Supporting Information

Bio-inspired Facile Strategy for Programmable Osmosis-driven Shape-morphing Elastomer Composite Structures

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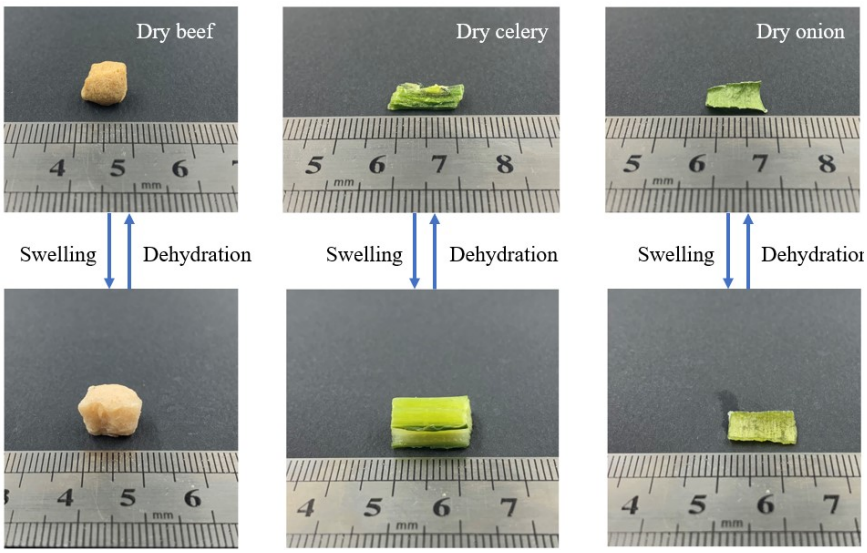

Figure S1. Shape changes of meat and plant tissues after swelling in water (Top row) and dehydration in air (Bottom row).

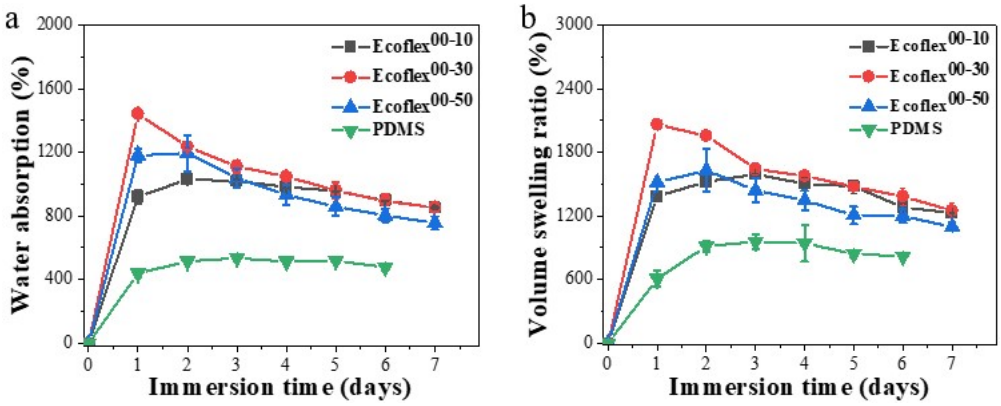

Figure S2. Swelling responses of Ecoflex$^{00\text{-}10}$/NaCl composites using different water-unswellable polymers as the matrix. (a) Water absorption and (b) volume swelling ratio of different polymer composites with 50 wt.% NaCl in 300 mL of DI water under 60 ^{o}C. The base-to-cure agent ratio of PDMS is 30:1.

