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Powerful artificial muscles for morphing composites and other applications

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Three successive generations of twist-spun artificial muscles are described and used to make morphing composites and textiles that are electrically, thermally, or chemically powered.[1] Our first generation of twist-spun muscles, which are electrochemically powered by volume changes induced by double-layer charge injection, provide torsional rotation speeds of 590 rpm, and torsional strokes of 250° per millimeter of actuator length, which is 1000 times that for earlier artificial muscles. Our second generation muscles, which require no electrolyte and are based on guest-infiltrated carbon nanotube yarns, can torsionally actuate at 11,500 rpm and deliver 85 times higher power density during contraction than natural muscles. Our third generation muscles, which are thermally, electrothermally, or chemically powered polymer fibers, can rotate a heavy rotor to above 70,000 rpm, contract by up to 49%, generate 5 times the gravimetric power of a car engine, lift 100 times heavier loads than the same length and weight human muscle, or actuate at 7.5 cycles/s for millions of cycles. These polymer muscles can be cheaply made from fishing line or sewing thread. Demonstrated applications using these muscles include peristaltic pumps based on polymer muscle composites; self-powered valves that automatically open and close depending on fluid temperature or composition; torsional and tensile electrical energy harvesters for converting low-grade thermal energy into electrical energy; environmentally powered windows that open and close depending upon temperature; and morphing textiles for comfort adjusting clothing. The combination of theory and experiment will be used to explain and optimize actuation for muscles that are highly twisted or so highly twisted that they coil.

1. This work resulted from collaboration between The University of Texas at Dallas, The University of Wollongong (Australia), The University of British Columbia (Canada), Hanyang University (South Korea), and Namık Kemal University (Turkey).