Supporting Information

Stimuli-Responsive Actuator Fabricated by Dynamic Asymmetric Femtosecond Bessel Beam for *In Situ* Particle and Cell Manipulation

Rui Li, [1]‡ Dongdong Jin,[2] ‡ Deng Pan,[1] Shengyun Ji,[1] Chen Xin,[1] Guangli Liu,[1] Shengying Fan,[1] Hao Wu,[1] Jiawen Li,[1]* Yanlei Hu,[1] Dong Wu,[1]* Li Zhang,[2]* and Jiaru Chu[1]

‡These authors contributed equally to this paper.

1. Key Laboratory of Precision Scientific Instrumentation of Anhui Higher Education Institutes, CAS Key Laboratory of Mechanical Behavior and Design of Materials, Department of Precision Machinery and Precision Instrumentation, University of Science and Technology of China, Hefei 230026, China.
2. Department of Mechanical and Automation Engineering The Chinese University of Hong Kong Hong Kong 999077, China

E-mail: jwl@ustc.edu.cn; dongwu@ustc.edu.cn and lizhang@mae.cuhk.edu.hk

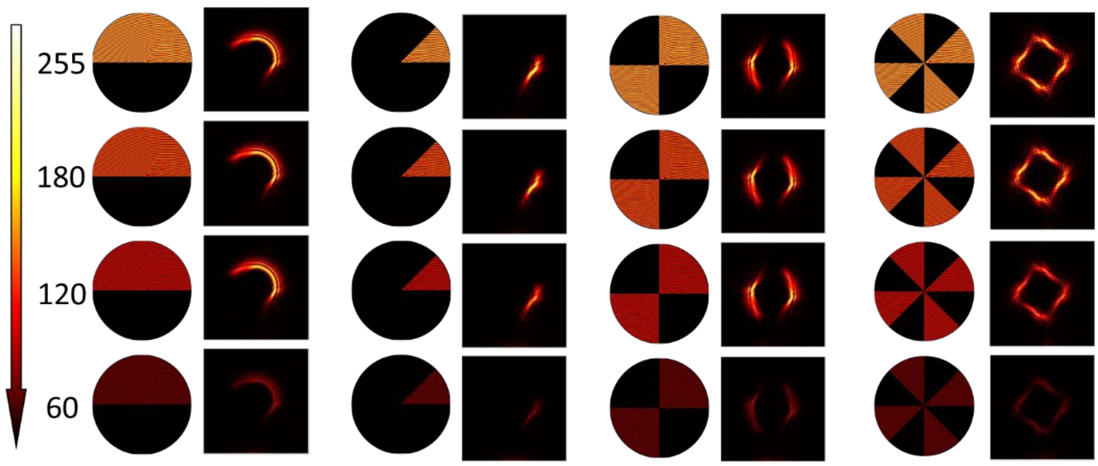

Figure S1. The shape and phase modulation depth of the LPM on holograms and the corresponding light field.

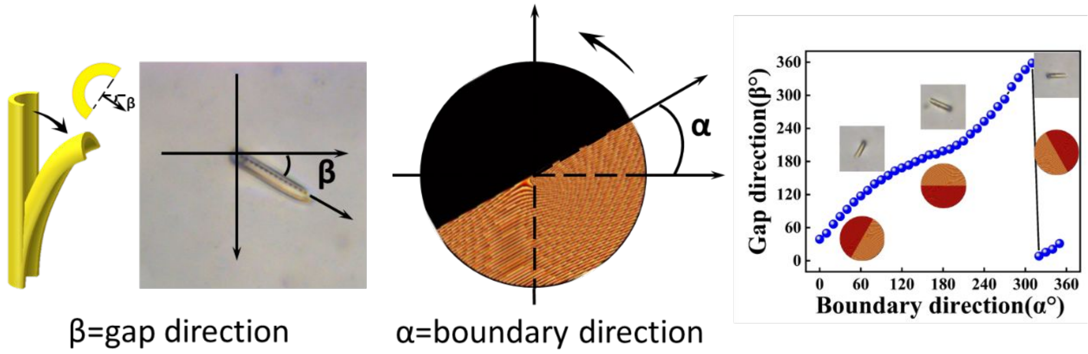

Figure S2. Gap direction of microtube, boundary direction of LPM in hologram and their relationship. (a) Gap direction is the direction perpendicular to Semicircle gap, and the direction of bending direction of contracted microtube. (b) Boundary direction is the direction of the boundary of LPM in hologram. Counterclockwise is positive and $\alpha \in [0,2\pi]$. (c) The gap direction is changing nearly linearly with boundary direction. So we can control the bending direction of microtube by changing the boundary direction.

