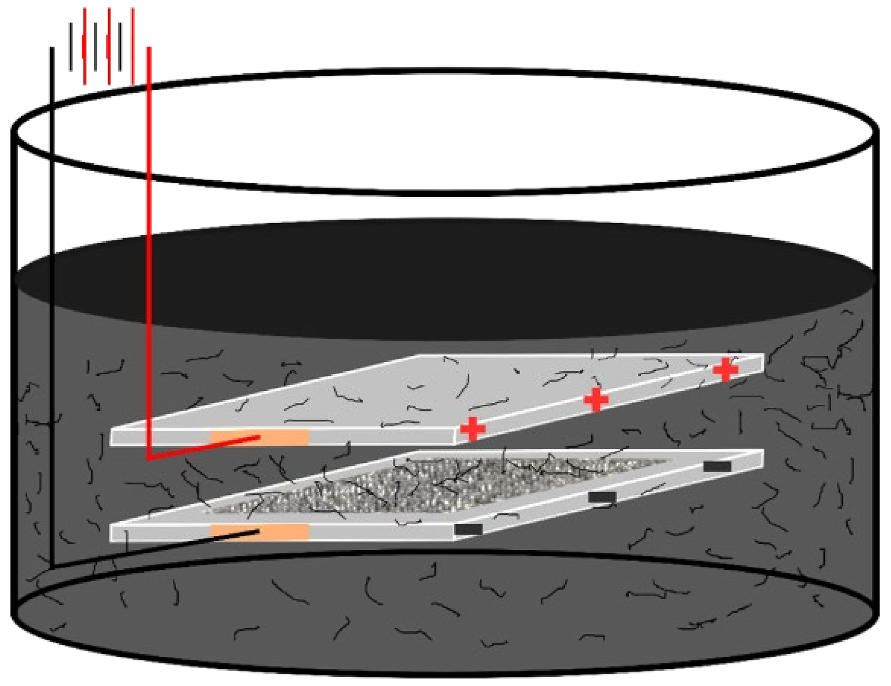
Introduction

- Carbon nanotubes (CNTs) create nerve-like electrically conductive networks and can be used as sensors for strain and damage.
- Adding a CNT film on the carbon fiber can enhance the piezoresistive electrical-mechanical response of
- Hybridization of long discontinuous fibers with CNTs offer the potential for simultaneous mechanical performance improvements and *in situ* sensing.
- Electrophoretic deposition is being investigated for nanoscale hybridization.

Electrophoretic Deposition

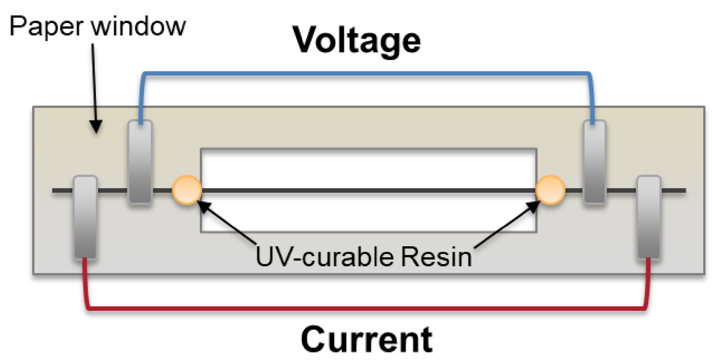
- Electrophoretic Deposition (EPD) is a method for depositing charged particles on a substrate using an electric field.
- Carbon nanotubes are functionalized with polyethyleneimine (PEI) to create an aqueous uniform dispersion and deposited using direct current (DC).



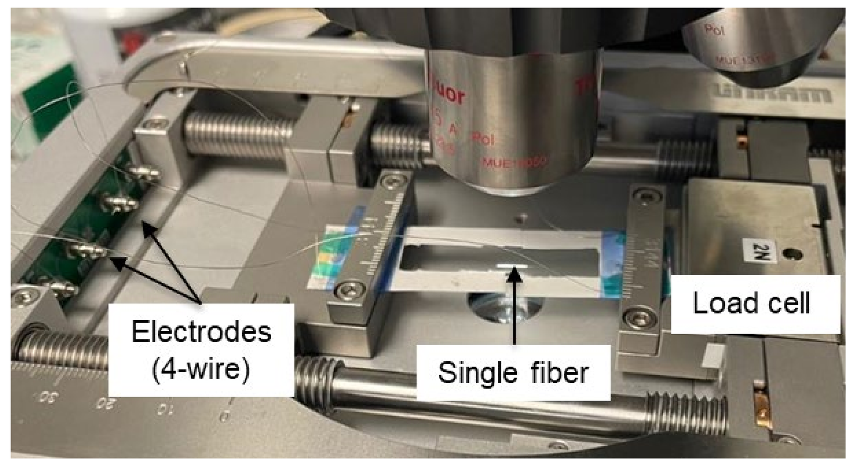
- A thin film of PEI functionalized nanotubes is created on the substrate.
- EPD can coat both conductive and non-conductive fibers in filament, bundle and fabric forms.

