Carbon Nanotube Fiber Electromechanical Characterization

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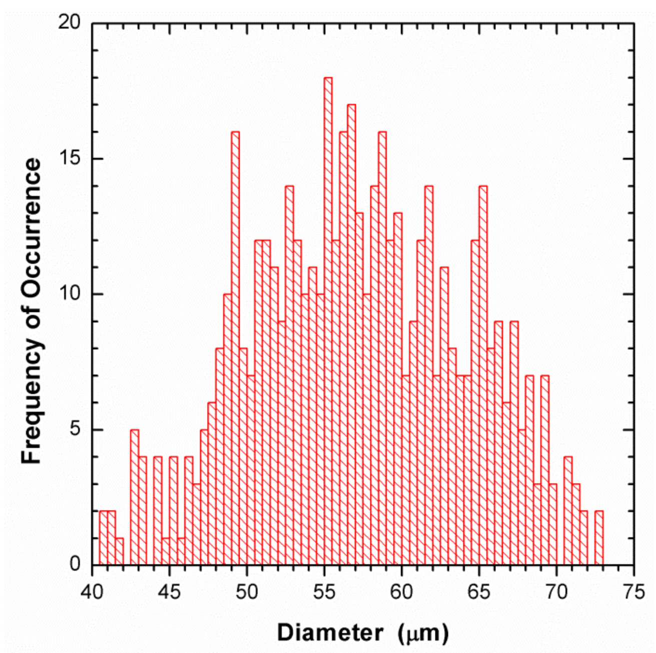
CARBON NANOTUBE FIBERS

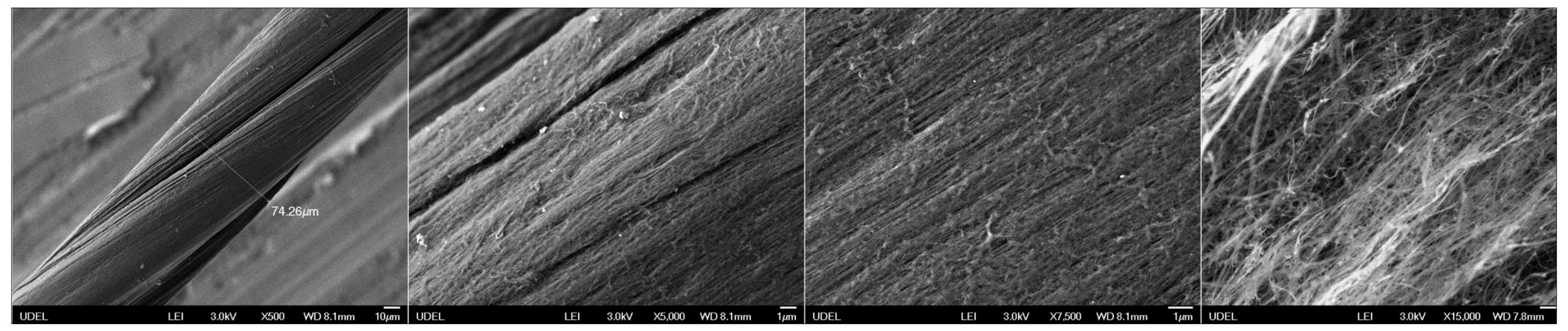
Carbon nanotubes are held in place through nanotube-nanotube entanglements and van der Waals interactions.

Fiber microstructure:

- **Diameter varies significantly.**
- **In some specimens, twist produces a ribbon-like microstructure.**



Fibers comprised mainly of single walled carbon nanotubes



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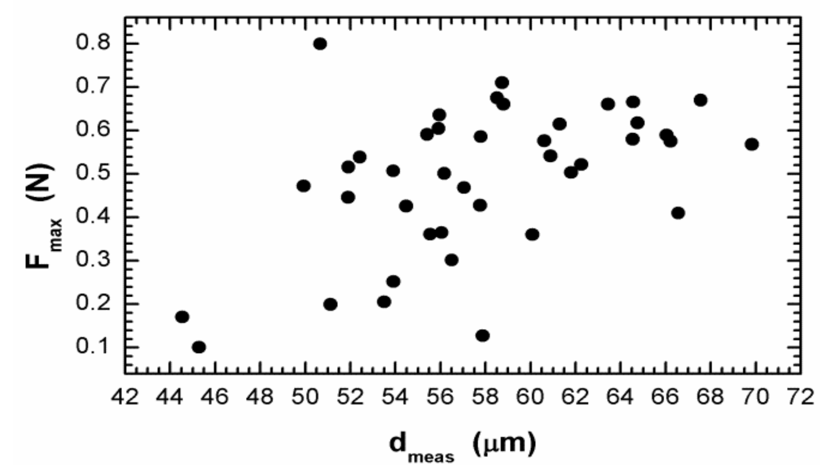
FIBER CHARACTERIZATION

Fibers are tested under quasi-static tensile loading.

