Electrospun Biopolymer-Based Micro/Nanofibers

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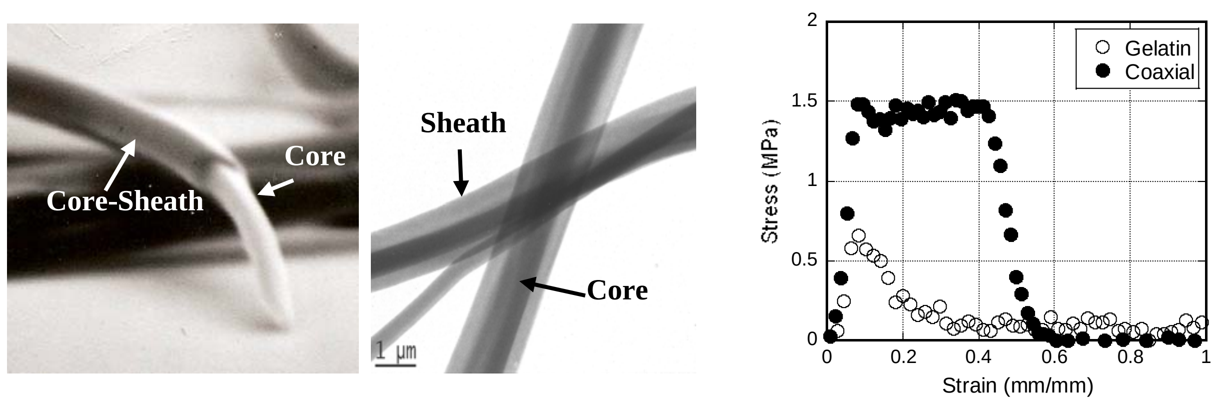
Electrospinning is an established method for creating polymer and bio-polymer fibers[1] of dimensions ranging from microns to 10s of nanometers. The process involves applying a high voltage between the source of solution (usually a capillary or syringe) and the substrate to which the nanofibers are deposited on. The potential creates a liquid droplet at the tip of one electrode. Additional applied voltage ejects the solution in the droplet toward the counter electrode. One of the advantages of the electrospinning technique is that it is relatively easy to produce large amounts of nanofibers without expensive fabrication methods. Another advantage is that nanofibers composites can be made, with the only restriction being that the dispersed phase needs to be soluble in the initial solutions. Some examples of this include quantum dots[2], carbon nanotubes[3], and viruses[4]. It has also been demonstrated that coaxial electrospinning is possible[5], wherein the nanofiber has two distinct phases, one being the core, and another being the sheath. The electrospinning technique has been used in a variety of applications, including tissue engineering[6], field-effect transistors (FET)[7], and light emission.[8] Here we employ electrospinning to make fibers for uses in tissue engineering, bio-photovoltaics, and bio-FETs.

Tissue engineering involves the creation of artificial tissue for the body. By combining bio-compatible materials with cells and other biologically active species, tissue scaffolds can be made. Taking advantage of the core-sheath architecture, tissue scaffolds have been made using electrospun fibers containing polycaprolactone (PCL) as the core material and gelatin as the sheath. The exterior gelatin is biodegradable, biocompatible, and promotes cell generation, while the biodegradable PCL core gives the fiber a higher modulus. SEM and TEM images of the gelatin/PCL coaxial fibers are shown in Figure 1, along with tensile measurements of the skin scaffolds.



(a) SEM (b) TEM (c) Mechanical properties comparison

Fig. 1 Coaxial fiber structure

Chlorophyll is the light gathering pigment that gives plants and some bacteria the ability to generate energy from the sun. Chlorophyll molecules and other light gathering molecules known as accessory pigments are located in membrane-spanning proteins called photosystems. These accessory pigments along with chlorophyll allow for the absorption of all wavelengths in the visible spectrum. Photosynthetic identities (chlorophyll, photosystems, chloroplast, etc.) have a high energy yield and quantum efficiencies of nearly one, making them promising candidates for photovoltaic devices.[9] Since the polymer fibers can somewhat mimic the biomolecular environment of the pigments and photosystems, electrospun polymer fibers are a great candidate for the creation of photovoltaic fibers based on plant biology. The photovoltaic is in the form of a fiber, thus it can be woven into other textiles, allowing for light-weight energy generation capabilities. Polymer fibers can also include photosystems, which may have improved properties over the stand-alone chlorophylls and accessory pigments. Various properties of the polymer may help enhance the properties of the photovoltaic device. For example, a conductive polymer can improve electron mobility in the devices, or a thermosetting polymer can improve mechanical and strength properties. Examples presented here include isolated pigments and photosystems in a variety of polymers and biopolymers. An optical microscopy image of spinach pigment doped poly vinyl pyrrolidone (PVP) is shown in Figure 2.