Single Fiber Piezoresistivity

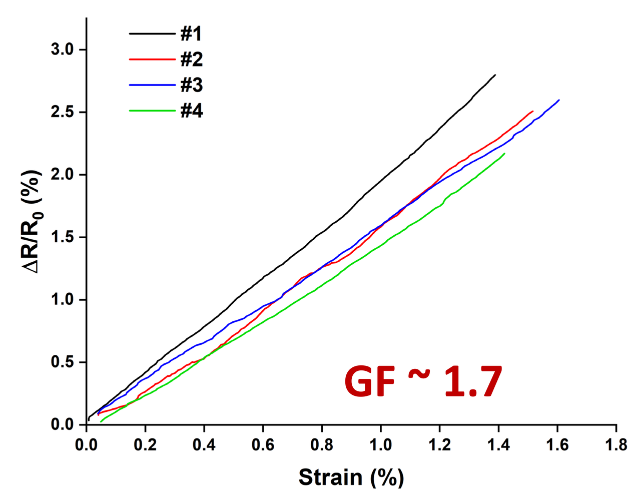
- Individual carbon fibers were tested for their piezoresistive behavior.
- Uncoated and CNT coated single fibers are tested using Linkam hot stage.

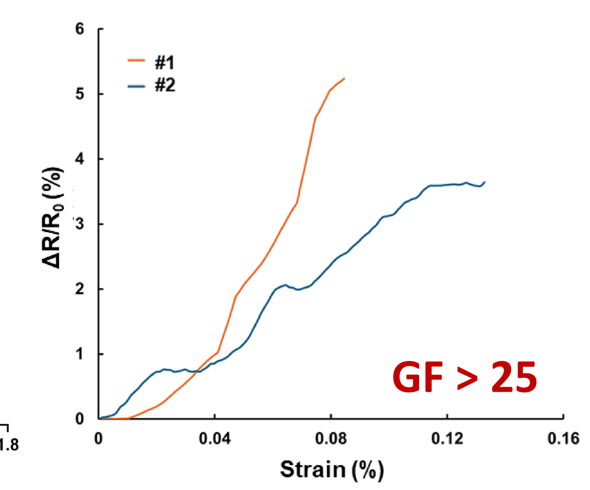


- The fibers were tested at a displacement rate of 20 µm/s.
- Resistance was recorded using a 4-wire measurement technique.

