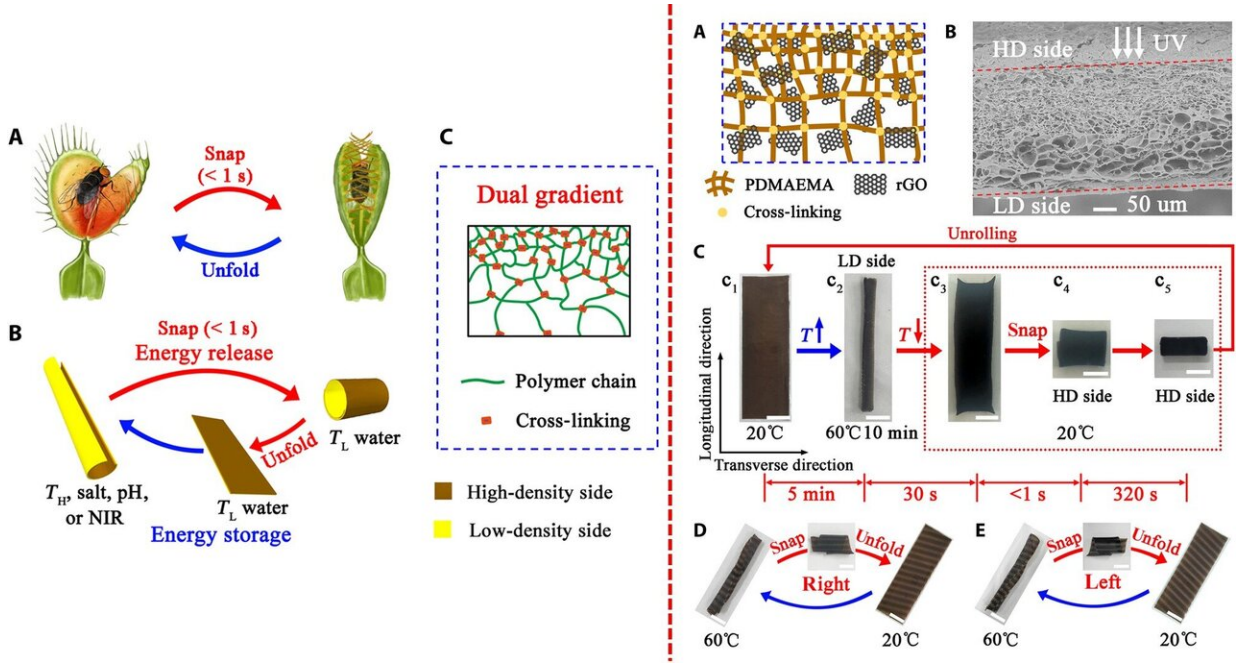
Developing a dual-gradient ultrafast biomimetic snapping hydrogel material

April 24 2019, by Thamarasee Jeewandara



LEFT: Illustrative scheme of the snapping deformation. (A) Snapping of the Venus flytrap. (B) Inverse snapping of a dual-gradient hydrogel sheet. (C) A carton showing the cross section of a dual-gradient hydrogel. RIGHT: Inverse snapping of dual-gradient rGO/PDMAEMA hydrogel sheets. (A and B) Schematic illustration (A) and cross-sectional SEM image (B) of the dual-gradient structure of rGO/PDMAEMA hydrogel sheets. (C) Shape transformation of the sheets in response to temperature variation. (D and E) Inverse snapping of the sheets with strip patterns to form chiral structures with controlled handedness. Scale bars, 1 cm (C and D). Credit: Science Advances, doi: 10.1126/sciadv.aav7174

