Supplementary Information

Fabrication and evaluation of bending properties

The hydrogel strip was fabricated by *in situ* photopolymerization. The gel network of polymerized actuator material is anionic and attracts positively-charged surfactant molecules to bind to the gel's surface. Such surfactant binding leads to an osmotic pressure difference between the gel interior and the external solution, inducing bending of the gel strip.[1] The bending properties of the gel strip were measured with respect to several factors such as voltage, length, and concentration of AA (acrylic acid), which is known to be an electro-sensitive component.[2] To this end, the gel strip was placed in an acrylic 'bath' (2 (width) x 5 (length) x 1 (height) cm) including 0.9 wt.% NaCl solution, and the platinum electrode plates (distance between electrodes: 2 cm) were used to apply the electric field. The bending angles were measured as a function of voltage variation (3, 6, 9, 12, and 15 V) and length of gel strip (1, 2, 3, and 4 mm). The effect of AA concentration was measured by preparing three different hydrogels with different AA concentrations, and the bending angle and Young's modulus for each hydrogel were measured. The response time to the applied voltage was another important factor determining the actuating performance. We investigated the bending behavior with respect to the frequency of the electric field by applying frequencies of 0.5, 1, 3, and 5 Hz.

Mechanical properties (elasticity and bending force) of the hydrogel

The elasticity of gel strips with different AA concentrations was measured by fabricating dumbbell-shaped samples (5 cm gage length, 2 mm neck width, and an approximate thickness of 300 μm) following the type IV geometry outlined in ASTM D 638-99.[1] The elasticity was measured using a tensile tester (Model 5548 MicroTester, Instron, USA) equipped with a 10 N load cell. A set of five samples were tested for each parameter of interest. We measured the bending force directly by using a home-built apparatus. The measurement was carried out using a load cell-based force measurement device (DPS-0.25K, IMADA, Japan) and the size of the gel strip was 4 mm (length) x 100 μm (width) x 300 (height) μm.

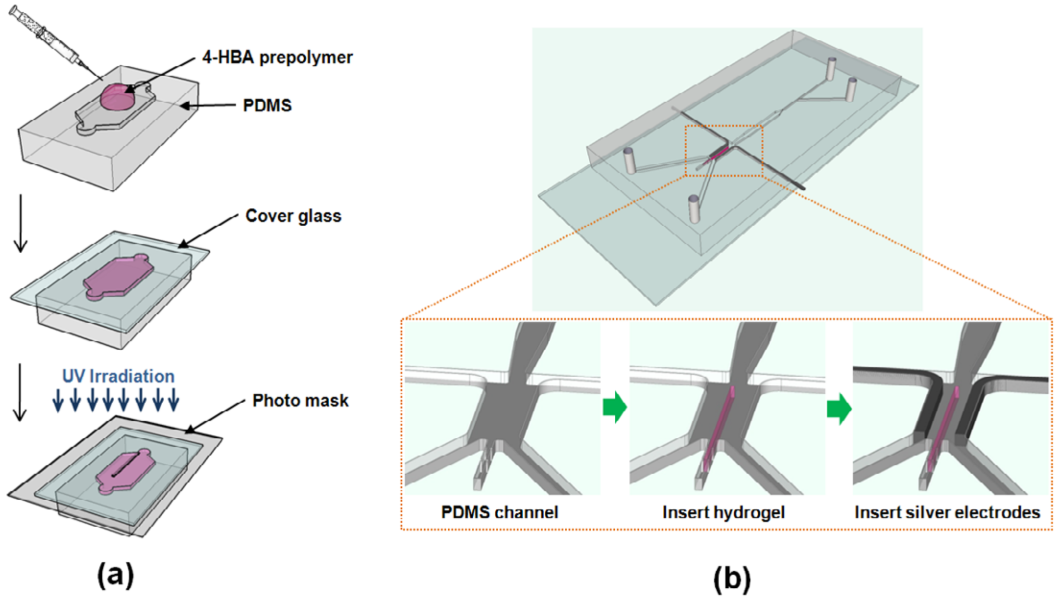

Figure S1. Schematic of the process for fabricating (a) a hydrogel strip via *in situ* photopolymerization, (b) the electroactive hydrogel sorter. The device was assembled from four components (PDMS channel, hydrogel, silver electrodes, and glass slide).

