Mechanical Properties of Hydrogel Fibers from Rapid Injection

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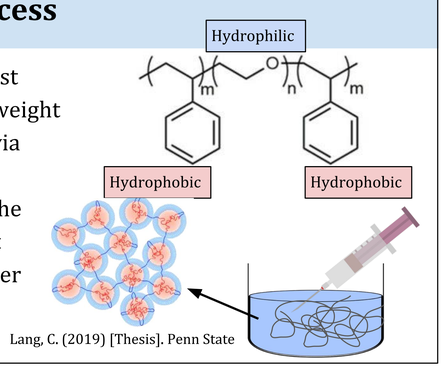
Introduction

A hydrogel is a network of polymers containing water. They are studied for their effectiveness in numerous fields such as tissue engineering, regenerative medicine, and soft robotics. The hydrogel fibers being analyzed are created through solvent-non-solvent rapid injection processing. The polymer of interest is an ABA triblock copolymer: polystyrene-*block*-polyethylene oxide-*block*-polystyrene (SOS). In my analysis, I will discuss how mechanical properties of these hydrogel fibers are affected by straining, drying, and then subsequent recovery in water.

Rapid Injection Process

The triblock copolymer is first dissolved in a solvent at 20 weight percent. Then, it is injected via syringe into a B selective solvent, in this case water. The hydrophobic sections collect together and are held together by the hydrophilic blocks.

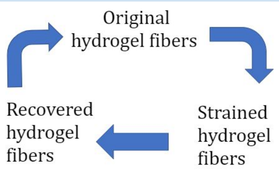


Lang, C. (2019) [Thesis]. Penn State

Materials/Methods

The variations of hydrogel fibers tested:

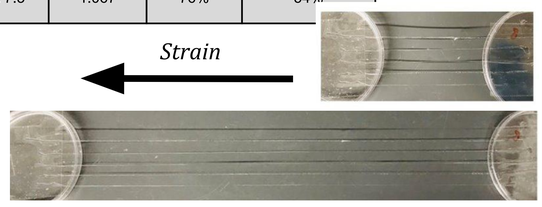
- original fibers directly after rapid injection into water
- dried fibers after they strained while wet to specific lengths
- dried fibers placed back into water and recovered



Sample ID	PS Mn (kg/mol)	Mn (kg/mol)	Dispersity	Actual vol % PEO	Coupling Efficiency
SOS-CE3	26	77.3	1.067	76%	54%

The specific characteristics of the polymer are as shown in the table.

Diagram to the right shows how the wet fibers are strained 4x its original length. The same method is used for each strain.



Results

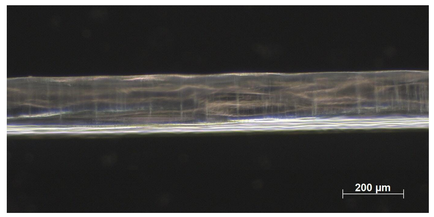


Figure 1: SOS dried fiber strained 3x its original length, before recovery in water

