Improving the Strength of Electrospun Nanofibers

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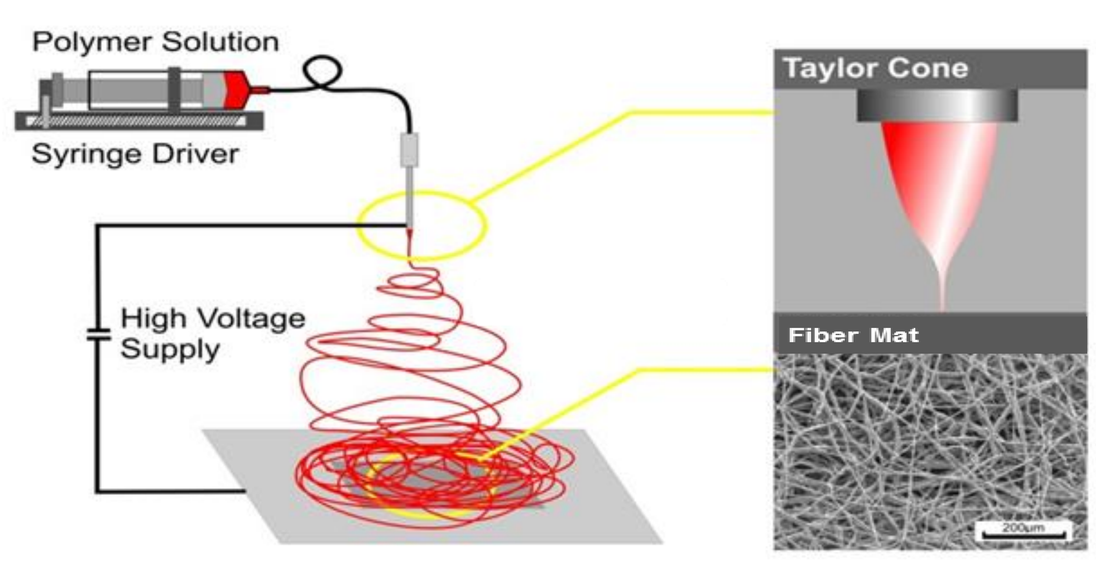
KX Technologies

The Technology:



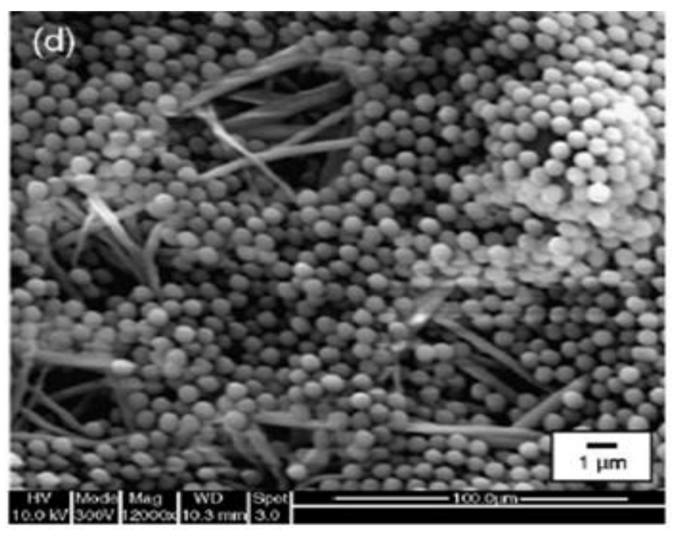
http://www.centropede.com/UKSB2006/ePoster/background.html

Nanofibers are made by a process called electrospinning. A high voltage supply is used to electrify polymer solution which shoots out of a needle tip, is whipped into nanoscale threads, and collects in a randomly oriented pattern on a grounded collector.

An industrial scale electrospinning device; the Elmarco Nanospider^{TM}. This electrospinning device is designed for 24/7 use and can produce 20,000,000 m^2 of nanofiber mats annually.

http://www.elmarco.com/upload/soubory/dokumenty/143-1-ns-8s1600u-profile-110207-72dpi.pdf

The Market:

