Actuating Properties of Carbon Nanotube Functionalized Spider Silk Fibers

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Introduction

Spider silk fiber has a natural water absorbing mechanism, where it swells or shrinks under a high or low humidity conditions, respectively. The shrinkage work density is exceptional, 50 times higher than typical biological muscle [1]. This property has been exploited for developing a humidity-driven silk actuator for lifting weights [1]. We have recently demonstrated that by depositing a thin layer of a CNT network on the silk fiber and using the coating as a local heating element, it is possible to drive the silk actuator using electrical currents.

Experimental

A single carbon nanotube functionalized spider silk (CNT-SS) fiber (~1.8 mm long) was mounted between two G10 substrates in a 2-contact configuration using carbon paste. A 35 mg mass was used as a hanging weight. A 5-second current pulse (100 μA) was used to generate a 5 mW heat to the silk fiber.

Results and Discussion

We have developed a current-driven silk actuator that can be operated in two modes. First, the contraction mode is achieved by applying the current pulse while the fiber is in its partially hydrated state at ambient conditions. The heat generated by the current pulse dehydrates and contracts the fiber by ~1 %, lifting the weight by ~ 25 μm. After a few minutes, the fiber relaxes back close to its original length. The second mode is achieved by applying the current pulse to the fiber in a fully dehydrated state. In this case, the local heat expands the fiber by ~0.15 % via thermal expansion, causing the mass to be lowered by ~ 4 μm.

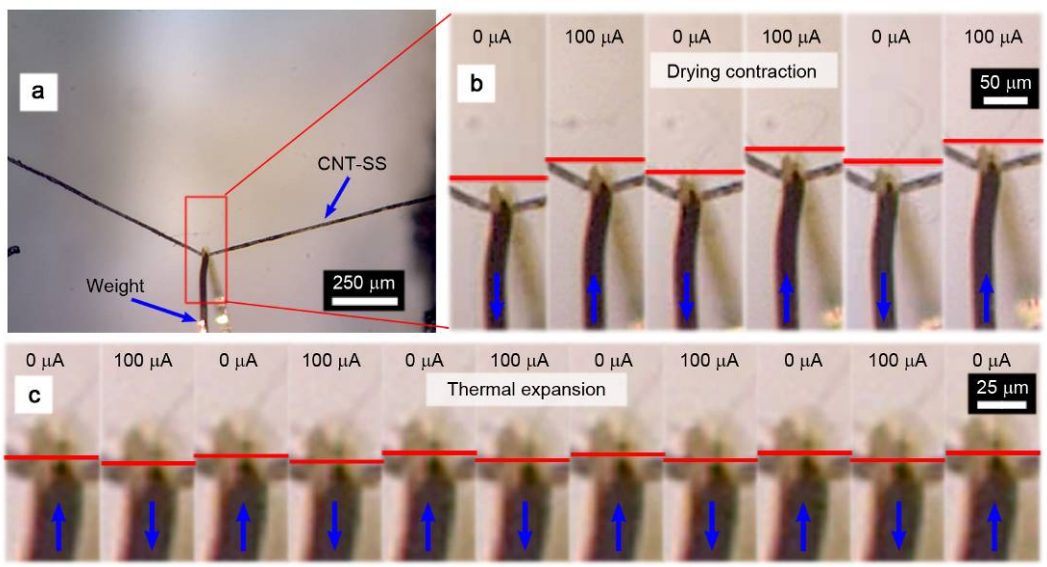

Figure 1. Actuating properties of a single CNT-SS fiber. (a) Photograph of a 35 mg mass hanging onto a single CNT-SS fiber. Cyclic CNT-SS (b) contraction and (c) expansion modes.

Conclusions

We have developed a silk actuator that can be driven by both humidity and electrical currents. The current-driven silk actuator can be driven in two modes, which further improve its versatility for technological applications.

Acknowledgements

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

Reference

[1] I. Agnarsson, A. Dhinojwala, V. Sahni and T.A. Blackledge, *J. Exp. Biol.* **212**, 1990-1994 (2009).