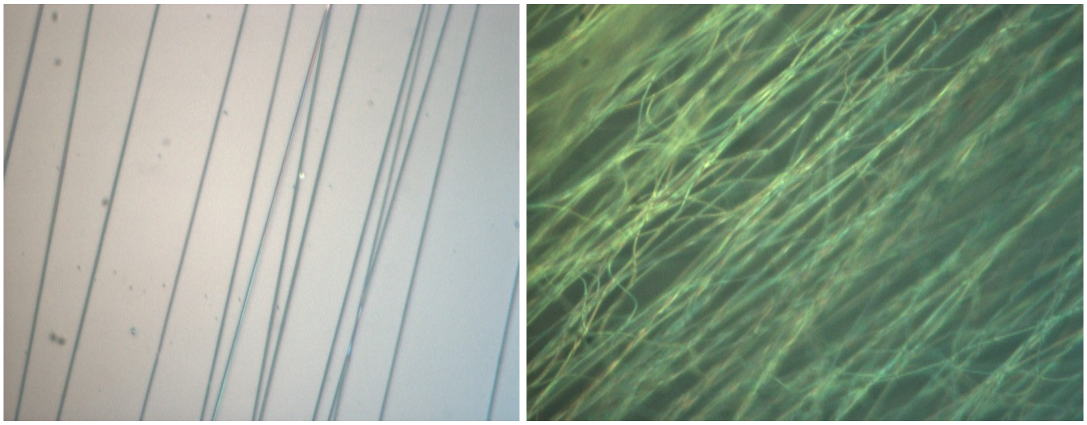
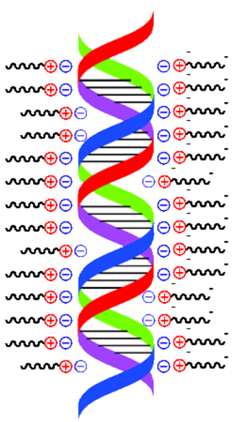
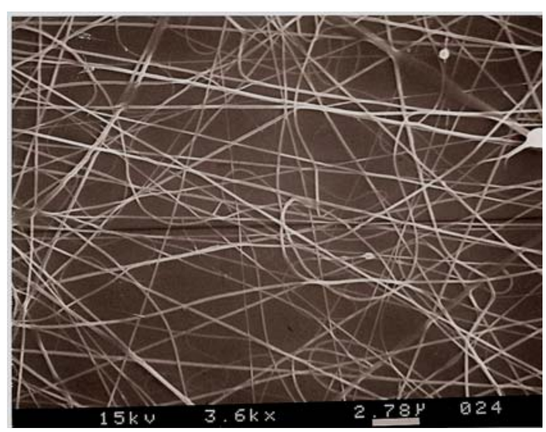


Figure 2. Poly vinyl pyrrolidone (PVP) fibers doped with photosynthetic pigments from spinach. The left image shows aligned PVP fibers (~ 1 micron in diameter) at 1000x magnification (optical microscope). The right images shows a mat of pigment doped PVP fibers at 1000x magnification

Electrospun fibers have previous been used as connective medium in FETs devices.[7] Production of electrospun fibers is relatively easy, and thus electrospun polymer fibers show a great deal of promise in a new generation of FETs. Here we use Deoxyribonucleic acid (DNA) and DNA polymer blends for FET connection to form bio-FETs. DNA is a very interesting material because it is not only one of most abundant organic materials in the world but also unique biomaterial due to its helical structure. We have utilized a cationic surfactant, which is a hexadecyltrimethylammonim chloride (CTMA) to make a DNA to be soluble in common organic solvents. Electrospun fibers of DNA/CTMA are shown in Figure 3 along with a schematic.



(a) DNA/CTMA structure



(b) SEM image of electrospun DNA/CTMA

Figure 3. Electrospinning of DNA/CTMA

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