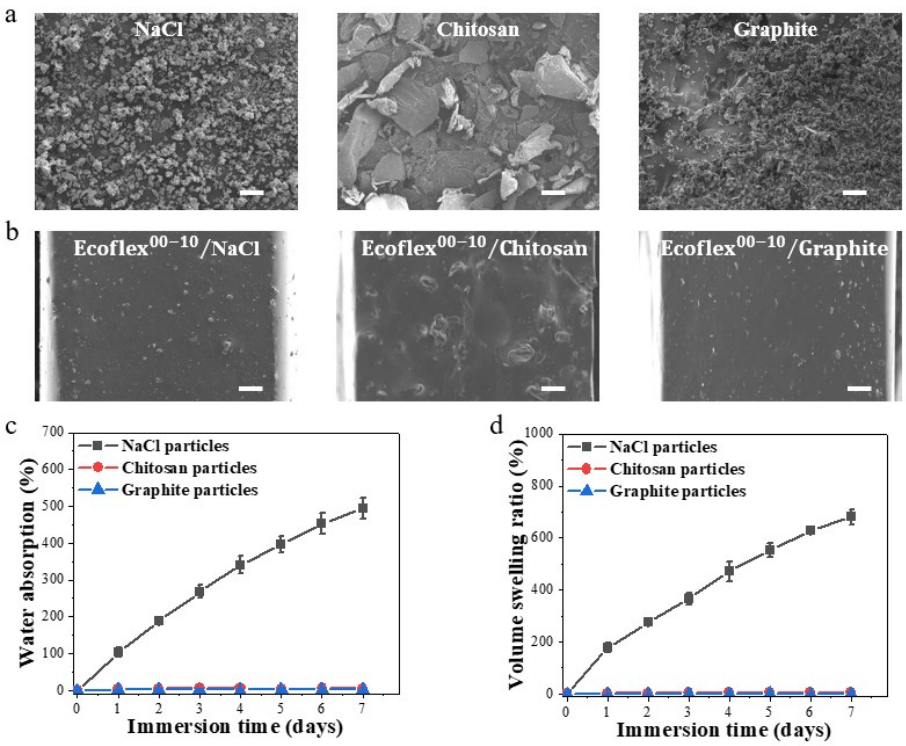

Figure S3. Swelling responses of Ecoflex$^{00\text{-}10}$-based polymer composites mixed with different particles. (a) Representative scanning electron microscopy (SEM) images of NaCl, chitosan, and graphite particles. (b) Representative cross-sectional morphologies of the Ecoflex$^{00\text{-}10}$/NaCl, Ecoflex$^{00\text{-}10}$/chitosan, and Ecoflex$^{00\text{-}10}$/graphite polymer composites. Scale bars: 100 μm. (c-d) Temporal evolution of the water absorption and volume swelling ratio of the polymer composites with 10 wt.% of different particles in 1 L of DI water under 60 °C.

