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Control of the water flux by variation of the interlamellar distance

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The manipulation with topography of surfaces, which can be achieved through the application of external stimuli, including temperature, magnetic fields, pH, light, and others stimuli, allows switching of wetting and adhesion. Shape-memory polymers is one kind of materials can alter their appearance under applied stress and can be used for fabrication of such smart surfaces. Particularly, thermo-responsive shape memory polymers can revert to their original structure after a thermal cycle involving heating, cooling, and reheating. Additionally, two-way actuation polymers can change their shape by adjusting the temperature in a stress-free regime. An intriguing example of such materials is poly(1,4-butylene adipate)-based poly(ester urethane) (PEU-PBA). During a thermal-mechanical pretreatment, the PEU-PBA contains regions which may crystallize at temperatures below 8℃, leading to a change in the polymer's shape [1]. Thermal-responsive polymers provide precise control over their shape through temperature manipulation, making them valuable for regulating fluid flow processes.

In our study, we employed polyurethane with poly(1,10-decylene adipate) as the soft segment [2]. We fabricated a lamellar structure with a height of approximately 1.5 mm and an interlamellar distance of 2 mm by using the melt-electrowriting technique at a temperature of 200℃ and an applied voltage of 3kV. These lamellae can change their shape when heated due to expansion and decrystallization effects, and this transformation is reversible. By adjusting the temperature, we can effectively control the volume between neighboring lamellae. The presence of a water droplet between two lamellae reduces the volume between them until they collapse. After evaporation, the space between the two lamellae is maintained. Furthermore, we can restore or modify the volume of the collapsed channel by adding another droplet between the collapsed lamella and the non-collapsed one. Varying the temperature enhances the flexibility of our lamellae, allowing us to modulate the fluid flow by altering the temperature and adjusting the surface tension of water. This characteristic opens up exciting possibilities for utilizing such topographies in microfluidic devices and for creating new materials for tubing fabrication.

[1] Martin Bothe and Thorsten Pretsch Bidirectional actuation of a thermoplastic polyurethane elastomer// J. Mater. Chem. A, 2013, 1, 14491–14497.
[2] Schönfeld, D.; Chalissery, D.; Wenz, F.; Specht, M.; Eberl, C.; Pretsch, T. Actuating Shape Memory Polymer for Thermoresponsive Soft Robotic Gripper and Programmable Materials// Molecules 2021, 26, 522.

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