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Fabrication of photocurable PDMS fiber for dielectric elastomer linear actuator

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Dielectric elastomers (DEs) exhibit high obtainable actuation speeds, large strains and high work densities, showing great potential for actuator applications such as flat screen loud speakers, lightweight morphing structures and prosthetics.[1] To date, varying configurations for dielectric elastomer actuators (DEAs) have been studied, including planar, tube, roll, extender, diaphragm, and bender.[2] Tube DEA consists of a thin-walled cylindrical tube of a dielectric elastomer, having two compliant electrodes on the internal and external lateral surfaces. By applying a voltage between the compliant electrodes, the interposed tube wall is squeezed, causing an axial elongation. Tube DEAs are potential candidates for the realisation of "artificial muscles" owing to their linear (along a line) actuation capabilities.[3] Electroactive fiber actuators include bundles of tube DEAs, which produce a very strong actuation force as a result of the accumulation of individual force generated by each tube DEA. Even if a fraction of the fibers in a bundle fail, the electroactive fiber actuator will in most cases continue to operate. Furthermore, because electroactive fibers have small thickness sometimes on the order of a few micrometers, actuation voltages less than 100 V can be used.[4]

In this work, polydimethylsiloxane (PDMS) fiber is prepared by means of wet spinning method using photocurable thiol-ene reaction between the carbon-based sulfhydryl (R-SH) group and alkene (C=C) group in the thiol-ene-based PDMS resins to form an alkyl sulfide. The morphology of PDMS fiber is adjusted by changing the stoichiometry between R-SH and C=C groups and also by varying the irradiation time of ultraviolet curing, as well as by modifying the flow rate of PDMS layer and internal ethanol solvent during spinning process. The developed PDMS fiber with a fiber external diameter of 463 μm and uniform wall thickness of 78 μm shows enhanced tensile properties of 552% strain at break and 0.62 MPa tensile strength compared to the planar film (91% strain at break and 0.13 MPa tensile strength), due to a higher orientation degree of the polymer chains in a fiber produced through the spinning process. The resulting fiber DEA exhibits a larger and repeatable linear deformation when working in multiple cyclic actuation tests. This work provides wider avenues for creating active soft matter with complex architectures enable fast programmable actuation for a myriad of applications including soft actuators and robots.

Keywords: polydimethylsiloxane fiber, wet spinning, photocurable thiol-ene reaction, dielectric elastomer linear actuator

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