Table Material properties of the aerogel-spun CNT fibres (average values).

Diameter, d_{avg} [µm]	57.3 ± 5.9
Failure Load, F_{max} [N]	0.49 ± 0.17
Failure Strain, ε_{max}	0.096 ± 0.021
Strength, σ_{UTS} [GPa]	0.189 ± 0.052[a]
Modulus, E [GPa]	9.16 ± 2.53[a]
Conductivity, κ [S m^{-1}]	5.1 ± 1.7 (10^4)
Resistance, R [Ω]	67.5 ± 23.6

[a] Properties are calculated based on actual fiber cross-sectional area.



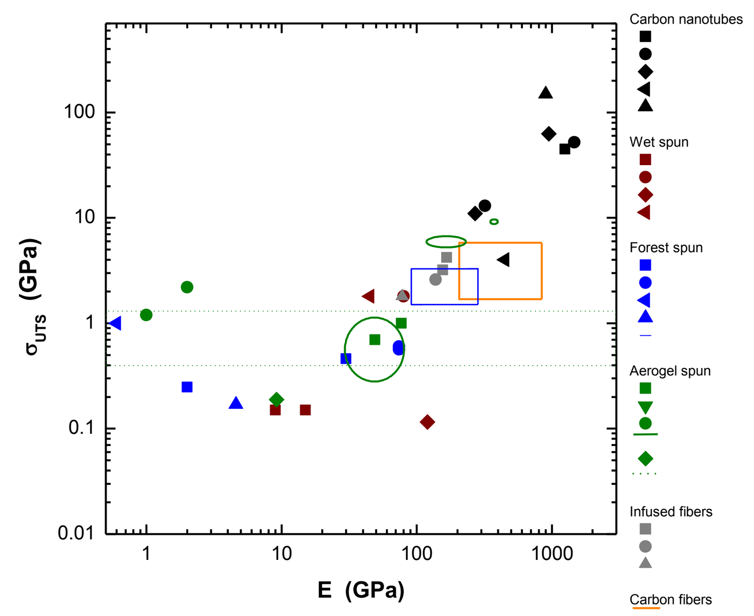
- **Calculating fiber strength based on linear density yields 0.7 GPa.**
  - area method

$$\sigma = \frac{4F}{\pi d_{meas}^2}$$

  - linear density method

$$\sigma = \frac{F}{(LD/\rho)}$$

Comparison of various carbon nanotube fiber mechanical behavior (right).



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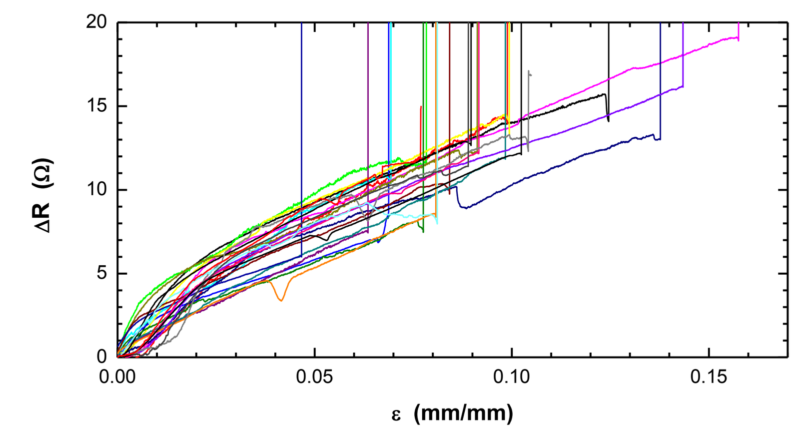
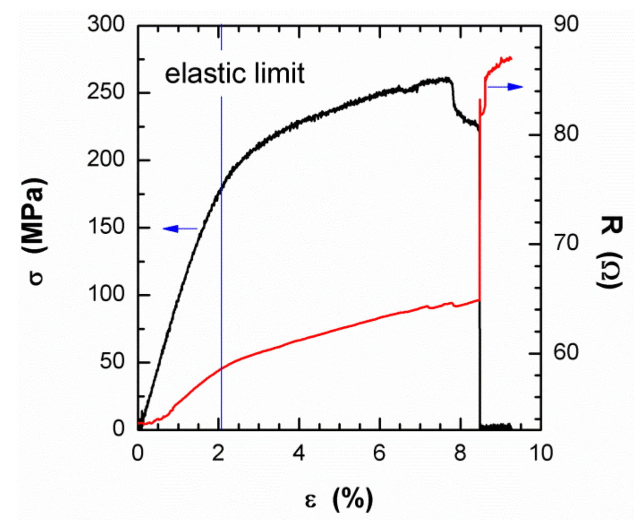
ELECTRICAL BEHAVIOR

