Reconfigurable 3D Mesotructures of Spatially Programmed Liquid Crystal Elastomers and Their Ferromagnetic Composites

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Introduction

- The **large, reversible shape changes** of liquid crystal elastomers (LCEs), which result from the coupling between the alignment of liquid crystal (LC) molecules and the macroscopic deformation of polymer networks, have attracted much attention for reconfigurable 3D mesotructures.
- However, it remains a daunting challenge to realize **complex reconfigurable, freestanding 3D mesostructures** of LCEs especially those with open mesh architectures.

Aims

- This work [1] introduces a facile and versatile strategy for creating previously inaccessible reconfigurable, freestanding 3D mesostructures of LCE and their ferromagnetic composites via buckling mechanics [2].
- Furthermore, we develop reconfigurable robots that invidually and simultaneously respond to magnetic forces and thermal stimuli.

Methods

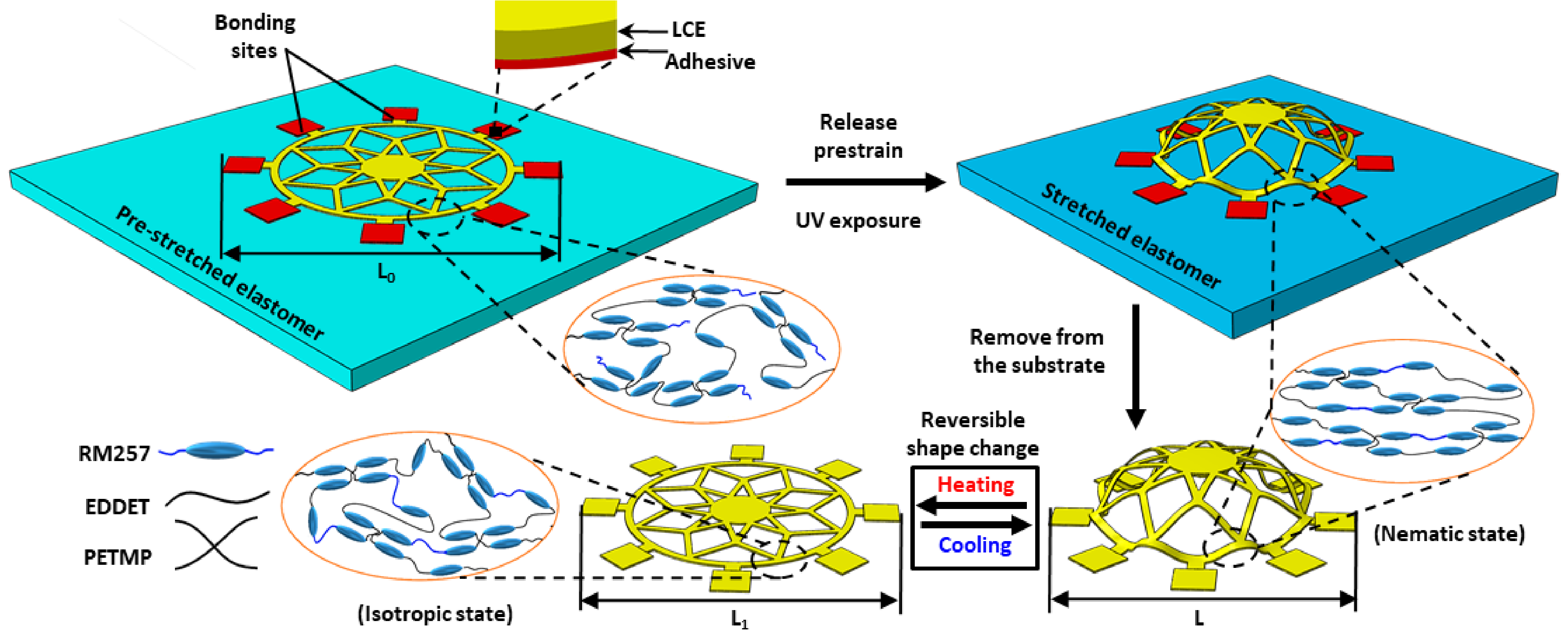

Fig.1 Schematic illustration of the assembly and reconfiguration of freestanding 3D LCE structure, and the associated microscale mechanism.

- To synthesize the liquid crystal elastomer (LCE), a two-stage thiol–acrylate Michael addition reaction (TAMAP) methodology was used in this work [3, 4].
- The mechanical buckling is used to spatially program LC molecules of 3D LCE mesostructures.
- The nematic-to-isotropic transition of LC molecular order can be reversibly realized via heating and cooling across the transition temperature (62 ℃ in this work [3]) thereby enabling the macroscopic reversible shape-switching.