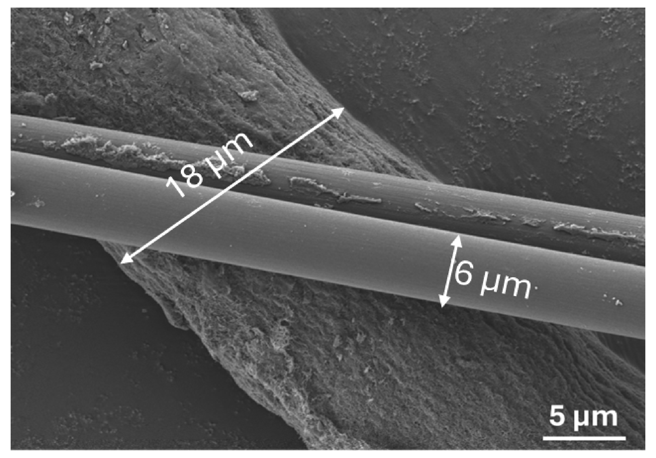


Uncoated Carbon Fiber | **CNT Coated Carbon Fiber**



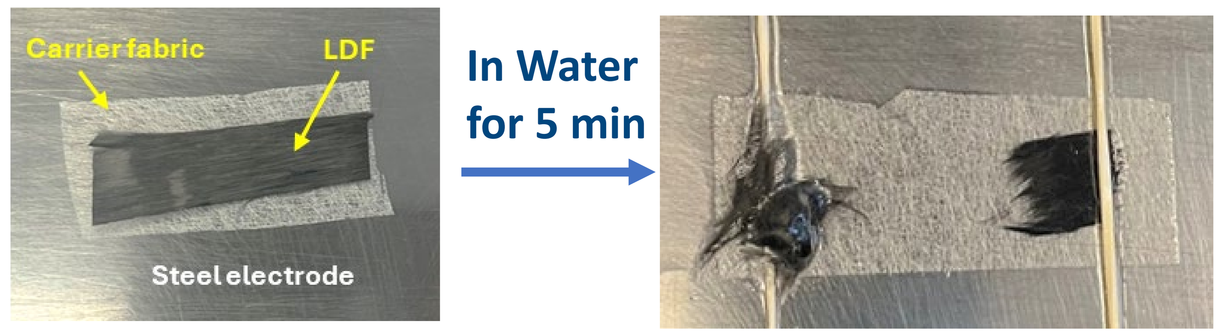


- The gauge factor, defined by the slope of the resistance/strain response for uncoated fibers is 1.7, while for coated fibers, it is greater than 25.
- The failure strain for the CNT coated fiber is 10% less than the uncoated fiber.
- The as-deposited CNT film was rather thick and appeared to initiate fiber fracture in areas of coating nonuniformity.



Electrophoretic Deposition of CNTs onto Long Discontinuous Fibers

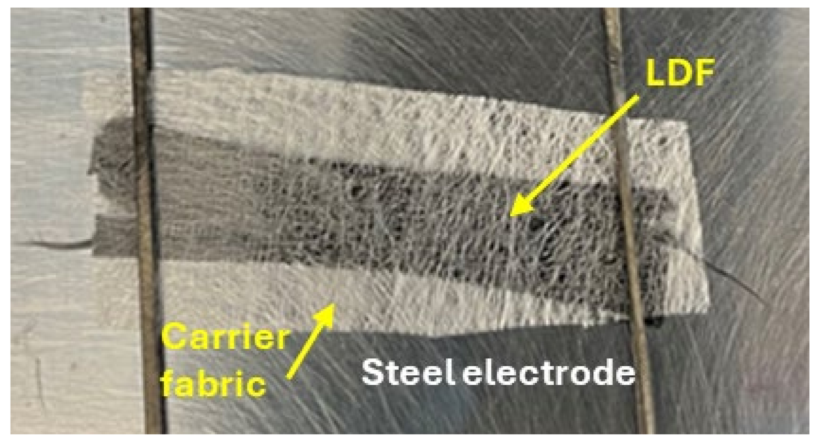
- Challenges include maintaining fiber alignment, keeping fibers together, and ensuring contact with the cathode.



- When fibers are submerged in water, shorts fibers are taken away.
- Two different methods are used for EPD on discontinuous fibers.

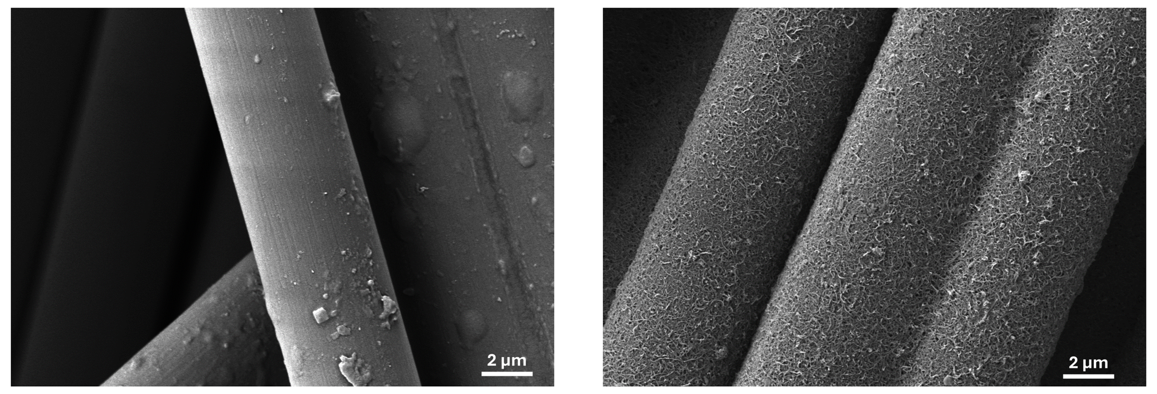
EPD on Fibers Under Carrier Fabric

- One way to keep long discontinuous fibers in contact with the electrode is by covering them with the carrier fabric.



- This process produced a uniform CNT coating on fibers surface.