Active resistance measurements demonstrate the piezoresistive nature of the fibres.

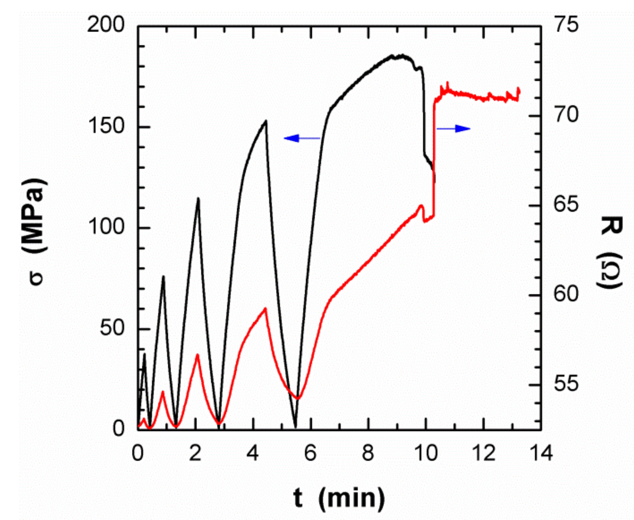
Potential for strain sensor applications*





Both R and σ increase at different rates before and after the elastic limit of the fiber (top right).

Cyclic experiments demonstrate that changes in electrical resistance are recoverable during the linear elastic regime (bottom right).



*Zhao, et al. *Nanotechnology* 21;305502 (2010)

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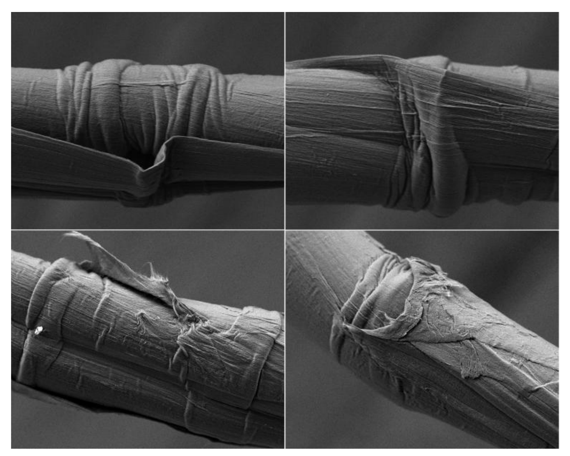
COMPRESSIVE FAILURE

Fiber specimens exhibited kinking after tensile failure



Tensile Strength [MPa]	Kink formation?
113.5	y
118.2	n
127.4	y
148.3	n
149.2	n
160.1	n
163.2	n
167.7	n
171.3	n
172.1	n
177.2	y
182.6	y
185.9	n
190.1	y
190.3	y
199.6	y
208.2	y
211.0	y
222.2	n
223.3	y
245.9	n
249.6	y
250.9	y
258.5	y

Kinking is likely due to compressive failure under tension-induced recoil.

Assuming compressive stress is equal in magnitude to the tensile stress at failure*, we can identify compressive strength of the fibers.

*Allen *Journal of Materials Science* 22;853 (1987)