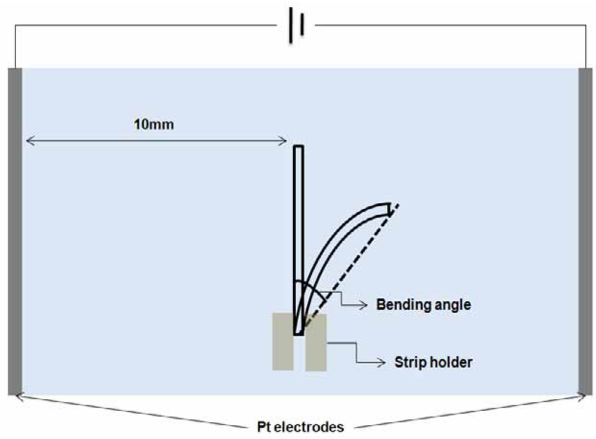

Figure S2. Experiment setup for measurement of bending angle.

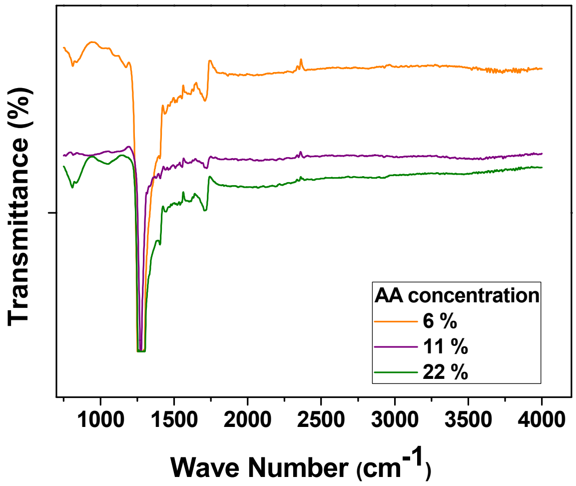

Figure S3. FTIR spectra of 4-HBA electroactive hydrogel strip fabricated through *in situ* photopolymerization the using of different AA (acryl acid) concentration (6, 11, and 22 %).

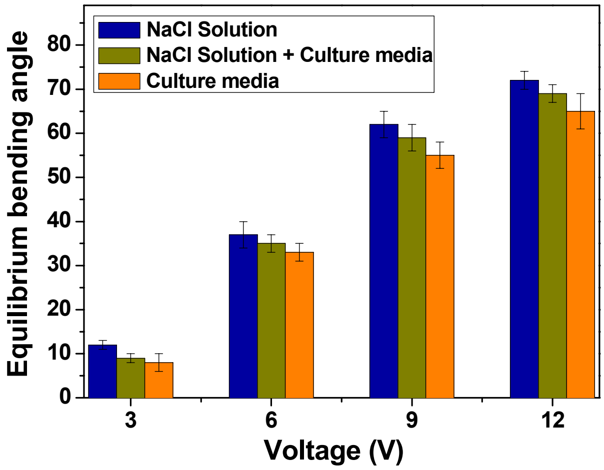

Figure S4. Comparison of hydrogel actuator bending performance in a 0.9 wt.% NaCl solution and mESc media. All error bars represent ± standard deviation (n=5).