Results

(1) Reconfigurable 3D mesostructures of LCEs assembled via spatial programming of LCs during 3D buckling

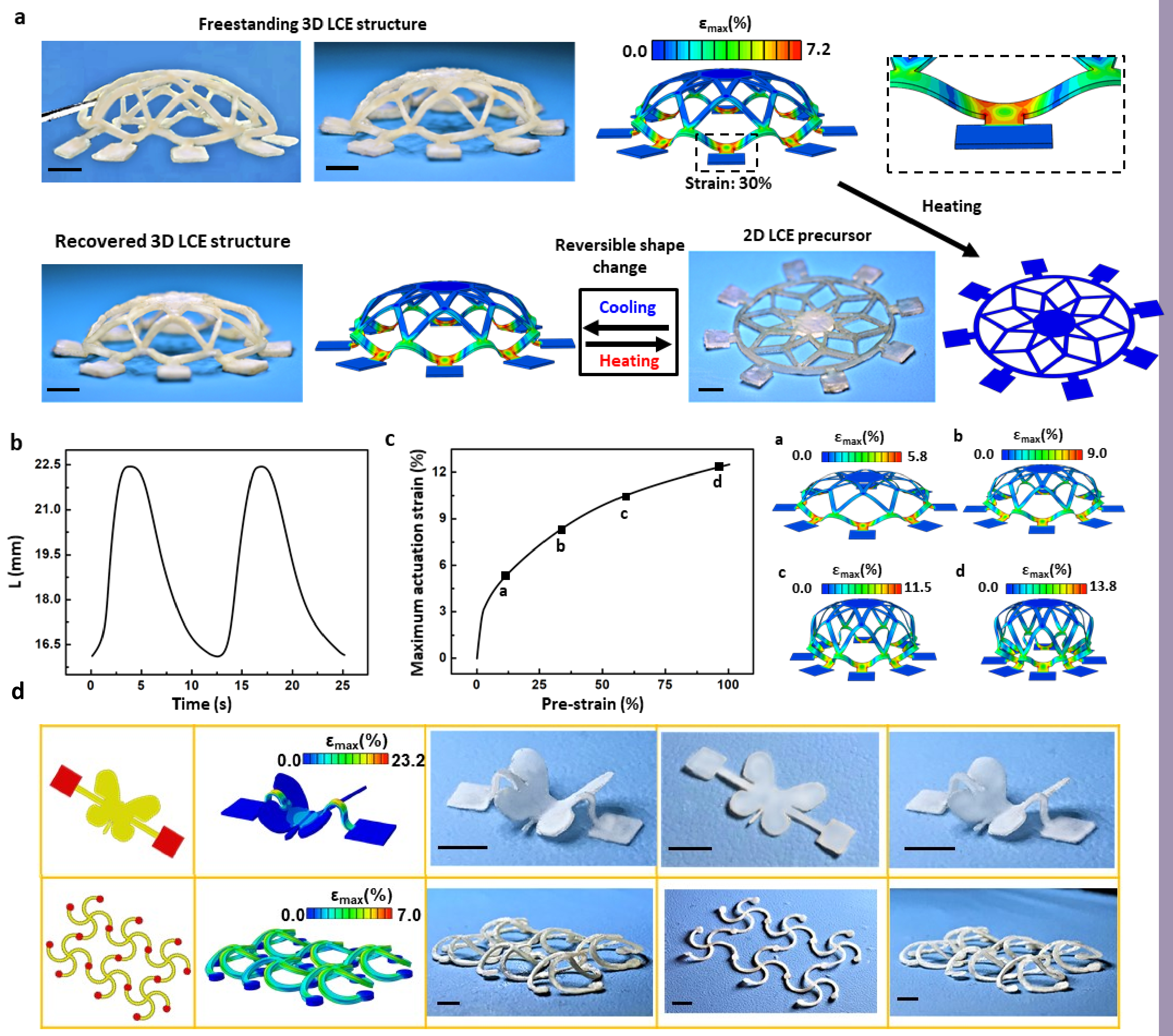

Fig.2 (a) Experimental and finite element modeling results of a 3D LCE structure. Scale bars, 2 mm. (b) Response time of the reversible shape morphing. (c) Finite element simulation results of the actuation strain in a LCE 3D structure. (d) Experimental and finite element simulation results of 3D LCE structures. Scale bars, 2 mm.

