Actuating and Self-healing Properties of *Bombyx mori* Silk Thin Film

E. Steven (FSU, Physics), J.S. Brooks (FSU, Physics)

Introduction

Natural *Bombyx mori* cocoon silk fibers can be processed into various forms, for example, micro-spheres, tubes, and thin films [1]. In addition to their robust mechanical properties, silk materials are bio-compatible, bio-renewable, and bio-degradable, which render the materials attractive for bio-medical applications. Using a series of water-based processing and annealing, we have fabricated silk thin films that exhibit actuating and self-healing properties for water-driven bio-mimetic muscle and memory applications.

Experimental

Bombyx mori silk cocoons were commercially purchased and washed using a Na_2CO_3 solution to extract the silk fibers. The silk fibers were then dissolved using a LiBr ionic solution, followed by a series of purification process involving dialysis and centrifugation. The purified silk solution was drop-casted to form thin films, after which the films were annealed under high humidity conditions for 6 hours. Finally, the annealed silk thin films were cut into thin strips and mounted on a glass slide.

Results and Discussion

We have found that by wetting one side of the silk strip, for example the bottom side (**Figure 1a**), it is possible to induce a reversible flexing motion, where the strip first bend upwards and then relaxes back to its original position after drying. The degree of reversibility depends on the amount of flexing. For extreme flexing, where the strip curls into a complete circle (**Figure 1b**), the flexing is only partially reversible. In **Figure 1c**, we show the final form of the strip after extreme downward flexing. The silk strip, however, can be reset into its original straight form by wetting both sides of the strip. These actuating and self-healing properties are similar to those observed in biological muscle. In principle, an artificial muscle/finger can be fabricated for lifting weights. Furthermore, the silk strip operates in a similar fashion to those of a memory device, where wetting one or two sides of the strip results in write or reset actions, respectively.

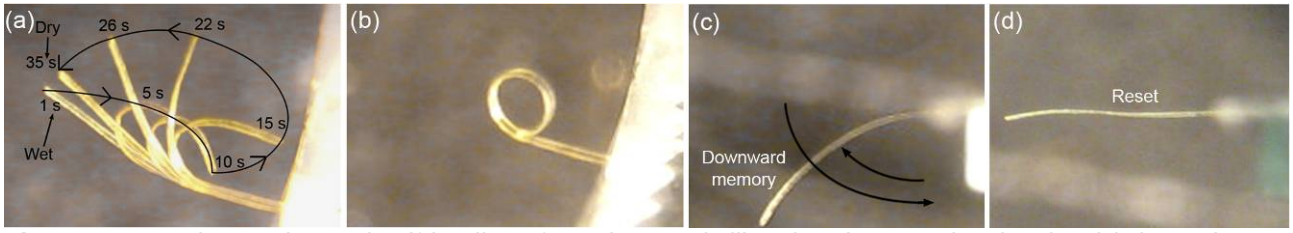

Figure 1. Actuating motion and self-healing of Bombyx Mori silk strip. Photographs showing (a) the path travelled by the tip of the silk strip during the upward flexing, (b) extreme upward flexing, (c) irreversible downward flexing after the top side is heavily wet, and (d) the resetting by wetting both sides of the silk strip.

Conclusions

We have found and devised a simple procedure of inducing actuating and self-healing behavior of *Bombyx mori* silk strip by selective wetting that are potentially useful for bio-mimetic muscle and memory device applications.

Acknowledgements

ES is supported by NSF-DMR 1005293. Experiments are carried out at the NHMFL Advanced Materials Lab.

Reference

[1] D.N. Rockwood *et al. Nat. Protoc.* **6**, 1612-1631 (2011).