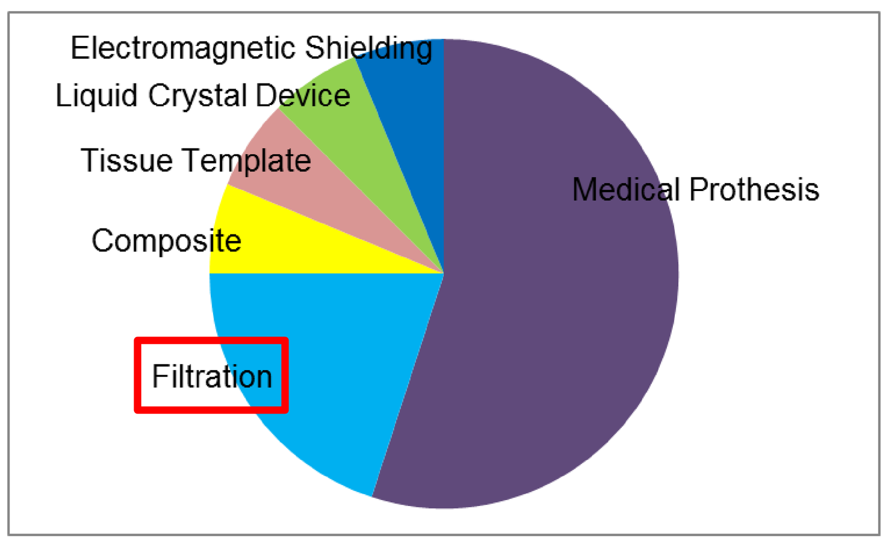


Gopal R, Kaur S, Ma ZW, Chan C, Ramakrishna S, and Matsuura T. Journal of Membrane Science 2006;281(1-2):581-586.

The image to the left is a scanning electron microscopy image showing nanofibers being used to filter out particles. The figure below shows many of the potential markets for polymer nanofibers.

Improving the strength of these nanofibers will enable them for potential for uses in:

- Waste water treatment
- Personal water filters
- Bacteria removal
- Bio-pharmaceutical filters

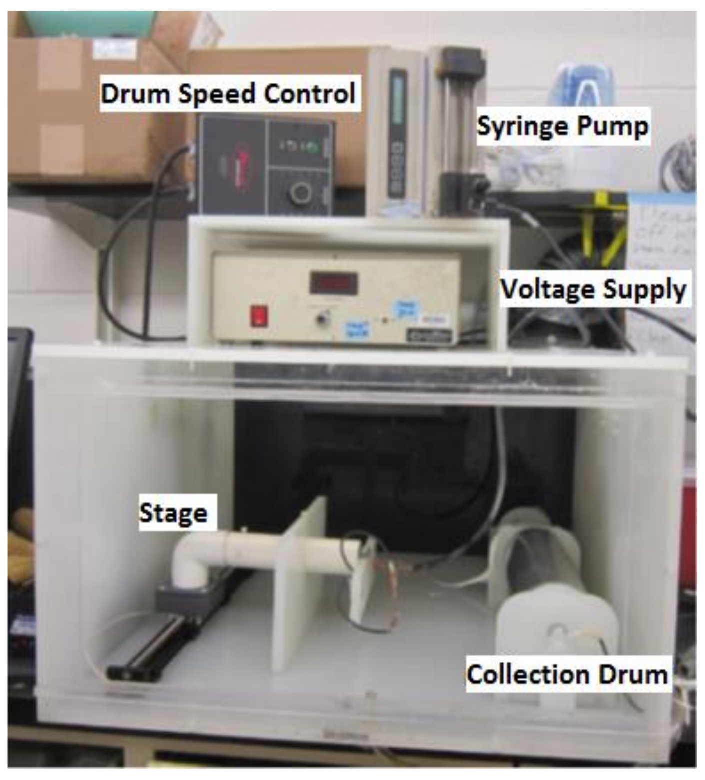


Adapted from: Huang Z-M, Zhang YZ, Kotaki M, and Ramakrishna S. Composites Science and Technology 2003;63(15):2223-2253

Objective: To experimentally determine the heat treatment that produces the strongest possible electrospun polyacrylonitrile nanofibers without compromising performance.

Methods:

