Hydrogel printing made easy and biocompatible for soft robotic systems

24 December 2019, by Yin Cheng, Ghim Wei Ho

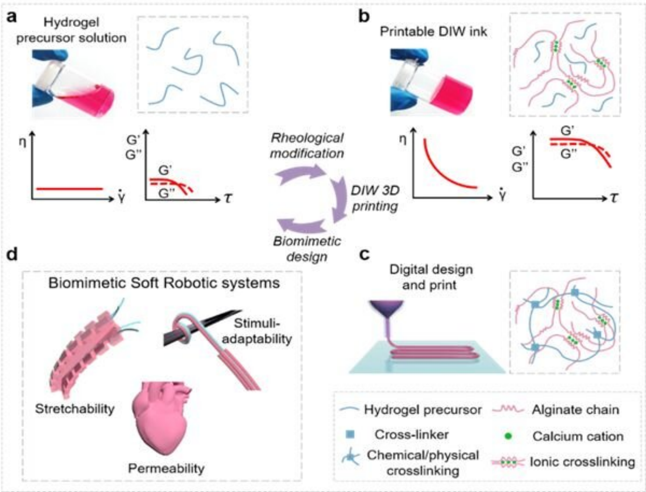

Figure 1. Schematic illustration of DIW 3D printing hydrogels into biomimetic soft robots. (a) Hydrogel precursor solution and the rheological behavior. (b) Printable DIW ink and the typical gel-like rheological behavior. (c) Digital design and print of DIW ink. (d) Biomimetic soft robotic systems. Credit: Yin Cheng, Ghim Wei Ho

Hydrogel materials possess intrinsic softness, and exhibit other favorable properties of natural organic parts, like stretchability, biocompatibility, permeability and stimuli-adaptability, owing to their diversified family. The combination of these unique properties makes hydrogel a perfect starting material for biomimetic soft robots, which aim to imitate the diverse features required for nature-inspired robotic systems.

Currently, the pervasive application of hydrogel for soft robot constructs is still hampered by two challenges. First, conventional hydrogels usually show limited mechanical robustness. Second, the building of hydrogel-based robots typically depends on custom-designed molds and laborious post-assembly, which limits the free-form 3-D structure design. In general, there manufacturing schemes are needed that can enable the rapid design of biomimetic soft robots from hydrogels with desired architectural sophistication and mechanical robustness.

Recently, Ho's group has developed a facile and versatile strategy to print hydrogels directly into biomimetic soft robots. "Biocompatible alginate rheological modifier of hydrogel allows straightforward manufacturing into arbitrary 3-D topologies using direct-ink-write (DIW) 3-D printing," says Ghim Wei Ho, an associate professor at the National University of Singapore. "Notably, the intrinsically hydrophilic alginate preserves the valuable properties of the host hydrogels, accompanied by enhanced mechanical toughness owing to the double polymer network."

Ho et al. reported their findings in *ACS Nano* in a paper titled "Direct-Ink-Write 3-D Printing of Hydrogels into Biomimetic Soft Robots." Figure 1 shows the design concept of this work.

"The integration of free structures and available functionalities from the diversified hydrogel family renders a rich design platform for bioinspired fluidic and stimulus-activated robotic prototypes," says first author Yin Cheng. A series of representative bioinspired fluidic and stimulus-activated robotic prototypes is shown in Figure 2: an polyacrylamide (PAM)-based artificial tentacle with 3-D mobility (Figure 3), a polyvinyl alcohol (PVA)-based bioengineered robotic heart with beating-transporting functions (Figure 4), and a poly (N-isopropylacrylamide) (PNIPAM) based artificial tendril with programmable phototropic motion (Figure 5).

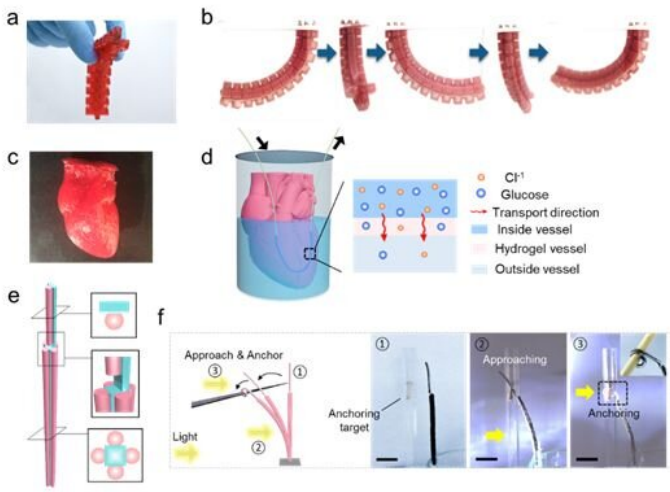

Figure 2. Biomimetic soft robotic prototypes. (a, b) The artificial tentacle and the controllable 3D rotation. (c, d) The bioengineered permeable robotic heart. (e, f) The artificial tendril with programmable phototropic motility. Credit: Yin Cheng, Ghim Wei Ho