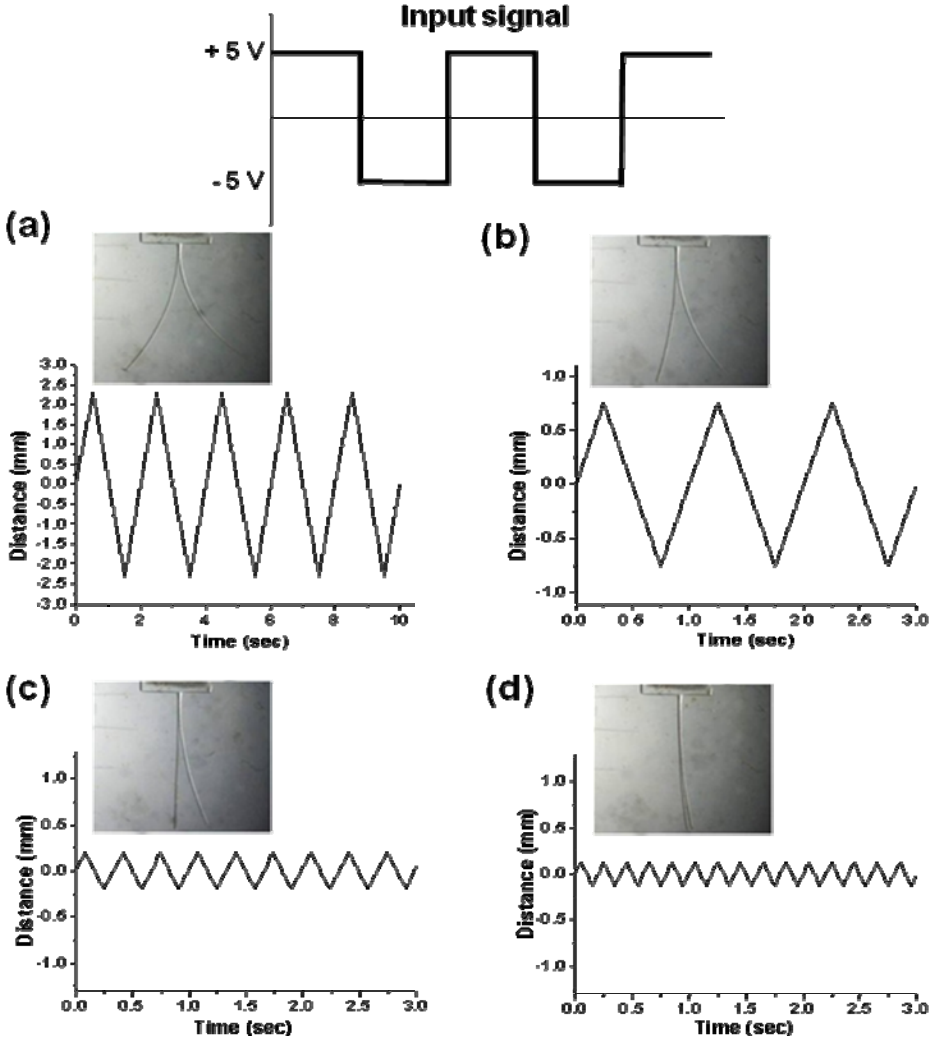

Figure S5. Performance of an electroactive hydrogel actuator (with strip dimensions as given in Figure 1) in response to alternating square-wave electric potentials. Time-dependent displacements of the actuator strip at applied square-wave electric potentials of 5 V with frequencies of (a) 0.5, (b) 1, (c) 3, and (d) 5 Hz.

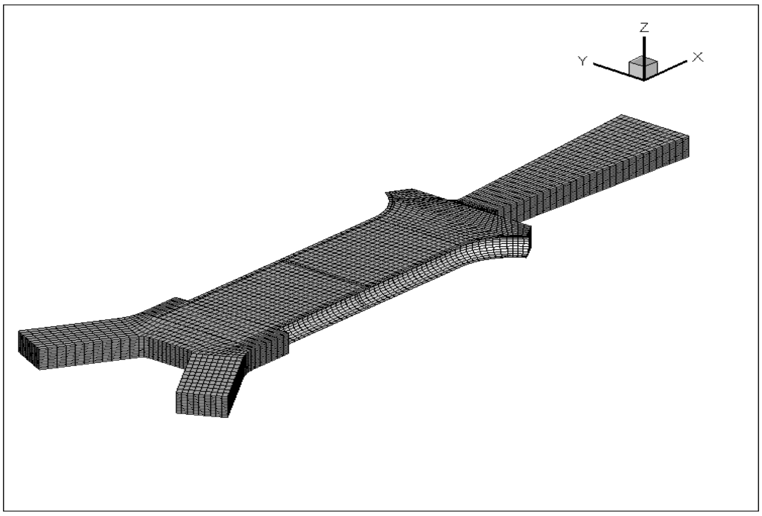

Figure S6. Computational geometry with mesh generated.

