Characterizing the Dynamic Swelling of Polymer-Based Artificial Muscles

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Background

- Polymers are substances that have many structural units that are linked together using the same type of linkage.
- Polymer artificial muscle technologies are being developed that produce similar strains to natural muscle and higher stresses using electrostatic forces, electrostriction, ion insertion, and molecular conformational changes [1]
- Artificial muscle is a generic term used for a class of bio-inspired materials and devices that can reversibly expand, contract, or rotate within one component due to an external stimulus (such as voltage, current, temperature, or light) [2]
- Although artificial muscles can mimic specific temporal, spatial, or force regimes seen in biological nature, they can not perfectly reproduce all these capabilities.

Methods

1. Choose a SPVA polymer. Measure the temperature, mass of dry polymer, and relative humidity of the room before measuring water uptake.
2. Place sample in a petri dish where it will be submerged in deionized (DI) water.
3. Remove sample from water, pat dry, and weigh. Set up near scale since you don't want the polymer to dry up and so you can get an accurate swollen mass.
4. After taking the mass of the polymer, place it into the Fourier Transform infrared (FTIR) spectrometer to get an absorbance plot. Then re-submerge in water.
5. You will do a total of 10 test trials for 30-second intervals (can track time with a stopwatch and record swollen mass each time).
6. After doing 10 test trials, put data into Excel sheet (will do more test until you get a positive correlation)
7. Let the polymer dry, then test the next one. (Repeat 1-6)