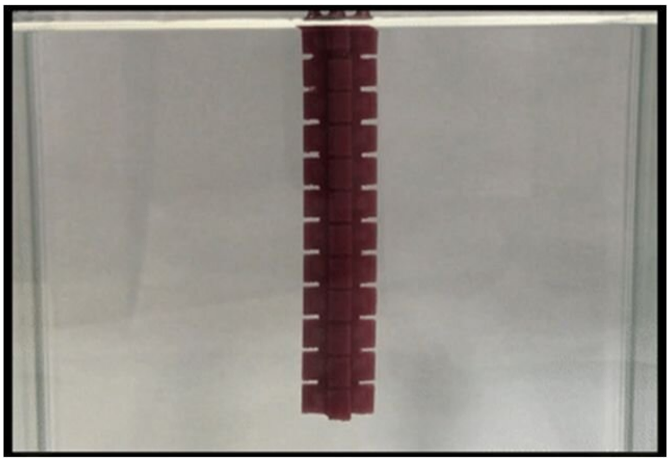

Figure 3. Controlled 3D rotation of the artificial tentacle. Credit: Yin Cheng, Ghim Wei Ho

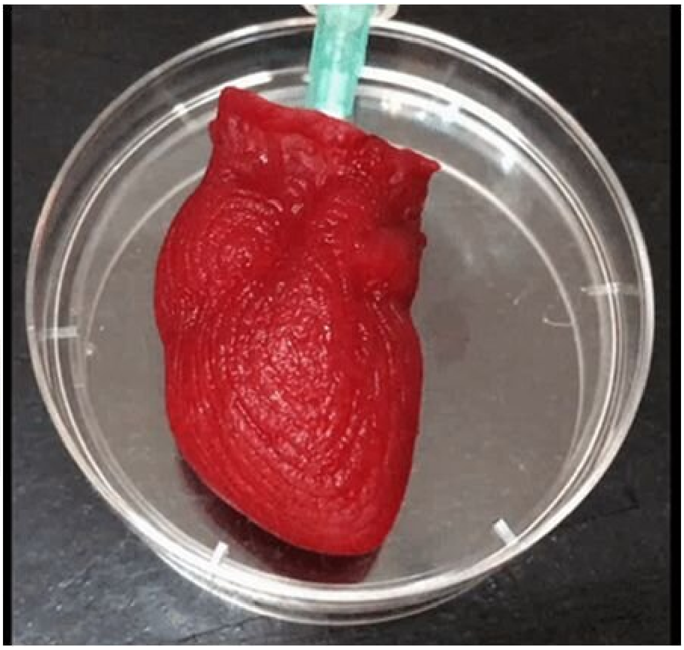

Figure 4. Pneumatic beating of the artificial robotic heart. Credit: Yin Cheng, Ghim Wei Ho

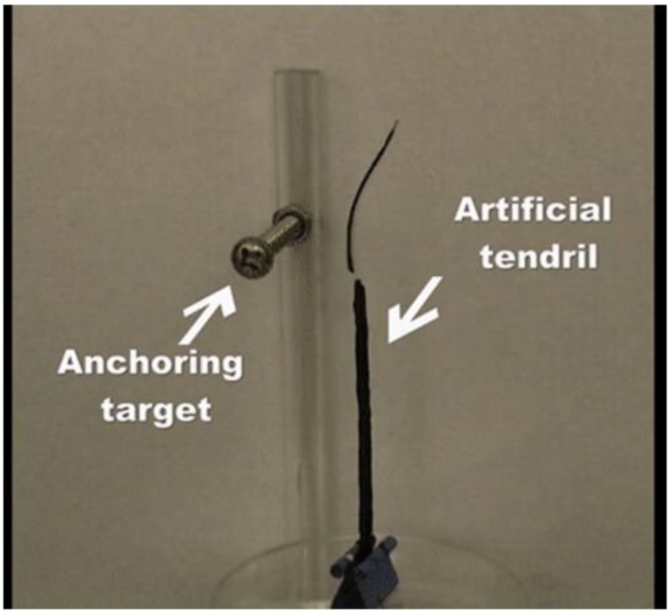

Figure 5. Phototropic bending and anchoring of the artificial tendril. Credit: Yin Cheng, Ghim Wei Ho

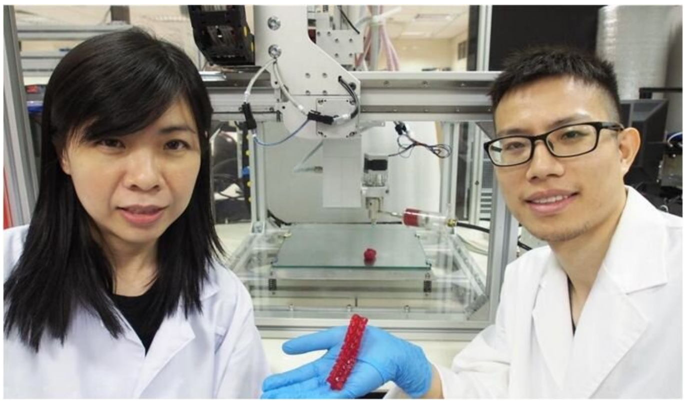

Figure 6. Prof. Ho Ghim Wei (left) and Cheng Yin (right) show the artificial tentacle and the customized hydrogel printer. Credit: Yin Cheng, Ghim Wei Ho

"We are targeting it at low-cost and low-toxicity soft materials, and we are convinced that the proposed DIW printing could empower design freedom toward embedded intelligence soft robots, possibly extendable to other applications, i.e., wearable electronics, sensors, tissue engineering and biomedical therapeutics," says Ho. In Figure 6, Ho and Cheng Yin display the printed artificial tentacle and the customized hydrogel printer.

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More information: Yin Cheng et al. Direct-Ink-Write 3D Printing of Hydrogels into Biomimetic Soft Robots, *ACS Nano* (2019). DOI: 10.1021/acsnano.9b06144

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