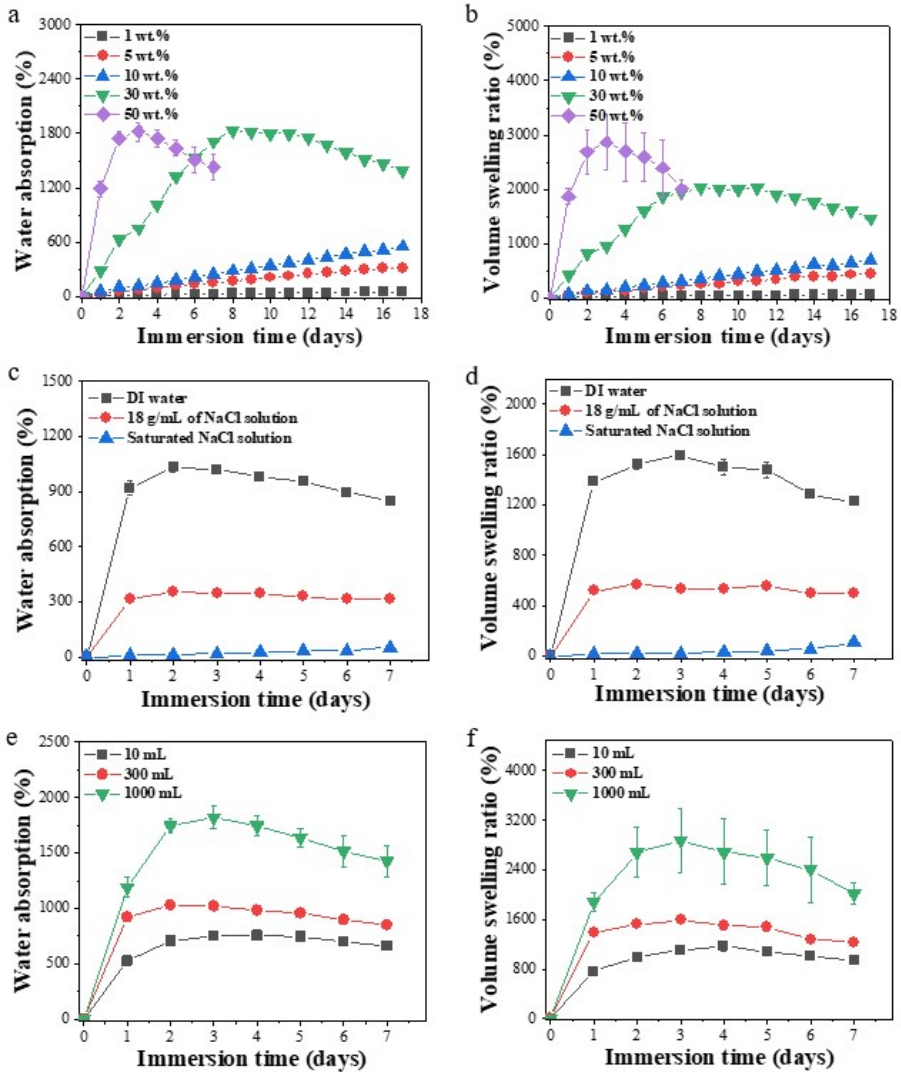

Figure S4. Swelling responses of the Ecoflex$^{00\text{-}10}$/NaCl polymer composites under various soaking conditions. (a-b) The water absorption and volume swelling ratio of the polymer composites with different NaCl concentrations in 1 L of DI water under 60 ℃. (c-d) The water absorption and volume swelling ratio of the polymer composite with 50 wt.% of NaCl in 300 mL of different solutions under 60 ℃. (e-f) The water absorption and volume swelling ratio of the polymer composite with 50 wt.% of NaCl in different amounts of DI water under 60 ℃.

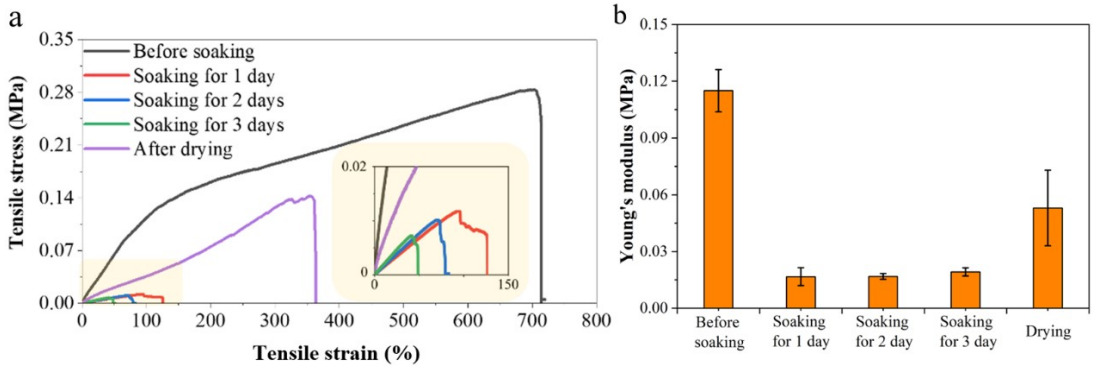

Figure S5. Characterization of the mechanical properties of the Ecoflex$^{00\text{-}10}$/NaCl polymer composite. (a) Representative stress-strain curves of the sample at different swelling states. (b) Young's modulus of the sample after different treatments.

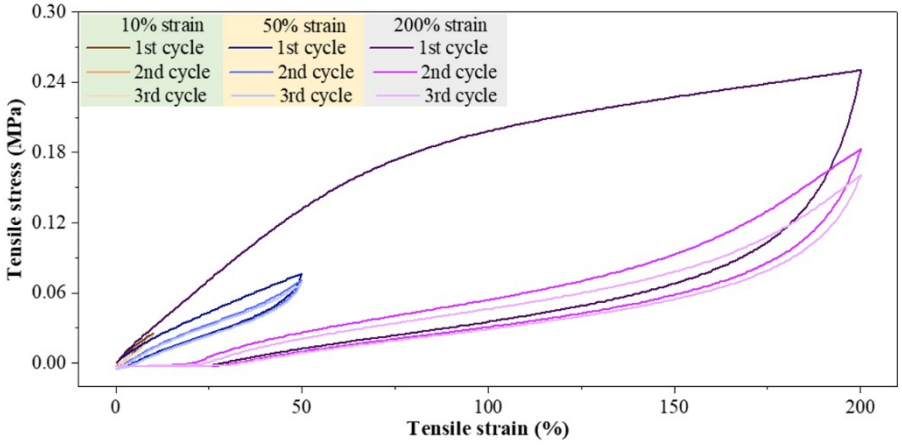

Figure S6. Stress-strain curves of the Ecoflex$^{00\text{-}10}$/NaCl polymer composite with 50 wt.% NaCl during the first three loading-unloading cycles under maximum 10%, 50% and 200% tensile strains.

