Mechano-responsive wetting of fs-laser-structured PDMS surfaces

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The wetting or non-wetting of surfaces with different liquids plays a central role in our daily life. Numerous technical applications such as microfluidics, inkjet printing and superhydrophobic self-cleaning surfaces are based on a specific wetting behavior. It can be influenced by the topography of the material surface in combination with a specific surface chemistry. In this context, ultra-short pulse lasers (fs-lasers) are highly qualified for the precise fabrication of nano- and microstructures on surfaces of various materials.

The present study combines material synthesis aspects (fs-laser processing, replica casting and chemical surface functionalization) with the mechano-responsive dynamic wetting of flexible polymer substrates (polydimethylsiloxane, PDMS). The wetting behavior is controlled by a well-defined laser-based micro- and nanostructuring, subsequent surface functionalization and the application of external mechanical strain. For this purpose, two different approaches were utilized to fabricate periodic structures of different size on the surface of PDMS substrates. On the sub-µm scale, laser-induced periodic surface structures (LIPSS, ripples) were generated on stainless steel masters by fs-laser irradiation and then transferred to flexible and stretchable polymer samples in a replica casting process. This resulted in detailed replication of the LIPSS without laser-induced alteration of the polymer substrate. In the second approach, periodically arranged channels were fabricated on the elastomer surface in its stretched state by direct fs-laser ablation [1], resulting in a pattern of equidistant channels. Both the depth and the width and therefore the aspect ratio of the grooves can be precisely controlled through the stretching state. After fs-laser irradiation, the elastomer surfaces were treated with oxygen plasma to achieve high hydrophilicity and then chemically stabilized to avoid hydrophobic recovery [2]. The selective functionalization of the structured PDMS samples at different expansion states allowed to locally induce either hydrophilic or hydrophobic sites at the surface which intensifies the dynamic wetting behavior.

The morphology and topography of the structured surfaces were characterized by scanning electron microscopy (SEM), atomic force microscopy (AFM) and confocal laser scanning microscopy (CLSM). The wettability was evaluated by conventional sessile drop measurements and by CLSM using a water droplet dyed with Rhodamine B. It was shown that the wettability of the polymer can be reversibly adjusted over a wide range between superhydrophilic and superhydrophobic states by mechanical deformation, depending on the structuring, functionalization and strain state. Furthermore, the study revealed the possibility to dynamically switch the wetting between hydrophilic and hydrophobic behavior under permanent contact with a water droplet. The obtained results provide a significant contribution to the dynamic wetting of surfaces, which might be of potential interest for applications in the field of sensors, water harvesting, and directed fluid flow.

References:

[1] S. Surdo et al., Towards nanopatterning by femtosecond laser ablation of pre-stretched elastomers, *Appl. Surf. Science* **374** (2016) 151-156.
[2] S. Hemmilä et al., Rapid, simple, and cost-effective treatments to achieve long-term hydrophilic PDMS surfaces, *Appl. Surf. Science* **258** (2012) 9864-9875.