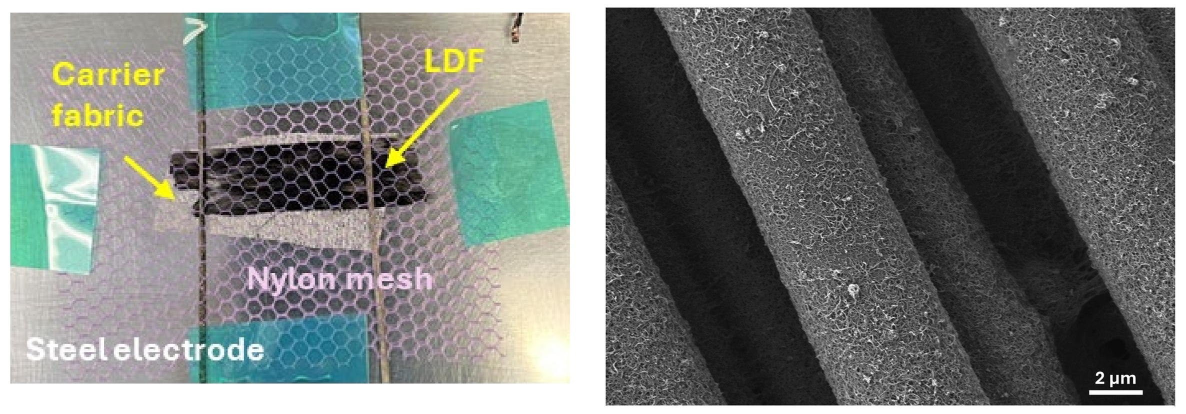
Uncoated Fibers | **CNT Coated Fibers**



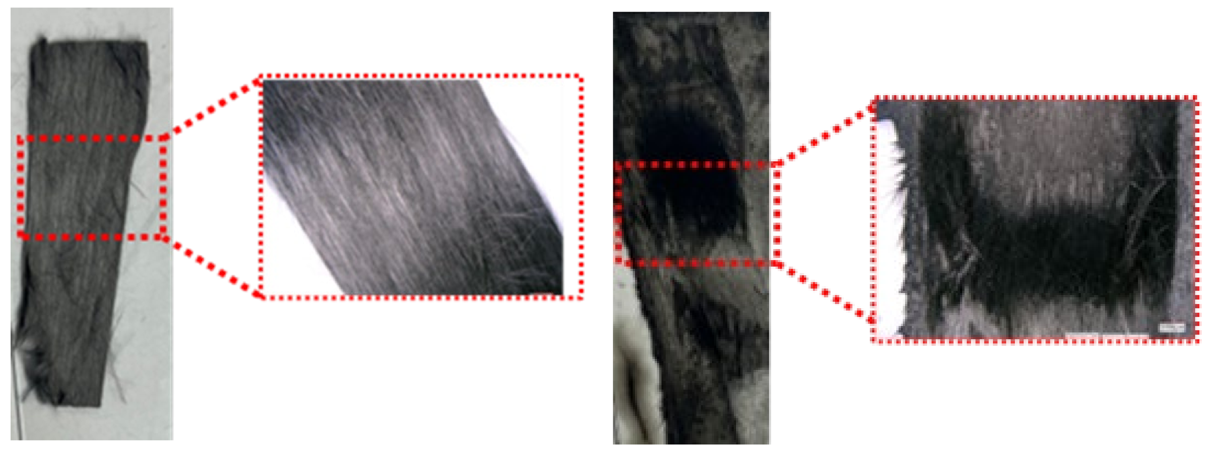
- An advantage of this process is the reduced EPD time, as CNTs grow directly onto the carbon fibers.
- A drawback of this process is that the fibers become misaligned while transferring to and from electrode.

EPD on Fibers Under a Nylon Mesh

- Commercial nylon mesh is used to cover the discontinuous fiber mat.
- The mesh was taped directly to the electrode to limit fiber movement.



- This process produced a uniform CNT coating, and fiber alignment was maintained after EPD.



Before EPD | **After EPD**

Conclusions and Future Work

- The integration of CNTs significantly increases the piezoresistive sensing response of carbon fibers.
- A large CNT film thickness influences the mechanical properties of the carbon fiber.
- The use of a nylon mesh to hold the dry fibers in place during the EPD process allowed for the deposition of CNTs onto the discontinuous fibers while maintaining fiber alignment.
- Testing is in progress to study the piezoresistivity of the CNT-coated long discontinuous carbon fiber composite.
- A detailed study is required to examine the influence of CNT film thickness on carbon fiber mechanical properties.