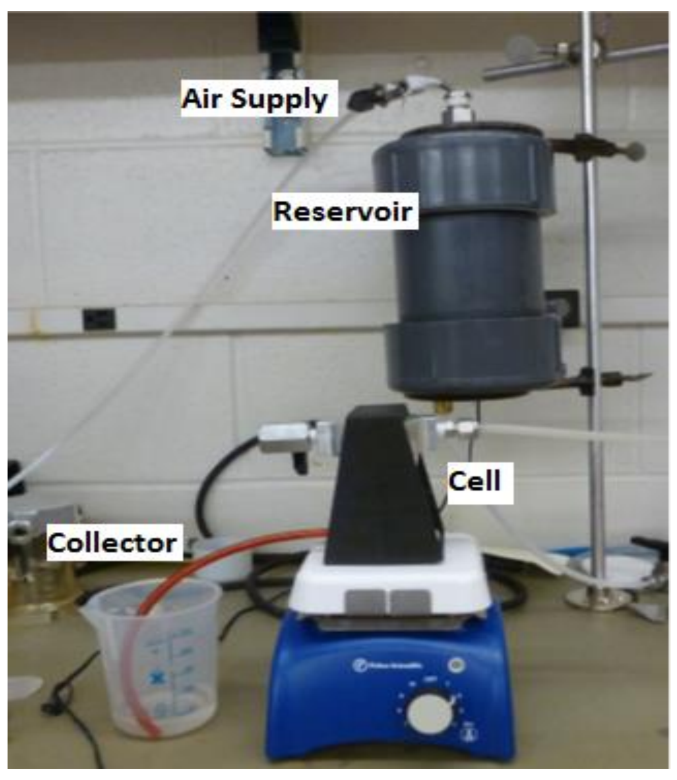
Electrospinning Device



Spinning Conditions:

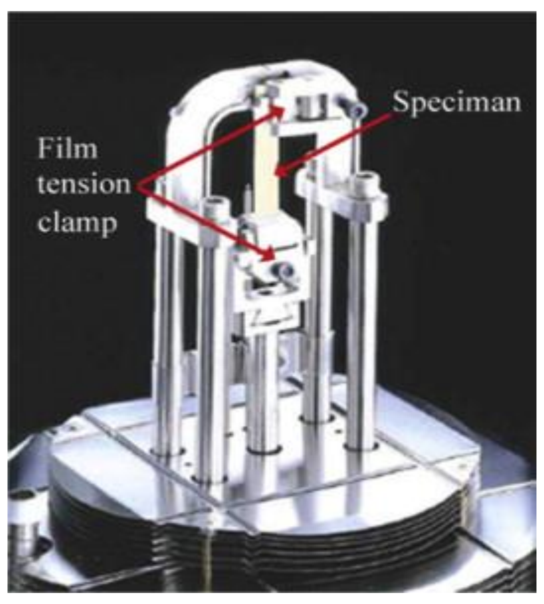
- Voltage: 28kV
- Flow Rate: 1 mL/hr
- Polymer: 10% Polyacrylonitrile
- Solvent: Dimethylformamide

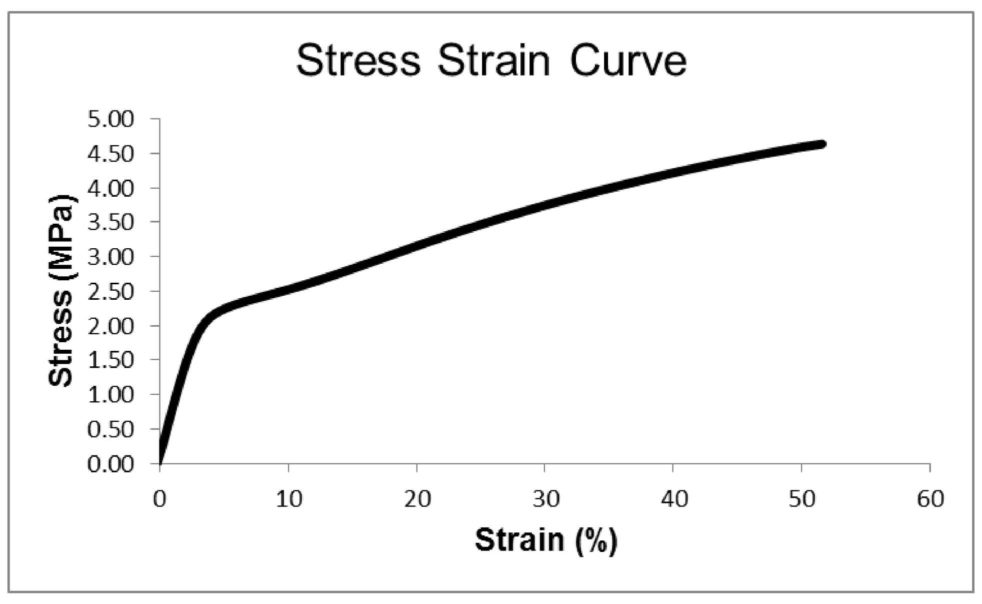
Dead End Cell



The dead end cell is used to calculate the pure water permeability of the nanofiber membranes.