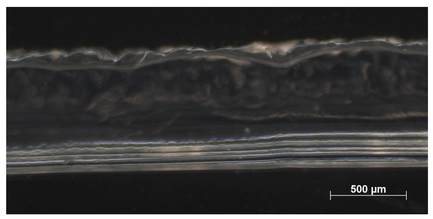


Figure 2: SOS hydrogel fiber from Figure 1 after being recovered in water

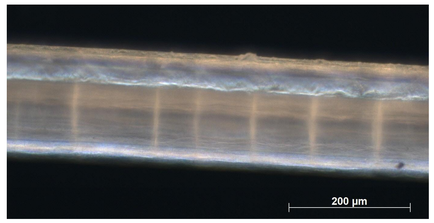


Figure 3: SOS dried fiber strained to 2x original length

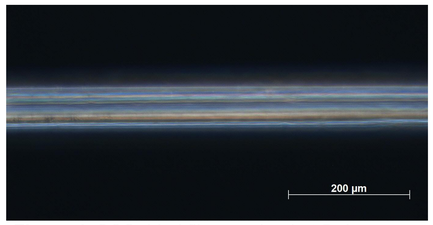
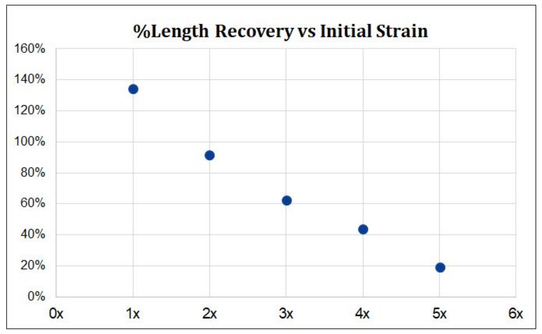
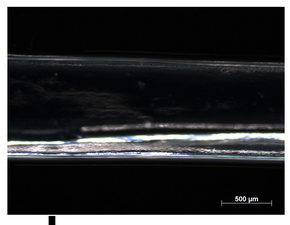


Figure 4: SOS dried fiber strained at 5x its original length



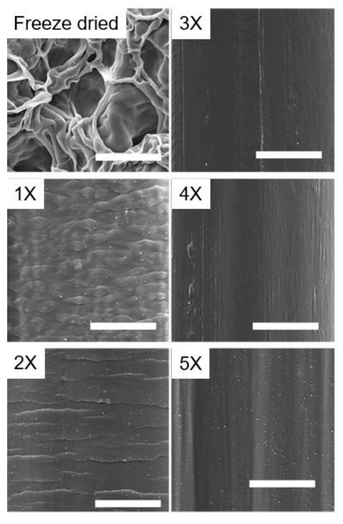
As seen in the optical microscope images above, the fiber swells when recovered in water. As it swells, the length decreases as shown in the figure to the left. The left axis is showing percentage of the original length of the dry fiber versus the submerged recovered fiber.



On the left:
The hydrogel directly after rapid injection is shown. After straining 4x original length and then resubmerging into water, noticable differences in uniformity can be seen.

On the right:
Scanning electron microscopy images of dry strained fibers. Showing the differences in fiber surfaces when strained to different lengths. As well as comparing drying techniques.

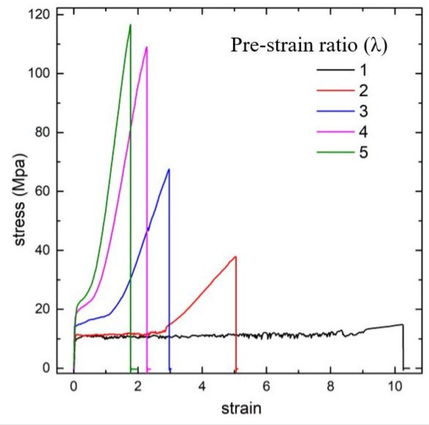
Scale bar: 20 um



Results: Tensile Tests

Sample	Strength (Mpa)	Strain	Modulus (Mpa)
1X	14.6	10.3	212.2
2X	37.8	5.1	396.4
3X	67.5	3	500.3
4X	109	2.3	572
5X	116.6	1.8	537.6

Tensile tests performed on Instron for dry hydrogel fibers which were strained at 1x-5x while wet.



Discussion/Conclusion

The data shows shape memory tendencies by the fibers when recovered in water. They contract effectively forcefully inwards, but not to its original lengths. The fibers also show good mechanical properties from the tensile tests for our proposed applications in tissue engineering and soft robotics.

Future Work

In the future we are looking to substitute polystyrene with a biodegradable polymer such as polylactic acid for biomedical applications. Also, another project is to 3D print these hydrogels to create unique and highly controllable shapes.

References

Lang, C. (2019). *Solvent-non-solvent rapid-injection for preparing nanostructured materials from micelles to hydrogels* [Thesis]. Penn State.
Nat. Comm. 2019, 10:3855
Polym. Chem. 2020, 11, 375:384

Acknowledgements

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