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Tough Hydrogel Robots: High-Speed, High-Force and Opto-sonically Invisible in Water[1]

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Sea animals such as leptocephali develop tissues and organs composed of active transparent hydrogels to achieve agile motions and natural camouflage in water. Hydrogel-based actuators that can imitate the capabilities of leptocephali will enable new applications in diverse fields. However, existing hydrogel actuators, mostly osmotic-driven, are intrinsically low-speed and/or low-force; and their camouflage capabilities have not been explored. Here we show that hydraulic actuations of tough hydrogels with designed structures and properties can give soft actuators and robots that are high-speed, high-force, and optically and sonically camouflaged in water. We invent a simple method capable of assembling physically-crosslinked hydrogel parts followed by covalent crosslinking to fabricate large-scale hydraulic hydrogel actuators and robots with robust bodies and interfaces. The hydrogel actuators and robots can maintain their robustness and functionality over multiple cycles of actuations, owning to the anti-fatigue property of the hydrogel under moderate stresses. A multiscale theoretical framework has been developed to guide the design and optimization of the hydrogel robots. We further demonstrate that the agile and transparent hydrogel actuators and robots perform extraordinary functions including swimming, kicking rubber-balls and catching a live fish in water.

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