(2) Reconfigurable 3D mesostructures of ferromagnetic LCE composites

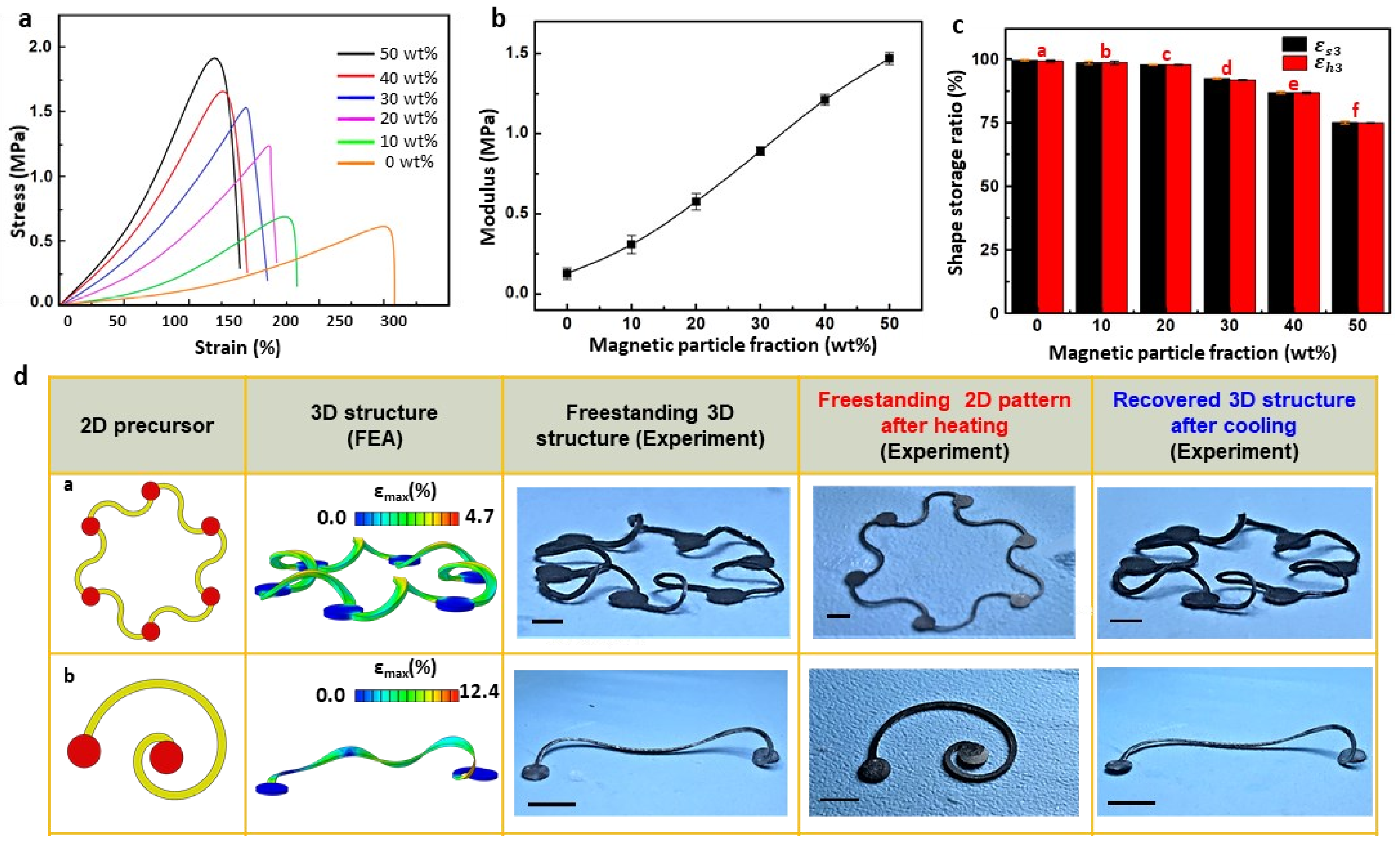

Fig.3 (a) Engineering stress-strain curves of ferromagnetic LCE composite films. (b) Plot of Young's modulus of ferromagnetic LCE composite. (c) 3D shape storage ratio change curve. (d) Experimental and finite element simulation results of 3D ferromagnetic LCE structures. Scale bars, 2 mm.

