ADVANCED MATERIALS INTERFACES

Supporting Information

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Controlled Cooperative Wetting Enabled Heterogeneous Structured 3D Morphing Transducers

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Side-view observation of wetting process in TPP system:

Due to the large aspect ratio (plate width : gap height) of the TPP system, typically larger than 100:1, the side-view observations (Fig. **1b** and **2c**) could be challenging if the DSA (Droplet Shape Analyzer) does not have a tilt-tip stage. We have therefore created an in-house developed system (**Fig. S1**).

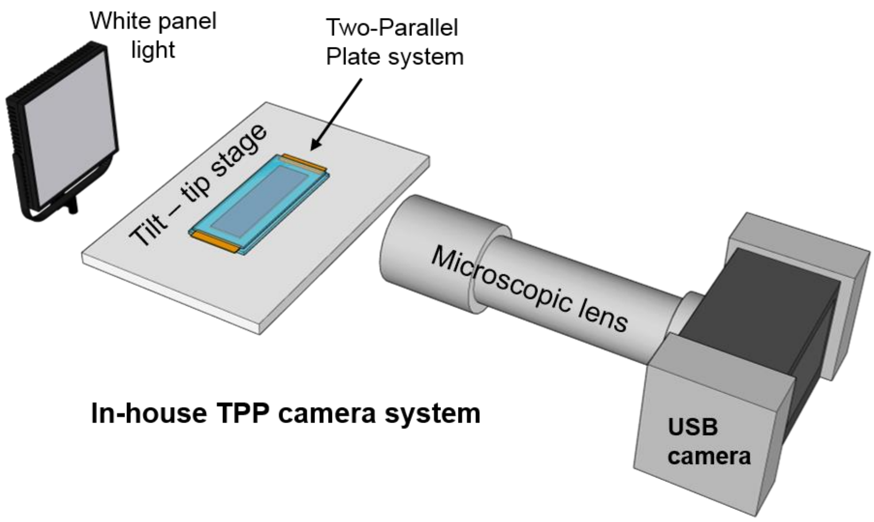

Figure S1. In-house developed camera system for side-view observation of the wetting process, through the gap of the TPP parallel plate system.

As the gap height g is in the range of 0.025 – 3 mm, long working distance microscopic lenses were employed and put on a USB camera (Thorlabs DCC1645C). Another critical element is the tilt-tip stage. The high aspect ratio (> 100:1) of the two-plate system means the tilting angle needs to achieve a minimum resolution of 0.5 ° ≈ arctan (0.01).

Numerical Simulation Details:

By immersing the gel structure in the PBS solution, the functional gel blocks will expand (swell) or shrink (de-swell) depending on the concentration of PBS solution. The mismatched strains between the expanded/contracted functional gel blocks and the non-functional substrate will induce an internal stress, which leads to the bending behaviour of the gel structure. To simultaneous simulate the expansion (swelling) and contraction (de-swelling) of different gel blocks under the same ionic environment (i.e. same PBS solution), complex diffusion kinetics must be developed, and the resulted coding and computation will be time-consuming. Therefore, we used the thermal expansion and contraction instead, which has already been incorporated in most commercial computing software. It is noted that our aim is to demonstrate a proof-of-concept simulation targeting at structure deformation design, not to precisely model the different diffusion processes.

The commercial finite element software ABAQUS is adopted to conduct the simulations. 2D plane-strain condition is assumed. Both the functional gel blocks and the non-functional substrate are modelled as hyper-elastic incompressible neo-Hookean material. For the functional gel, a non-zero thermal expansion coefficient is introduced. Moreover, the element type of "Coupled Temperature-Displacement" is selected and the step of "Coupled temp-displacement" is created to conduct the coupled thermo-mechanical analysis, i.e. solving simultaneously the mechanical equilibrium equation (for deformation) and the heat transfer equation (for temperature) with thermal expansion/contraction considered. The surface heat flux entering the gel is used as thermal load to induce the thermal expansion while the one leaving the gel is used for thermal contraction.

Three simulation results corresponding to three tests are shown in the paper: (1) one gel block expands with the principal strain around 0.25 and the other one contracts with the principal strain around −0.2, corresponding to the test of immersing the heterogeneous gel structure in the 0.2M PBS solution for 2 minutes; (2) both gel blocks contract with the principal strain around −0.2, corresponding to the test of immersing the gel structure in the 0.5M PBS solution for 2 minutes; (3) one gel block expands with the principal strain around 0.25 and the other one expands with the principal strain around 0.1, corresponding to the test of immersing the gel structure in the DI water for 2 minutes.

Besides 2D simulations, we have also performed a 3D simulation shown in **Figure S2** as an extra example of a structure incorporating more functional gel blocks, thus exhibiting more complex 3D wavy configuration.

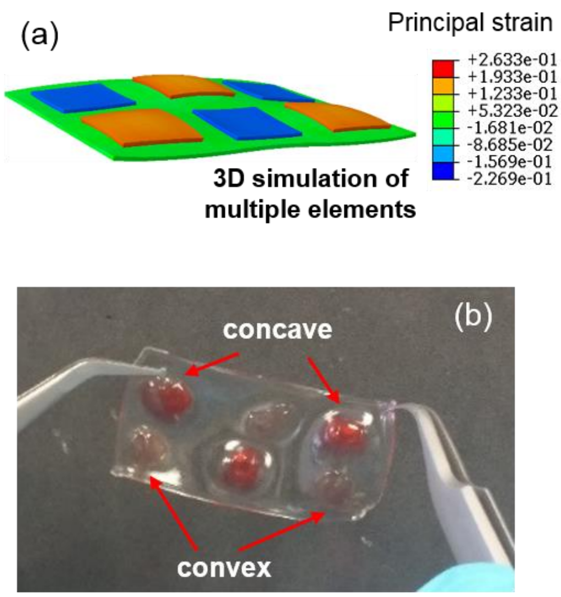

Figure S2. (a) 3D simulation of multiple elements; (b) Multiple concave and convex 3D wavy configuration obtained during experiment.