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Hygroscopic Metamorphic 4D Pleats[1]

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There have been significant interests in morphing 2D sheets into 3D structures via programmed out-of-plane distortion, including bending, tilting, rotating, and folding as seen in recent *origami* and *kirigami* strategies. Hydrogel is one of the unique soft materials that can swell and shrink, thereby enabling real-time 4D motions in response to external stimuli, such as pH, temperature, and moisture. To achieve reliable folding behaviors, it often requires a large amount of water molecules or ions diffusing in and out of the hydrogel sheet, thus the entire sheet is immersed in an aqueous solution. Here, we demonstrate the design and folding of hierarchical pleats patterned from a combination of hydrophobic and hygroscopic materials, allowing us to spatially and locally control the water condensation induced by environmental humidity. In turn, we show out-of-plane deformation of the 2D sheets only in the patterned hygroscopic regions, much like the folding behaviors of many plants. By designing the dimension, geometry, and density of hygroscopic microstructures (as pixels) in the hydrophobic materials, we can display the enhanced water condensation together with the spatial guidance of obtained droplets as unified water-harvesting systems. When the water droplets become large enough, they roll off from the hierarchical sheet along the inclined plane that is programmed by the hygroscopic motion of hydrogel, and eventually wrapped by the folded sheet to keep them from evaporation.

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