Results

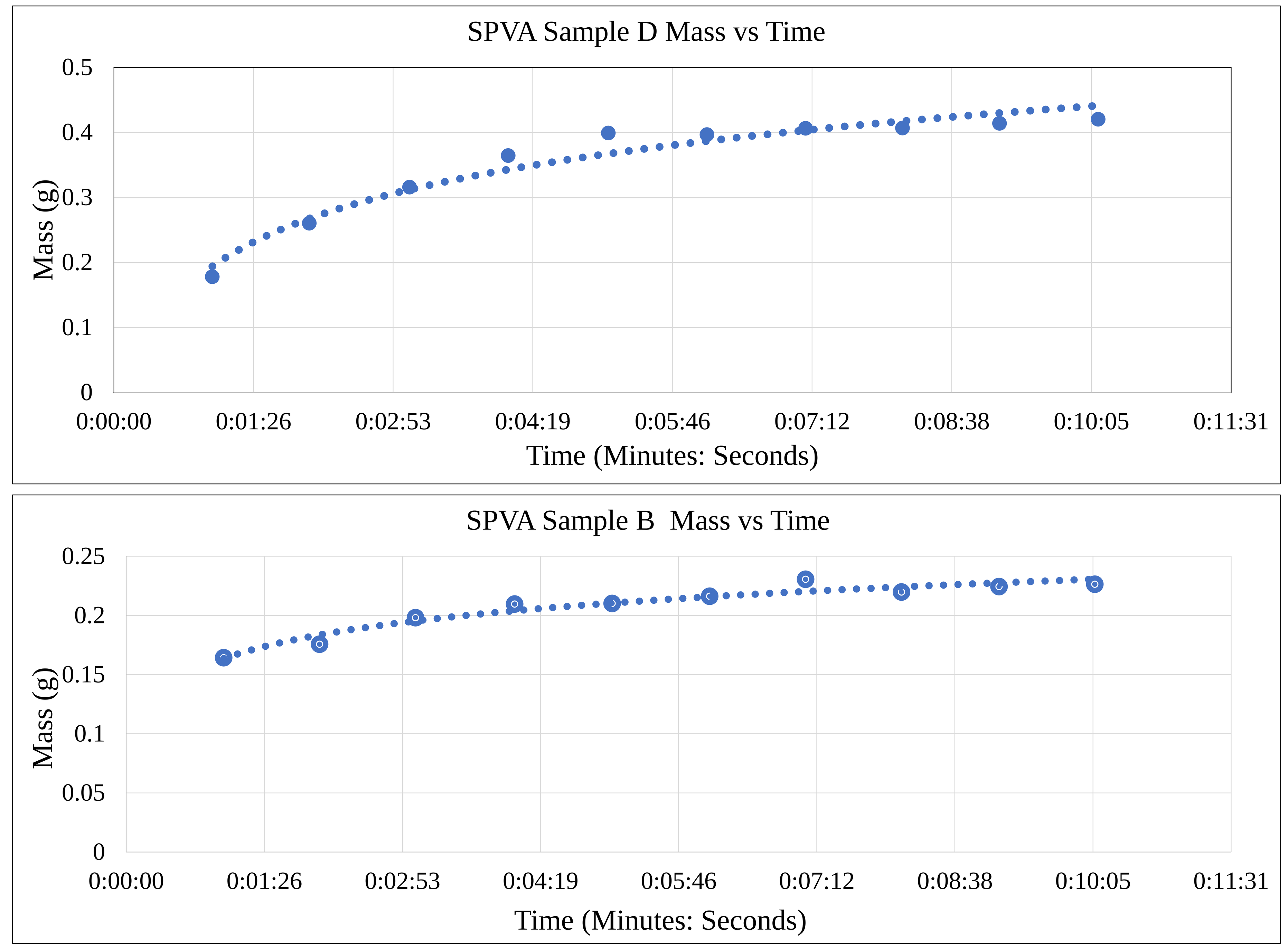

Figure 1: This mass vs time graph shows how much the SPVA Samples polymer swelled over time from running 10 tests for 1 minute duration in DI water. This was one of the few samples that had a positive correlation which means this sample could possibly be used for muscle actuation.

