Spider Silk Films: An Innovative Biomaterial

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Introduction

Although Spider silk has been around for 100s of millions of years, we are just starting to understand its many uses. The previous lack of understanding was due to a lack of technology sufficient to obtain large amounts of silk using genetic engineering of various hosts.

Synthetic spider silk fibers have exceptional mechanical properties, but they can be difficult to process and replicating specific properties can be challenging. In contrast, spider silk films require minimal processing and their formation is driven mainly by thermodynamic reactions. Although films and fibers have different applications, the enhancement of film mechanical properties could replace the need for mats of woven fibers, which are time consuming and expensive to produce.

Applications for spider silk films are broad, ranging from physical protection to biocompatible materials. Examples of these applications include: high performance helmets, coatings for medical devices, skin implants, and lightweight UV protection. Spider silk's potential to serve as a cellular scaffold holds great promise for the medical industry. Spider silk can easily be impregnated with nanotubes, enzymes, and other substances making it highly customizable.

Methods

Spider Silk

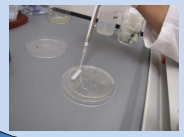
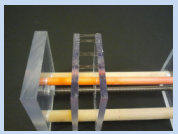
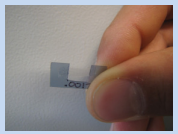
Spider silk solutions (dopes) were created by a 24 hour mixing of silk protein powder dissolved in hexafluoroisopropanol (HFIP) at a concentration of 0.05 g protein/mL HFIP. Protein powder was obtained from transgenic goats expressing the spider silk protein (MW approx. 65 kDa) in their milk. The spider silk films were formed using a mold made of the elastomer polydimethylsiloxane (PDMS) (see below). All post pour treatments were done in the solutions' vapor for 30 minutes.

PDMS Mold

PDMS was chosen due to its ability to prevent film sticking. Each well is 30 x 7 mm and produces two samples for testing. Test samples are cut to 13 x 3.5 mm and weighed to calculate thickness (thickness calculations are based on the protein's density: 1.23 g/cm^3). The samples are then super glued on c-shaped cards. After being mounted on the testing apparatus the card is cut to ensure that only the sample is being tested.

Stretching

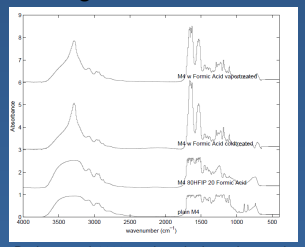
After films are poured and cut, they are glued to a stretching apparatus or "stretcher." This stretcher, which can be controlled both mechanically or manually, was made to ensure that all of the films tested were stretched at the same rate and to the same length; this ensures consistent processing across the sample set.

Acknowledgements Thanks to Dr. Britt of the BE Dept. for use of instruments and minor supply donation.

Results

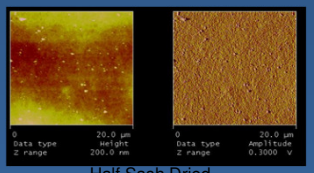
Figure 1: Structural Changes

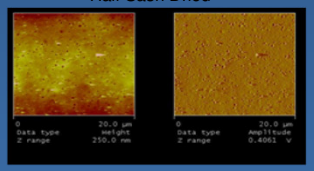


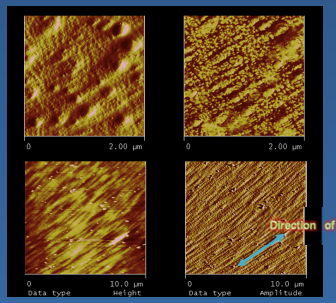
Peaks around 1600nm show the beta sheet and alpha helix secondary structures. The graph shows that Plain M4 with no treatment has less structure than the silk that has been formic acid and cold treated.

Figure 2: Atomic Force Microscope (AFM) Analysis

Tapping mode AFM was used to analyze the surface properties of the materials.


Half Sash Dried

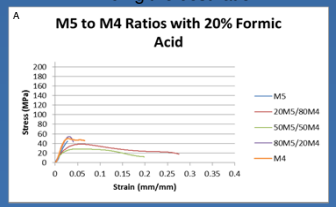

Refrigerator Dried



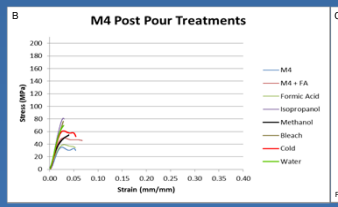
Alignment shown in stretched silk films

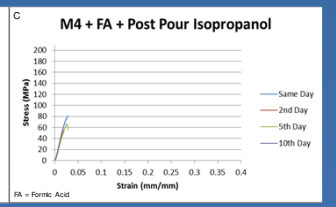
Figure 3: Tensile Testing Results

Finding the best ratio

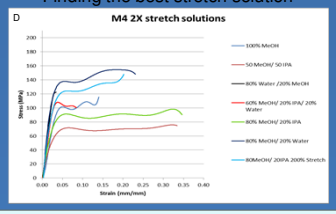


Finding the best treatment

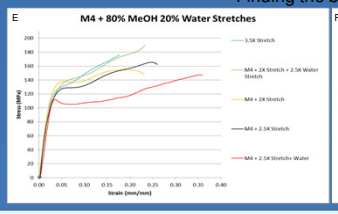


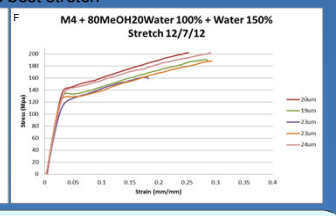


Finding the best stretch solution



Finding the best stretch





Conclusion

Non-Stretched Films

- Drying films in a fume hood with the sash halfway up produced films with the smallest and least number of pores (Fig.2)
- Films composed of 100% M4 have the best ratio of stress and extensibility(Fig. 3A)
- All post-pour treatments increase the stress compared to control M4. Only the M4 + FA and M4 post-pour cold samples show increased strain compared to non-treated samples, all other treatments lead to a decrease in strain, which can be attributed to the formation of secondary structure caused by these other treatments (Fig. 3B, 1)

Stretched Films

- Stretching films increased the energy to break of all films (Fig. 3D)
- 80/20 Methanol/Water stretching liquid increased max stress and strain the most (Fig. 3E)
- Film with the highest energy to break: 2X stretch in 80/20 MeOH/Water followed by a final stretch, totaling 2.5X. It was also one of the most consistent sample groups across all tested. (Fig. 3F)