Intelligent Textiles Prepared from Nanofiber Yarns and Polymer Fiber Actuators

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Technology description

While there has always been a desire for smart textiles, including fabrics which adapt depending on environmental stimuli, it has yet to be effectively accomplished due to the lack of suitable materials. These polymer fiber actuators have enabled the creation of fabrics that can reversibly change properties such as porosity, shape, color and texture. Nylon is inexpensive and easily obtainable and already used in clothing worldwide, enabling the incorporation of these coiled fibers in actuating textiles and braids for a multitude of applications. Shape-memory polymers (SMPs) are currently used to create morphing textiles, but they typically only show a one-way shape-memory effect and do not provide a desirable drape or soft touch to the fabrics in which they are integrated. Despite the high performance of shape-memory metal wire actuators, their cost and uncomfortable feel has limited realization of textiles and other woven structures.

An actuating textile containing torsional or tensile polymer fiber and polymer yarn actuators (artificial muscle yarns) can change porosity, shape, texture, and color when exposed to a stimulus, such as a temperature change, electrical power, electromagnetic energy, or chemicals. These new muscles provide fast, high-stroke, torsional and tensile actuation and can be sewn, woven, or knitted into textiles and braids that actuate to either change porosity or accomplish external mechanical work. Normally, these muscles are thermally responsive, but they can also be powered electrically using volt or sub-volt voltages, photonically, or chemically.

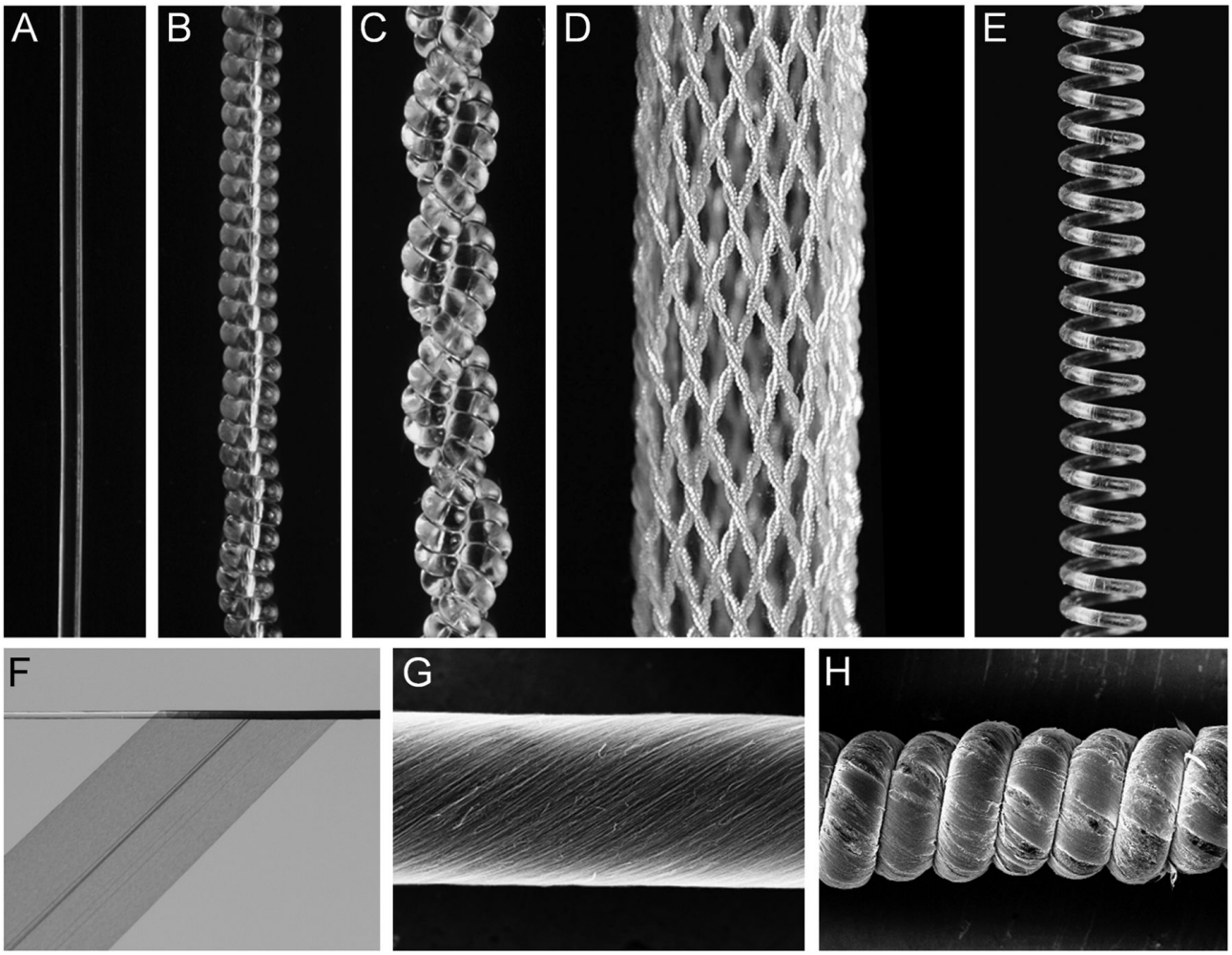

Figure 1: Muscle and precursor structures using nylon 6,6 monofilament sewing thread.Optical images of(A)a nontwisted 300-μm-diameter fiber;(B)the fiber of (A) after coiling by twist insertion;(C)a two-ply muscle formed from the coil in (B);(D)a braid formed from 32 two-ply, coiled, 102-μm-diameter fibers produced as in (C);(E)a 1.55-mm-diameter coil formed by inserting twist in the fiber of (A), coiling it around a mandrel, and then thermally annealing the structure; and(F)helically wrapping the fiber of (A) with a forest-drawn CNT sheet and scanning electron microscope images of a CNT-wrapped, 76-μm-diameter nylon 6,6 monofilament(G)before and(H)after coiling by twist insertion.

Technical Summary:

Polymer fibers (i.e. nylon) are twisted to the point of coiling to make artificial muscles. The bias angle and muscle chirality can affect the actuation of the muscle so that the pores will either open or close during heating or other stimuli. Furthermore, the muscles can be coiled with varying diameters so that the muscle collapses into itself upon actuation, allowing for nearly limitless stroke of up to 8,600%.

Value Proposition:

Highly customizable and versatile configurations of polymer fiber actuators have been demonstrated to create intelligent, comfort-adjusting textiles with materials already commonly used in clothing.

Haines, C. S., M. D. Lima, N. Li, S. Fang, F. Goktepe, O. Goktepe, and R. H. Baughman. "Artificial Muscles from Fishing Line and Sewing Thread." Science 343.6173 (2014): 868-72.

Application area

Clothing and Apparel Outdoor gear – tents, sleeping bags, bags
Parachutes
Environmentally-responsive packaging
Home goods – blankets and curtains
Medical blankets – maintain constant temperature

Advantages

Versatile– Polymer fibers can be reversibly actuated passively by environmental changes, or actively by thermal, electrical, photonic, or chemical stimuli.
Comfortable– Textiles woven from these polymer fiber actuators can be designed to adjust porosity to maintain homeostasis in hot or cold conditions while remaining soft to the touch, unlike shape-memory compounds.
Giant stroke– Elimination of coil-coil interference allows actuators to achieve an astonishing 8,600% stroke, which could be used for intelligent insulation fabrics
Customizable– It has been demonstrated that polymer fiber actuators may be combined in various ways to provide actuation properties specific for innumerable applications.

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