Results

(3) Applications

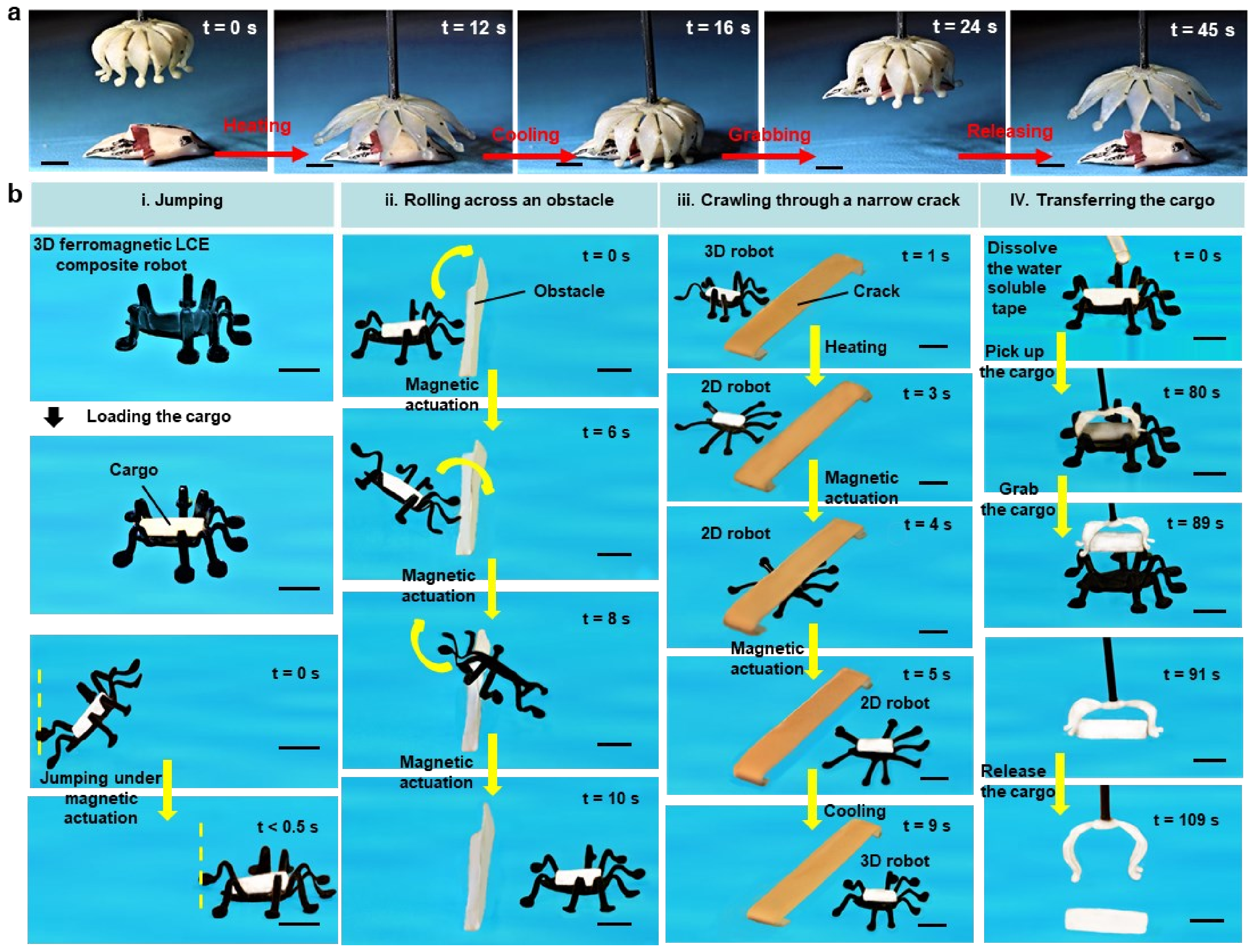

Fig.4 (a) Remotely thermal-controlled grabbing/releasing robot. Scale bars, 3 mm. (b) The multimodal soft "bug" robot which is fabricated by 10wt% ferromagnetic LCE film. Scale bars, 5 mm.

Conclusions

- Experimental and quantitative FEA studies of freestanding 3D LCE structures achieve large, reversible shape-morphing behaviors.
- The addition of ferromagnetic significantly enhance the mechanical properties of LCEs, thus enriching the design space of reconfigurable 3D LCE structures and, in the meantime, enabled magnetic actuation.
- LCE gripper and the soft magnetic LCE robot with multiple biomimetic motion modes provide the potential to allow for distributed actuation and sensing and somatic control for next-generation shape changing robots and other functional systems.

References

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