Dynamic Mechanical Analyzer (DMA)



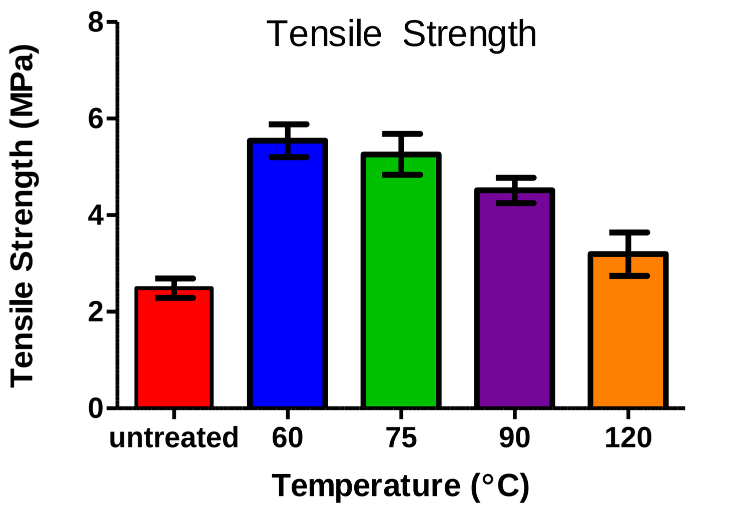


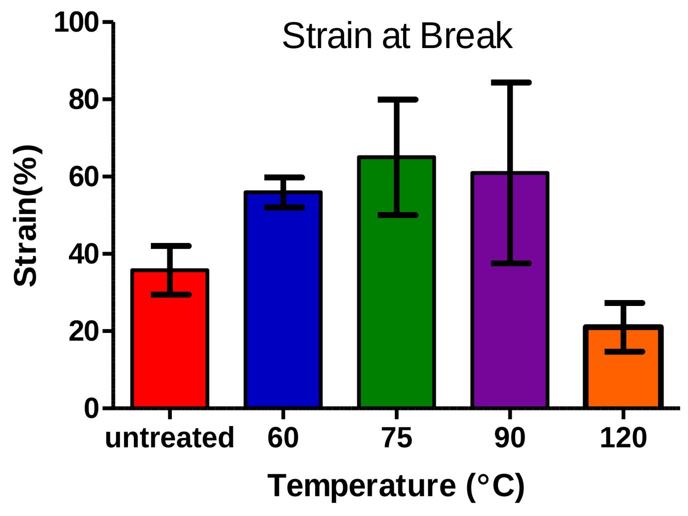
The DMA test stretches and pulls a sample until it breaks, outputting a stress vs. strain curve which is used to calculate mechanical properties.

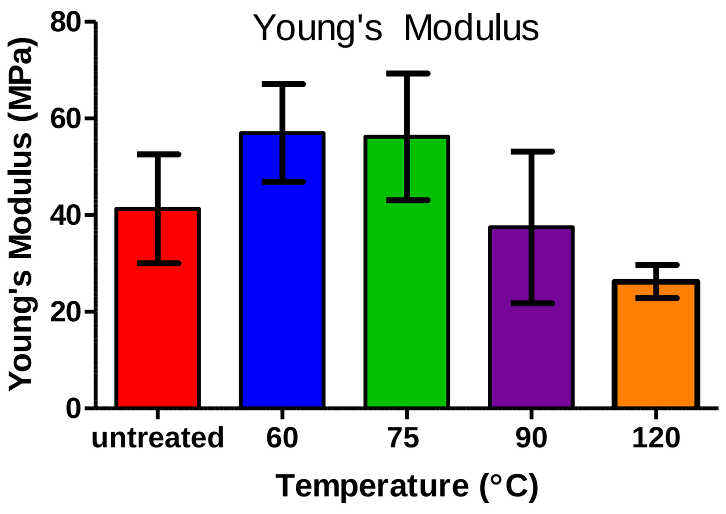
Results:

Mechanical Properties

Tensile strength, strain at break and stiffness all increase upon heating, with the best results occurring around 75°C