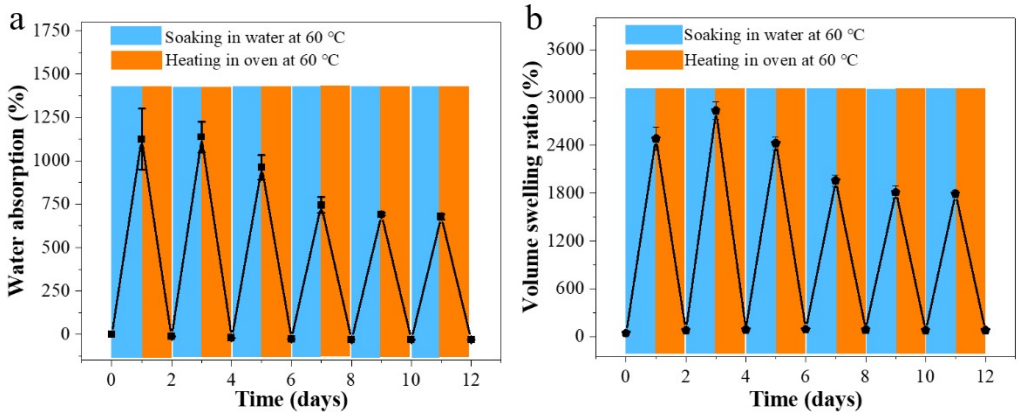

Figure S7. Characterization of the swelling repeatability of Ecoflex$^{00\text{-}10}$/NaCl polymer composite with 50 wt.% NaCl under cyclic soaking-drying conditions. (a) Water absorption and (b) volume swelling ratio during multiple immersion and drying cycles.

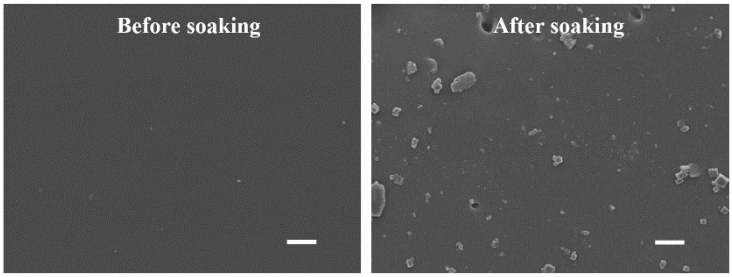

Figure S8. Representative SEM images of the Ecoflex$^{00\text{-}10}$/NaCl polymer composite surface morphologies before and after soaking in DI water. The swelled sample was dried in oven before imaging. Scale bars: 10 μm.