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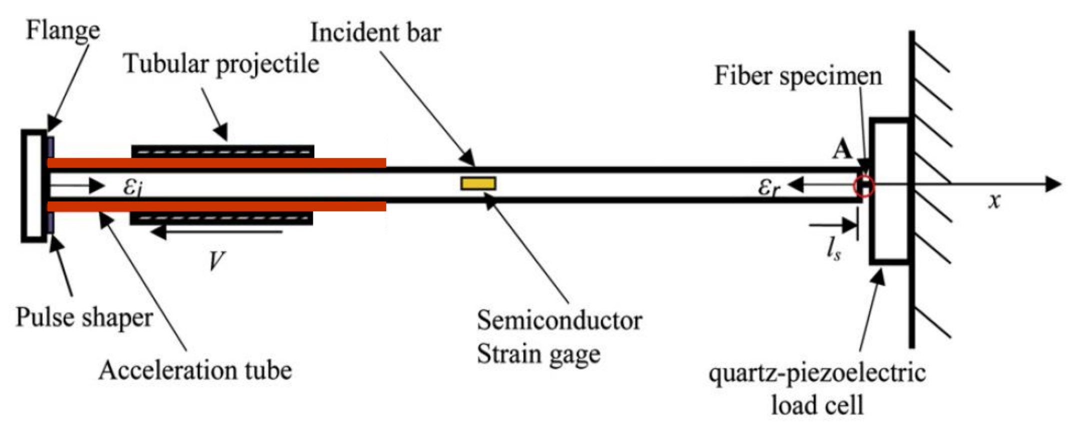
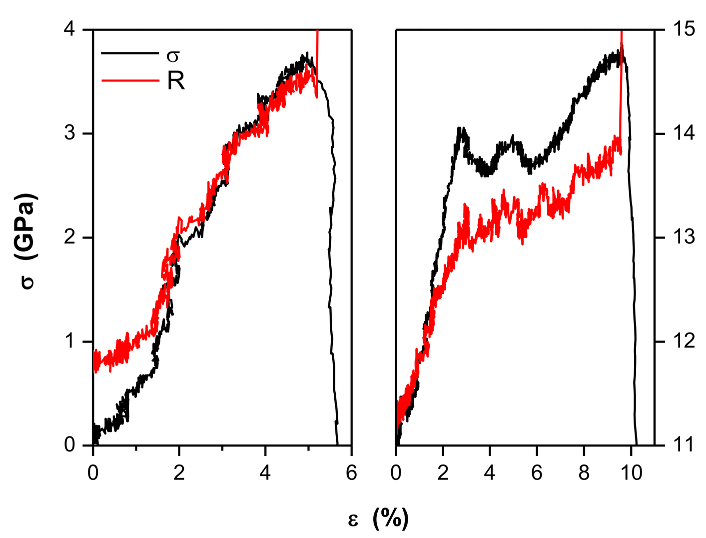
DYNAMIC BEHAVIOR



Kolsky tension bar

- **Fiber specimen attached using set screws**
- **Air driven striker bar (25 and 50 psi)**
- **22.24 N (5 lbf) quartz–piezoelectric load cell (Kistler 9712B5)**
- **Displacement measured via laser emitter-detector pair**



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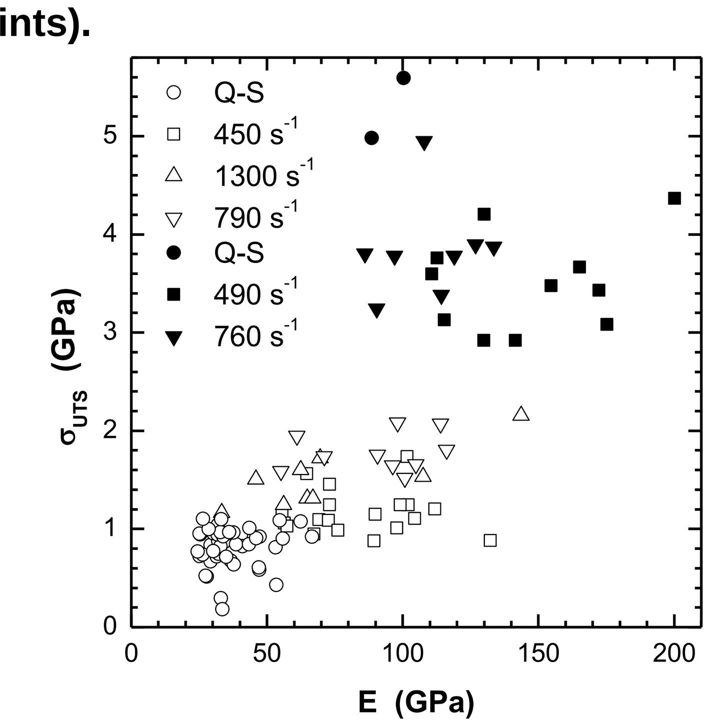
POST-PROCESSING EFFECT

- **Fibers exhibit piezoresistivity during dynamic tensile loading.**
  - Potential to sense strain/damage during high-rate loading
- **Chemically treated and stretched fibers (filled-in data points) possess higher strengths and moduli than untreated (hollow data points).**



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