Porosities of contracted and expanded hydrogel microtube

The SEM of the cross section of contracted and expanded freeze-dried hydrogel microtubes, cut by FIB, are processed in ImageJ. All pores in the SEM are outlining with yellow lines by chonsing the Polygon selections in ImageJ. After obtaining all the pores area and then the diameters D is approximately calculated by regarding the pores as circular pores.

$$D=\sqrt{\frac{4S}{\pi}}$$

S denotes the area of pores. The poriosities of the hydrogel are represented by the mean diameters of the pores, which are 146 nm in contracted state and 198 nm in expanded state.

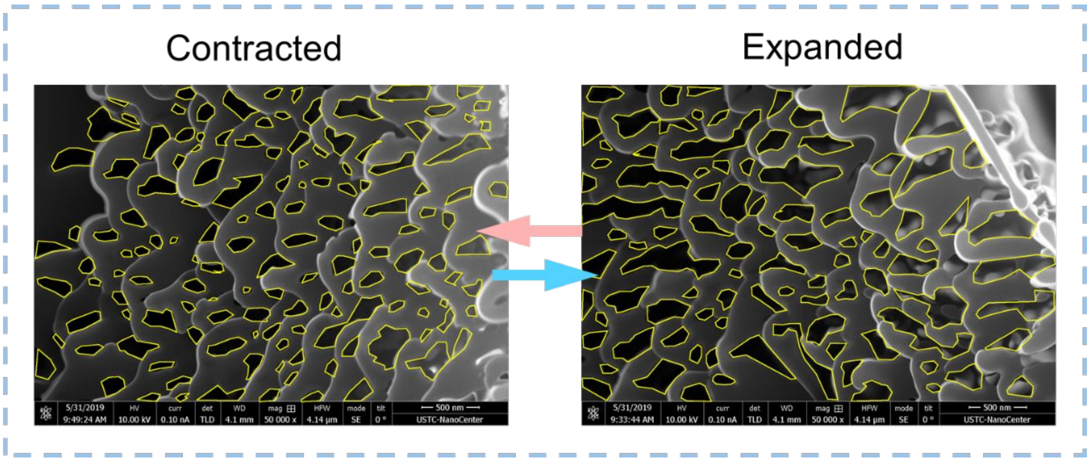

Figure S3. The porosities of pH-responsive hydrogel in contracted and expanded states. The pores of the contracted and expanded hydrogel is outlined by by yellow polygon line,

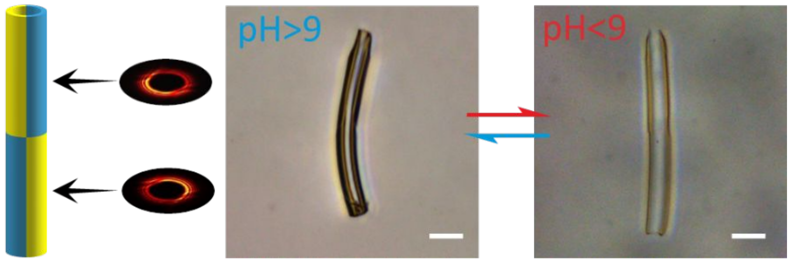

Figure S4. Two-segment microtube without middle section to change the upper and lower bending direction. Scale bars: 20 μm.