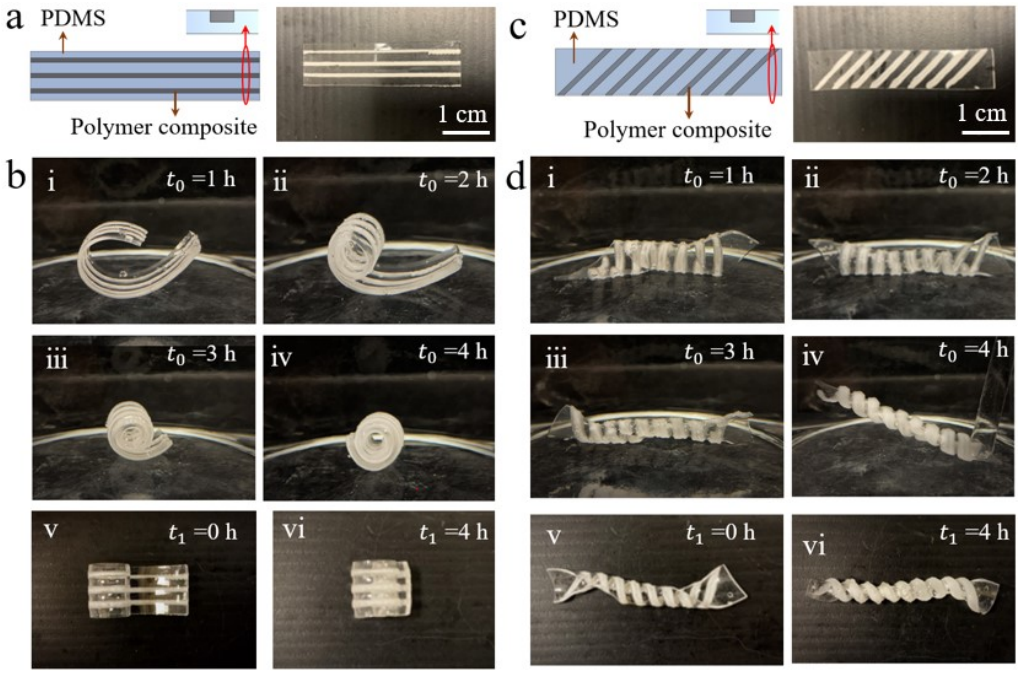

Figure S9. Swelling-induced shape morphing of PDMS structures with semi-embedded polymer composite strips. (a) Schematic illustration and an image of a rectangular PDMS strip with polymer composite strips semi-embedded in parallel to the PDMS strip. (b) Shape morphing of the sample in (a) at different stages (Panels i-iv: progressive shape morphing process as immersion extends from one to four hours;

Panels iv-v: morphed shape partially recovers with drying; Panels v-vi: re-morphing after putting the sample back in water). (c) Schematic illustration and an image of a rectangular PDMS strip consisting of polymer composite strips semi-embedded in PDMS in 45°. (d) Shape morphing of the sample in (c) at different stages (Panels i-iv: progressive shape morphing process as immersion extends from one to four hours; Panels iv-v: morphed shape partially recovers with drying; Panels v-vi: re-morphing after putting the sample back in water).

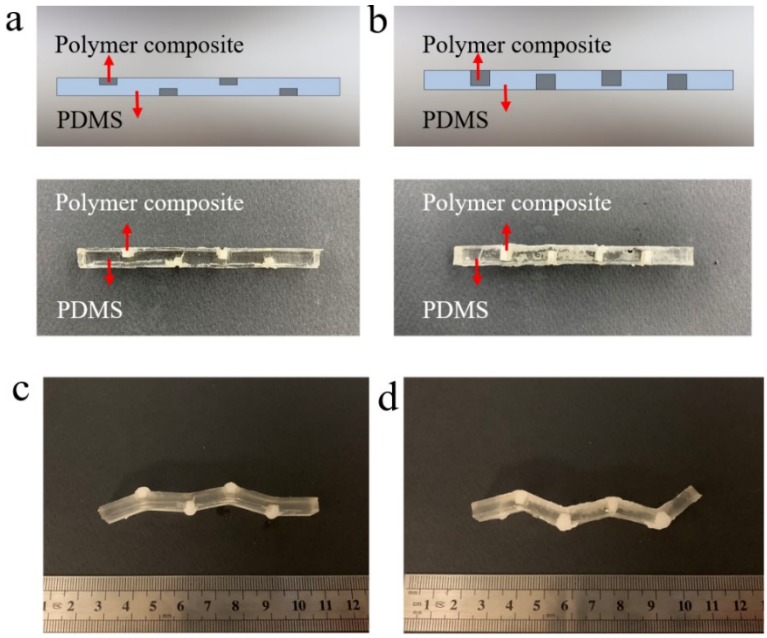

Figure S10. Swelling-induced zigzag-shaped bending of PDMS strips. (a-b) Schematic illustration and the physical models of the PDMS strips with semi-embedded Ecoflex$^{00\text{-}10}$/NaCl polymer composite strips of different thicknesses. (c-d) The fully swelled configurations of the samples in (a) and (b), respectively.