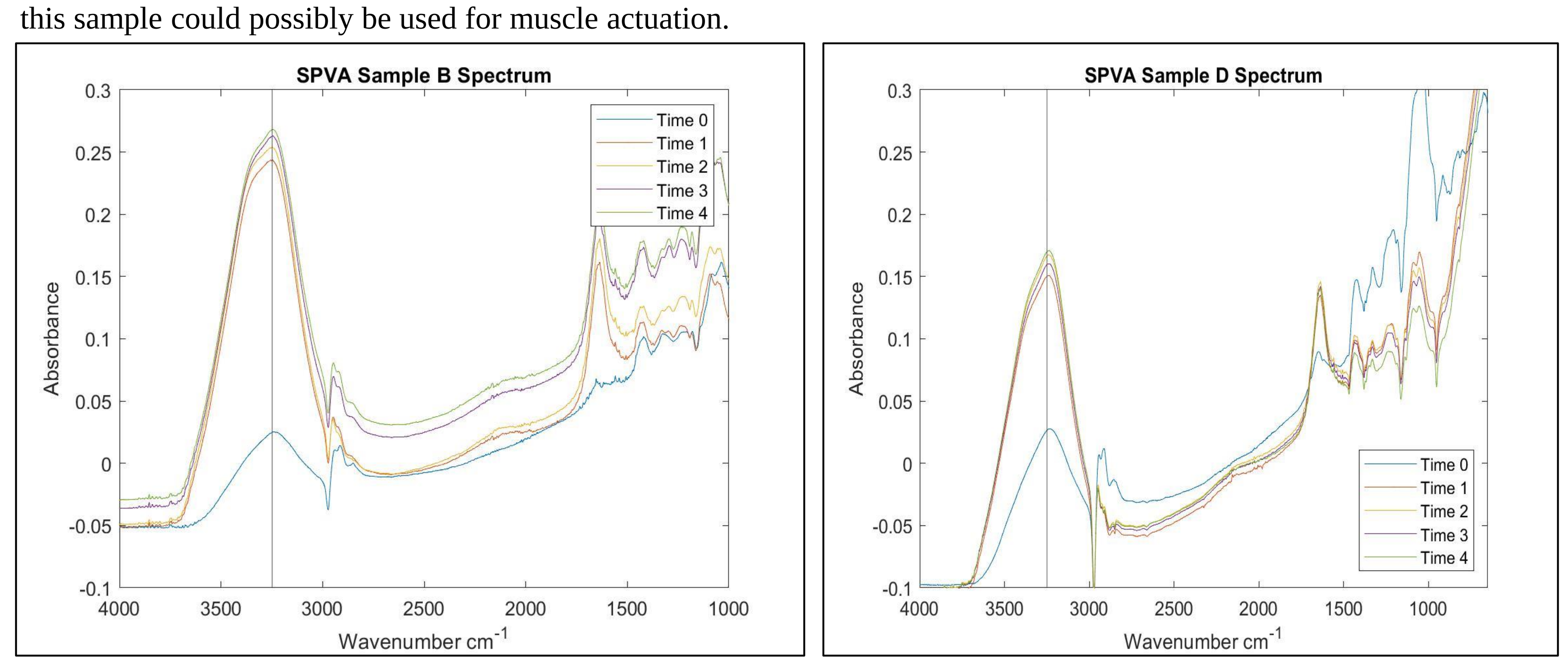

Figure 2: This is a graph from running our sulfonated poly(vinyl alcohol) (SPVA) Samples in the FTIR. This shows how much water the sample absorbed from the ten 1-minute test runs; from this we noticed there was positive correlation to gravimetric swelling data. SPVA samples had better swelling and mass change over time, however, it degrades in water and is not a durable sample.

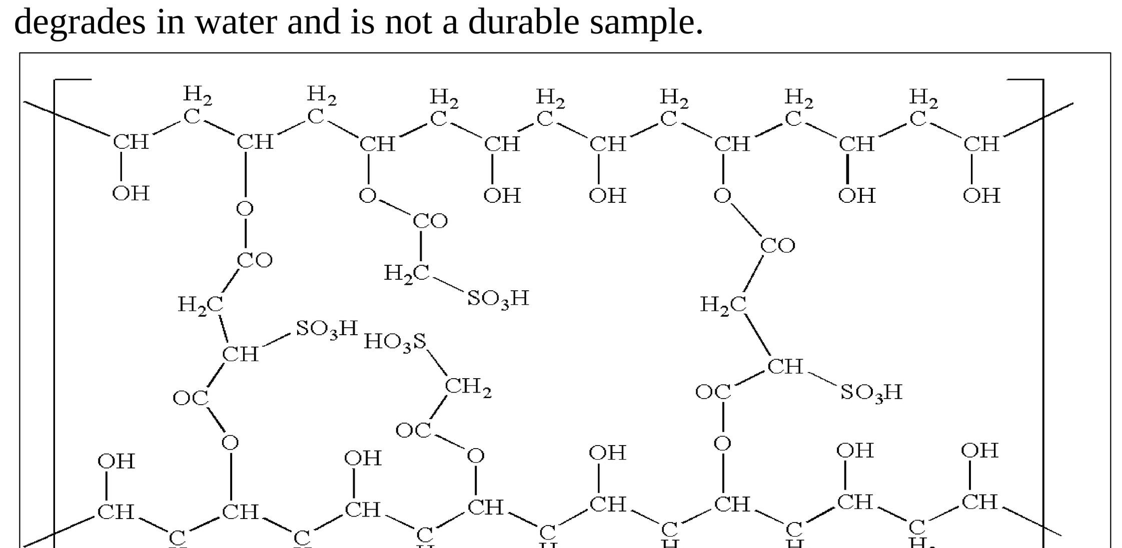

Figure 3: This is the chemical formula of sulfonated poly (vinyl alcohol) (SPVA) polymer

Conclusion

- The purpose of research was to characterize the dynamic swelling of polymer-based artificial muscles.
- We hypothesize that conducting polymers will be the best material candidate to use for artificial muscle.
- The experiment is ongoing because we found that a few of the polymer samples had a positive correlation and we want to run more tests on the polymer samples to find out why only a few of them had a positive correlation.
- This experiment demonstrated that certain polymer samples could possibly be used as a candidate for artificial muscles.

Future Works

- Run swelling measurements on the polymers that had a positive correlation again
- Synthesize hydrogel polymers to see if they could possibly be used for artificial muscles
- Retest SPEEK 90-1 since the first test gave us an unusual reading

References

[1] T. Mirfkhrai, J. D. W. Madden, and R. H. Baughman, "Polymer artificial muscles," *Materials Today*, 21-Apr-2007.

[2] Y. Chen, C. Chen, H. U. Rehman, X. Zheng, H. Li, H. Liu, and M. S. Hedenqvist, "Shape-memory polymeric artificial muscles: Mechanisms, applications and challenges," *Molecules*, vol. 25, no. 18, p. 4246, 2020.

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