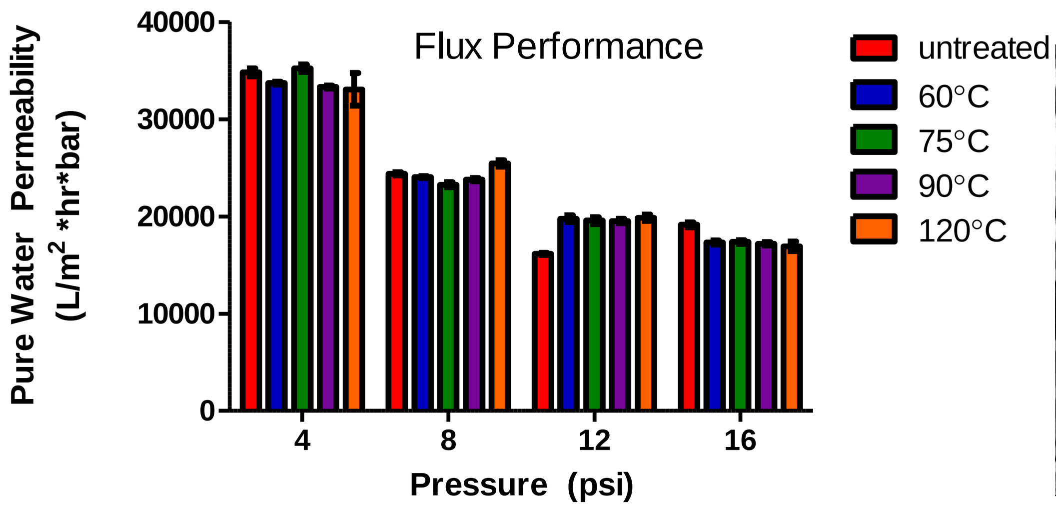


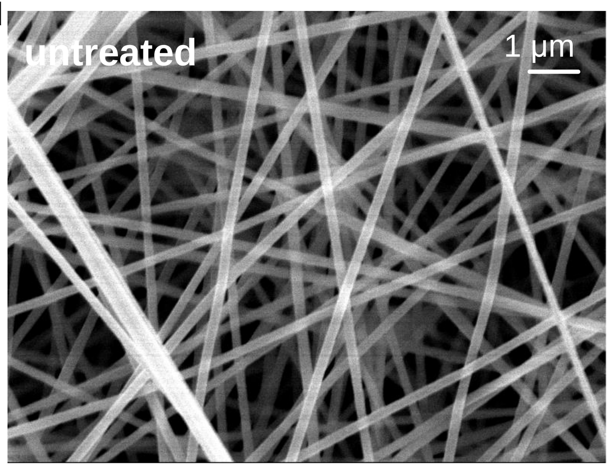


As these graphs show, the mechanical properties of the nanofiber mats increase upon heating with peaks between 60 and 75°C but with no significant effect on the performance of the fibers, shown below.

Performance

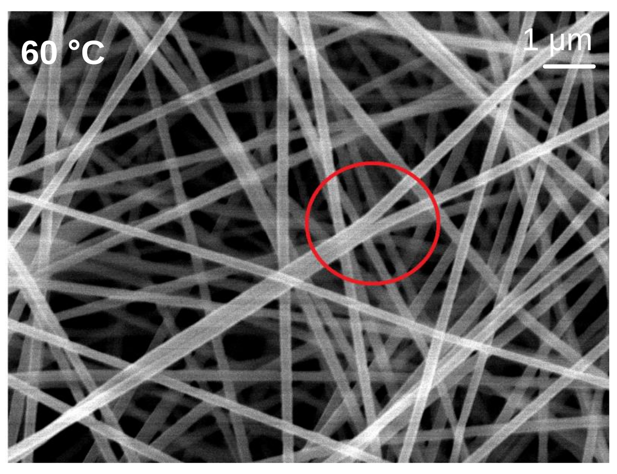
The pure water permeability decreases as pressure increases but is not significantly impacted by different heating temperatures.

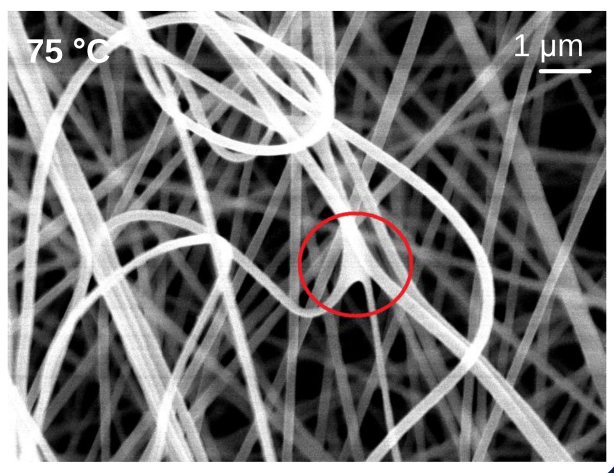




SEM Images

In these images you can see increased binding of fibers at junction points.





Conclusions:

- Heating the nanofibers showed an increase in mechanical properties.
- The glass transition temperature of polyacrylonitrile is 85°C, which may explain the decrease in strength above that temperature because the sample becomes more glass-like and breaks easier.
- The heat treatment does not appear to change the structure of the fibers or compromise their performance because the water permeability does not change significantly with treatment.

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