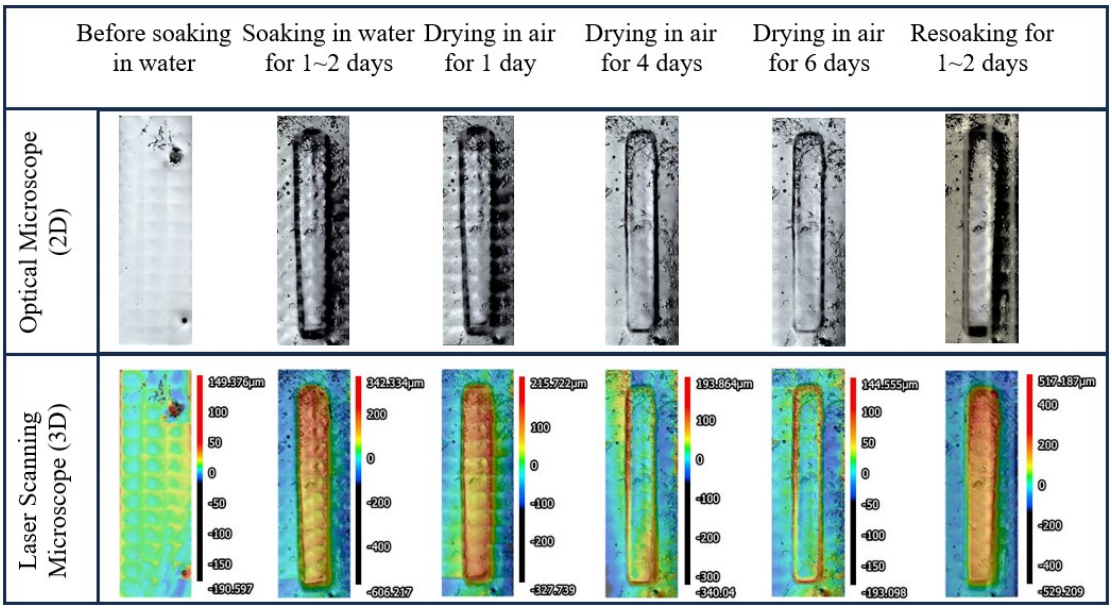

Figure S11. The optical microscopy and laser scanning microscopy images of Braille surface before and after soaking in water, drying in ambient air, and resoaking in water.

Figure S12. Schematic illustration of the control over the thickness of the liquid PDMS layer on top of PDMS samples with semi-embedded Ecoflex$^{00\text{-}10}$/NaCl polymer composite by adopting different spin-coating speeds.