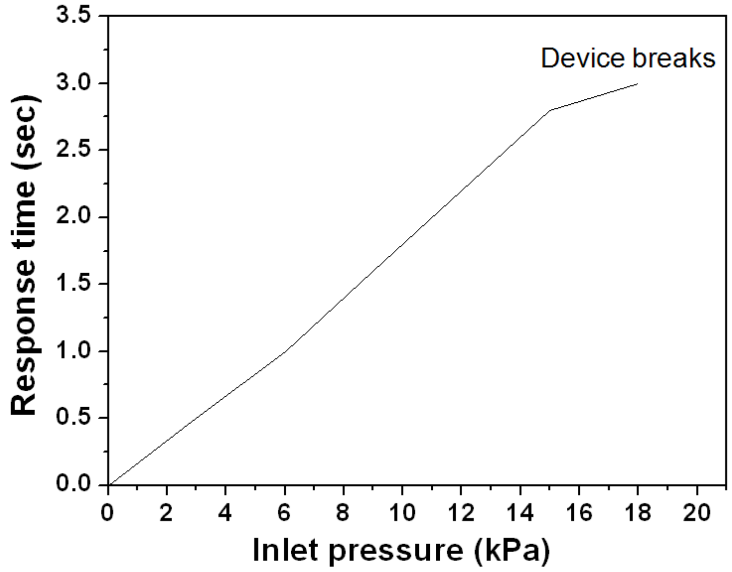

Figure S7. The resistance of the valve to the increase of inlet pressure. At the ‘device break’ point hydrogel does not operate.

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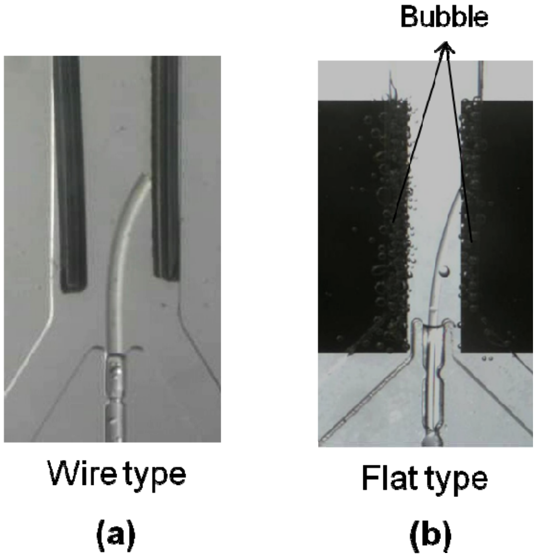

Figure S8. Operation of hydrogel: (a) between wire electrodes and the applying voltage is 1Volt, (b) between planar gold electrode and the hydrogel starts to move at 3Volt, and bubbles are generated around electrodes.

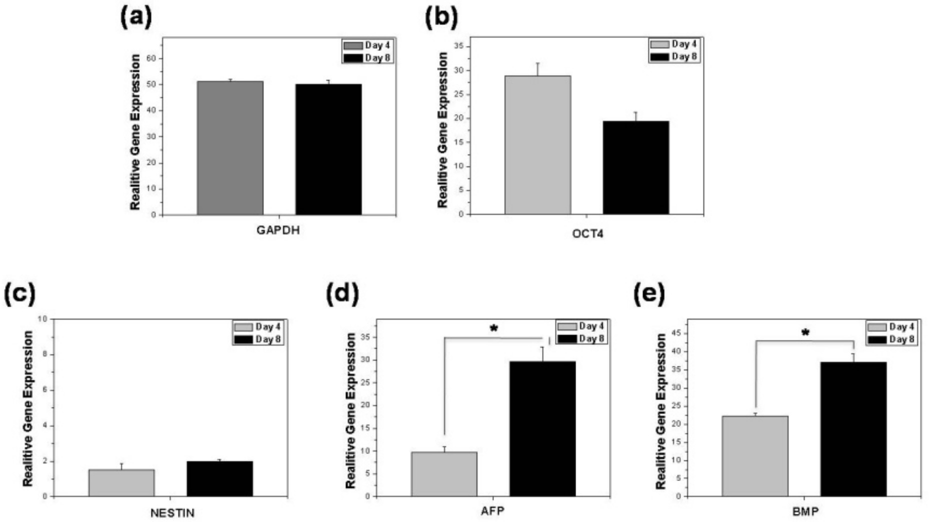

Figure S9. Quantification of gene expressions showed the upregulation of mesodermal and endodermal genes in day 8 EBs. (a) GAPDH, (b) Oct4, (c) Nestin (d) AFP and, (e) BMP. Error bars indicate ± standard deviation (n=3). Statistical comparisons were performed with SPSS (*: $p < 0.05$).

References

1. *ASTM D 638-99, Standard Test Method for Tensile Properties of Plastics* ASTM International, 1999.
2. J. Park, H. Oh, D. Kim, J. Baek and S. Lee, *J. Micromech. Microeng* 2006, 16, 656–663.