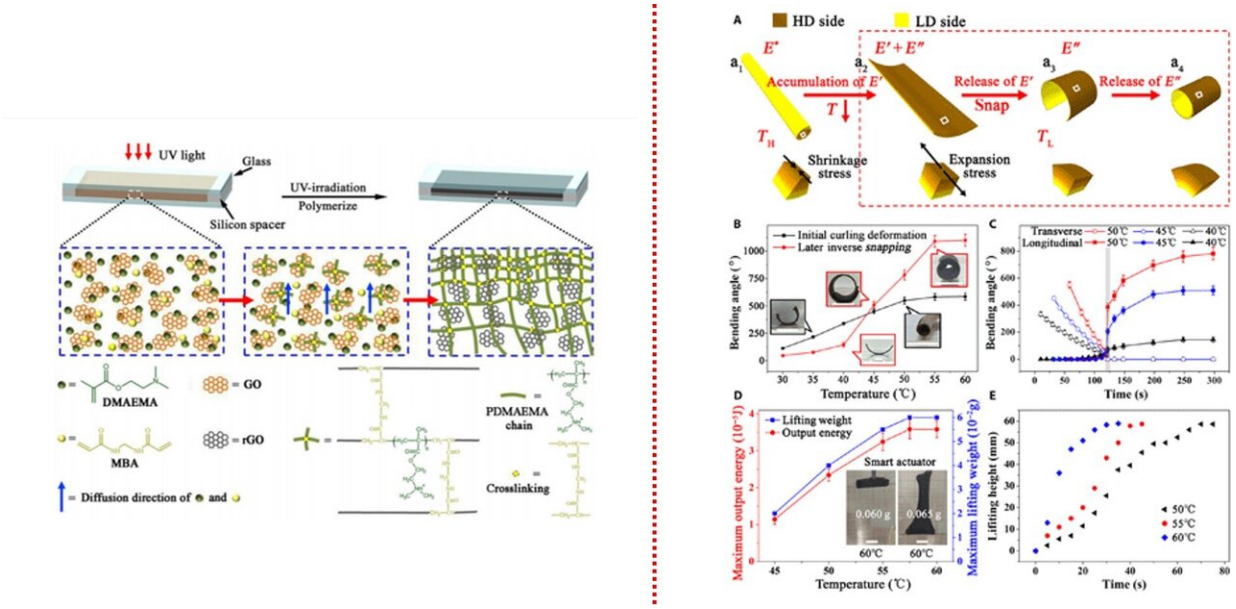
Bioinspired materials are designed and engineered to mimic the biological functions of nature; however fast actuation is an important but challenging task to recreate in the lab. In a recent study, Wenxin Fan and co-workers in the interdisciplinary departments of materials science, engineering, chemistry, biochemistry and macromolecular science in the USA and China, presented a new paradigm to design responsive hydrogel sheets that could exhibit ultrafast and inverse snapping deformation. They engineered the hydrogel sheets with dual-gradient architecture to accumulate elastic energy in the polymers by converting prestored energy for rapid reverse snapping and energy release.

Fan et al. controlled the magnitude and location of stored energy in the hydrogel sheets to program their snapping reaction and achieve different structures and actuation behaviors. They developed a theoretical model thereafter to demonstrate the crucial role of dual gradients and predicted the snapping motion of a variety of different hydrogel materials. The new design principle will provide guidance to engineer actuation materials for applications in tissue engineering, soft robotics and as active medical implants. The results are now published in *Science Advances*.

Shape transformation is ubiquitous in living systems such as carnivorous plants that strategically capture prey, providing a natural source of inspiration to engineer functional shape-transforming materials in the lab. Responsive hydrogels are capable of shape transformation under a variety of stimuli, with promising applications already delivered in soft robotics, drug delivery, tissue engineering and microfluidics.

Scientists have used thermo-responsive polymers such as poly(N,N-dimethylaminoethyl methacrylate) (PDMAEMA) and poly(N-isopropylacrylamide) (PNIPAM) to design such shape-transforming materials. Shape transformation of hydrogels mainly rely on the different swelling rates of hydrogels in different regions of the materials,

where the gradual shape evolution is driven via in-plane and out-of-plane mismatch in the changing volume of hydrogels. Present efforts therefore focus on enhancing the shape complexity to diversify the materials response to external stimuli.



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As an example, leaves of the Venus flytrap can rapidly close and capture

insects in one-tenth of a second, which is distinct from synthetic hydrogels that have thus far only shown gradual and relatively slow shape transformation. The extremely rapid motion of the Venus flytrap is credited to the accumulation and quick release of energy that can assist the sudden, yet, discontinuous motion essential to develop ultrafast actuators with broad applications in soft robotics through biomimicry. Existing approaches to achieve this type of motion rely on reversible switching between concave and convex structures of bi-stable polymeric sheets – but this strategy only allows limited structural complexity and actuation behavior. As a result, an existing need remains to design new principles of snapping motion that will be interlaced into responsive biomaterials.

In the present work, Fan et al. reported a nature-inspired design of responsive hydrogel sheets that accumulated elastic energy and rapidly released the energy during ultrafast snapping deformation. Using experimental results and theoretical models, the scientists showed that the snapping motion of the hydrogels originated from their dual-gradient (polymer chain density gradient and cross-linking density gradient) structural design. In the experiments they used reduced graphene oxide (rGO)/PDMAEMA composite hydrogel sheets with dual gradient structures as a model system and demonstrated that the sheets could accumulate elastic energy and convert the pre-stored thermal or chemical energy to rapidly snap.

Mechanically, the novel hydrogel could snap in reverse under a second (