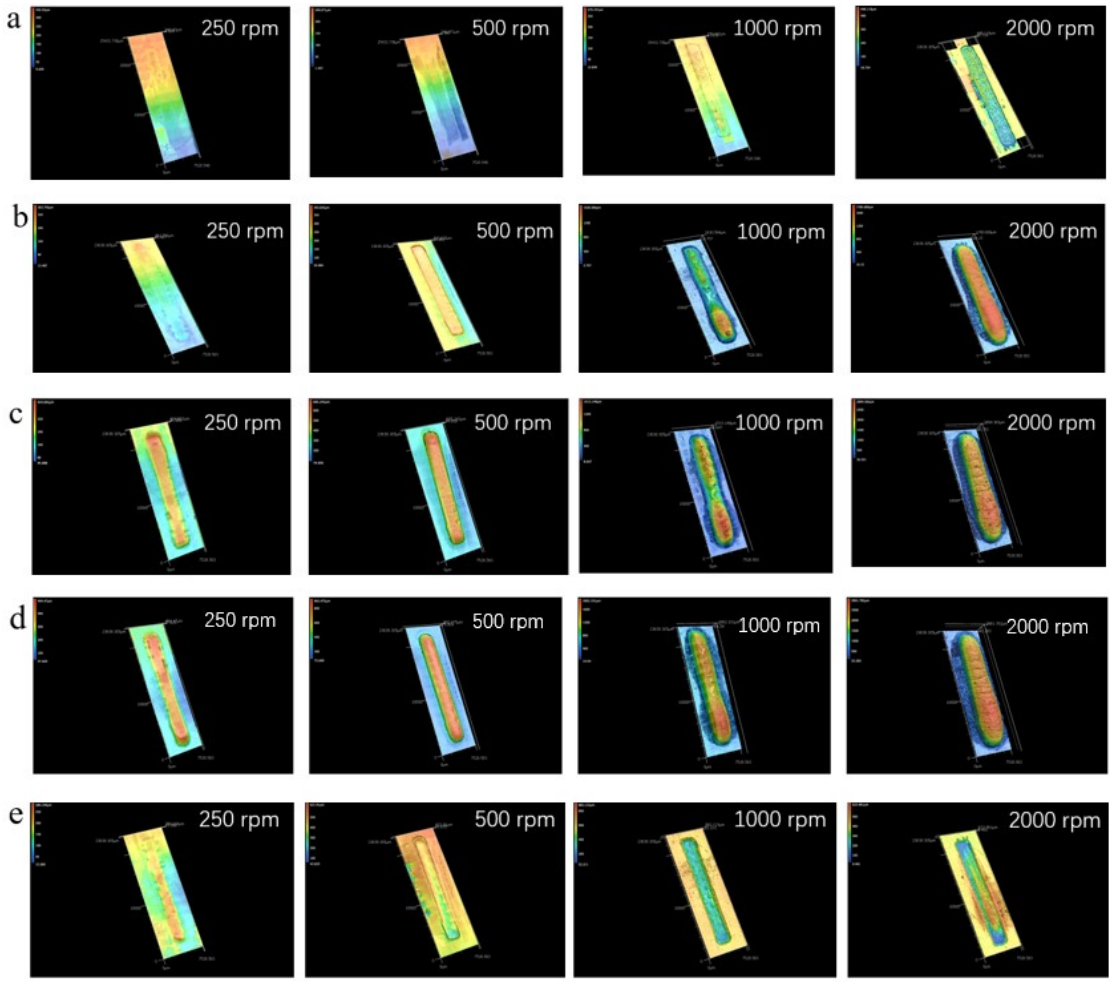

Figure S13. Surface morphologies of the sample that covered with PDMS of different thicknesses under different swelling states. (a) Before soaking in water. (b) After soaking in water for 1 day. (c) After soaking in water for 2 days. (d) After soaking in water for 3 days. (e) After drying.

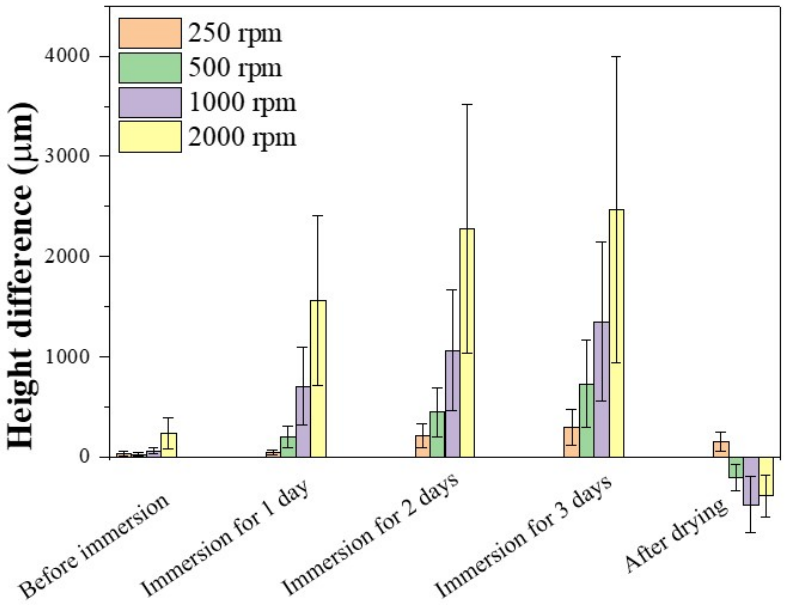

Figure S14. Calculated height change based on the surface morphologies in Figure S13.

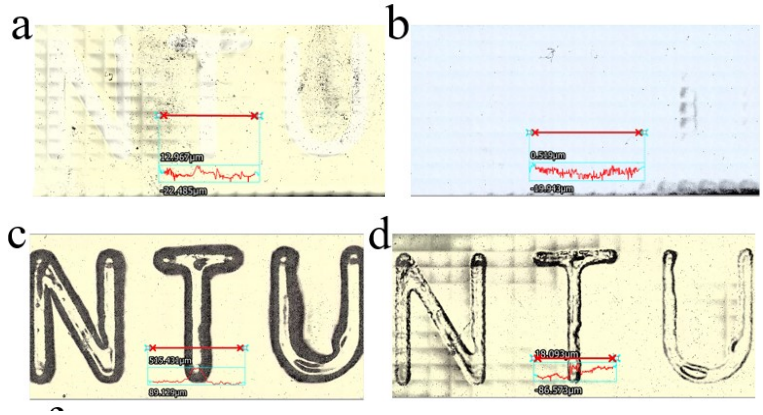

Figure S15. Optical images of the PDMS samples embedded with Ecoflex$^{00\text{-}10}$/NaCl polymer composite after different treatments. (a) Braille “NTU” with a visual difference before soaking. (b) Braille “NTU” without a visual and tactile difference before soaking. (c) Braille “NTU” with a clear visual and tactile regulation after soaking. (d) Decrease of a visual and tactile regulation after drying.