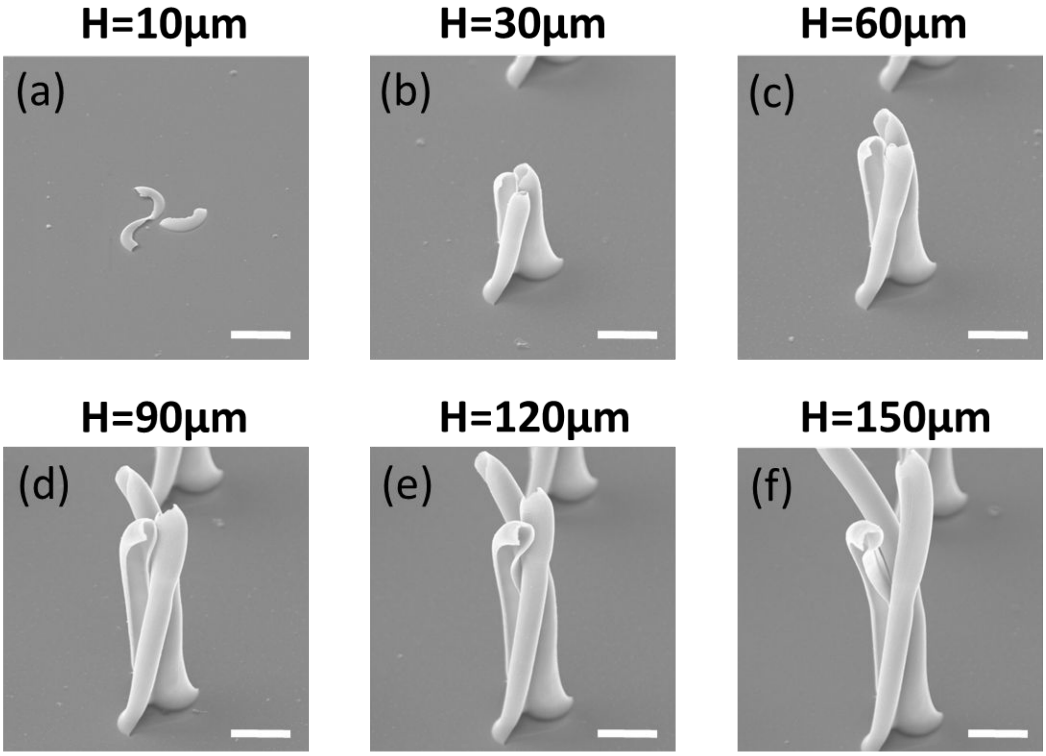

Figure S5. The SEM morphology of right-charity microstructure with different height. When H is lower than 90 μm. (a-c), semi-microtubes will keep contact with each other, while semi-microtubes with separate when H is higher than 90 μm(d-f). Scale bars: 10 μm.

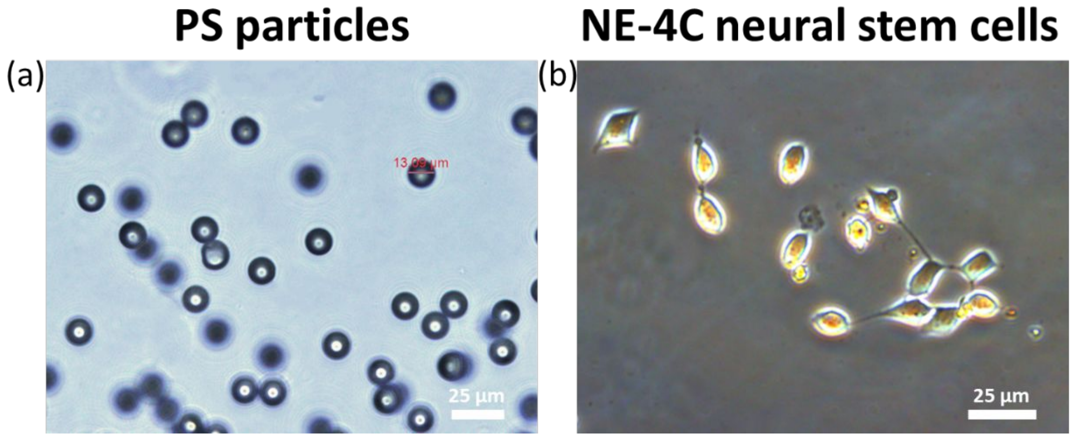

Figure S6. The PS particles and NE-4C neural stem cells in solution. (a) 10% v/v PS particles is dropped on coverslip. The diameter is about 13 μm. (b) NE-4C neural stem cells are grown in coverslip the second day. The diameter is 10~15 μm.

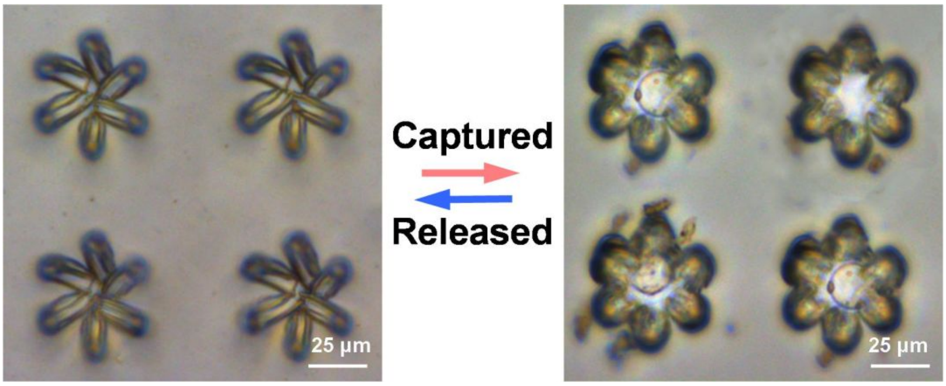

Figure S7. An array of 6-finger cell microgrippers with and without neural stem cells.

Video S1-S7:

Video S1. The swelling and shrinking deformation process of bendable microtubes. In order to observe the deformation process in detail, we add NaOH solution and HCl solution slowly.

Video S2. The swelling and shrinking deformation process of S-shaped microtubes.

Video S3. The swelling and shrinking deformation process of C-shaped microtubes.

Video S4. Three-segment microtubes have shrunk into ‘C+C’, ‘S+S’, ‘C+S’ and ‘S+C’ shapes after adding HCl solution and return to their original station after swelling.

Video S5. The twist process of trivalve left- and right-charity microstructures.

Video S6. The twist process of four-valve and six-valve right-handed microstructures.

Video S7. The trapping and releasing process of PS microparticle using pH-responsive micro-gripper.