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Robust nanoporous metals for water-responsive actuation

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Many organisms in nature use water to modulate the dimensions of their components for actuation. Inspired by the nature, water-responsive actuation has been reported for the synthetic materials such as hydrogels and polymers. But most man-made water-responsive actuators work well only under low (even zero) loads because i) the actuation materials are complaint and cannot bear high load and/or ii) the actuation stroke decreases rapidly with increasing load. Here we demonstrate that the metals can also be water-responsive when they gain a nanoporous structure. The nanoporous metals can be prepared by the dealloying, with macroscopic sample outer-dimensions, uniform and open porous structure whose characteristic size is at nm scale, and high strength. We found that the nanoporous metals can respond elastically to the stress of the water-capillarity in pore channels during drying and wetting, without inducing any cracking or material failure. It gives rise to actuations with large stress-generation and large actuation strokes. The water-capillarity can induce actuations in nanoporous Au and np Au(Pt), with reversible linear strain up to 1.26% (volume strain: 3.7 %) and stress-generation as large as 23 MPa. Most importantly, this type of actuator can operate under high load and generate load-independent stress and actuation stokes. The water-responsive nanoporous metals are expected to act as "artificial muscle" in future to propel the micro-robots or the micro-generators that operate by harvesting the environmental energy.

Keywords: Nanoporous metals; dealloying; capillarity; surface tension; actuation