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Switchable topography of lamellar structure by changing temperature and capillary forces

Nowadays, there are many applications where knowledge of surface wettability is needed. For example, these are microfluidic devices, oil/water separation, drug delivery, etc. There are two approaches to control the wettability properties of materials: changing their topography or modifying them with different surface groups. Changing the surface topography, which can be achieved by applying external stimuli including temperature, magnetic fields, pH, light and others, can modify the wettability. One type of material that can reversibly change its topography when exposed to external stimuli are shape memory polymers (SMPs), which can be used to create smart surfaces. Changes in topography can also be associated with crystallization or melting processes. One popular material for this purpose is polyether urethane with poly(1,4-butylene adipate) (PEU-PBA) as a soft segment. These soft segments can crystallize at temperatures below 8 ℃ allowing switching of mechanical properties of topographically structured surfaces. This ability to change topography has been utilized in the field of wettability [1].

Here we present an advancement of our strategy to allow active switching of surface topography. For this, we use polyurethane with poly(1,10-decylene adipate) (PEU-PDA) as a soft segment [2], which undergoes expansion/contraction associated with melting/crystallization, respectively. A lamellar structure with a height of about 2.5 mm and an interlamellar distance of 2 mm was fabricated using meltelectrowriting technique. The polymer was heated to 200℃ and a voltage of 3 kV was applied between the polymer and the substrate. These lamellae can buckle when heated to a temperature higher than the melting point (ca. 61℃) of the soft segments, and this buckling process is reversible. However, the buckling process doesn't have a definite direction. In this case, we can add an additional force that has a direction, such as capillary forces when water droplets are added to the interlamellar space. These forces cannot bend the lamellae at room temperature because the elastic modulus is high enough. However, at temperatures above the melting point, the elastic modulus decreases by more than 12.7 times, and the lamellae are easily bent by capillary forces. After evaporation of the water drop, the deflection of the lamellae remains, but we can restore or change the volume of the bent lamellae by changing the direction of the capillary forces. Controlling the elastic and capillary forces by changing the temperature or perimeter of the drop allows us to change the interlamellar volume. Such adjustments may open us to new possibilities for using such topographies in microfluidic devices or creating tubular structures.

[1] Constante, G.; Apsite, I.; Auerbach, P.; Aland, S.; Schönfeld, D.; Pretsch, T.; Milkin, P.; Ionov, L. Smart Mechanically Tunable Surfaces with Shape Memory Behavior and Wetting-Programmable Topography// ACS Applied Materials & Interfaces 2022, 14, 17, 20208–20219
[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.

Primary author: SADILOV, Ilia (Universität Bayreuth)

Co-Autoren: CONSTANTE, Gissela (Universität Bayreuth); Dr. DULLE, Martin (Forschungszentrum Jülich); Dr. SCHÖNFELD, Dennis (Fraunhofer Institute for Applied Polymer Research IAP); Dr. PRETSCH, Thorsten (Fraunhofer Institute for Applied Polymer Research IAP); IONOV, Leonid

Vortragende(r): SADILOV, Ilia (Universität Bayreuth)