Project A6: Slippery when wet: Wet adhesion and friction on nano/micro-structured surfaces

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Current state of the research. The field of the control of wetting properties, wet adhesion and low friction surfaces has gained considerable momentum recently due to the inspiration from natural examples, on the one hand, and the more and more refined ways to control chemistry and topology of surfaces on a micrometer and nanometer level, on the other hand Examples for a rather subtle control of such properties are the topological structures of the butterfly wings which need to overcome the capillary forces that would inevitably glue them together in the wet state. Other examples are the approaches of plants to render their surfaces superhydrophobic e.g. through wax crystals forming microrough surfaces (Lotus leaf) or through hairs which bundle inside a drop and hold it away from the surface (Achimilla vulgaris). Reproducing such surface architectures that provide the desired properties often suffers from the fragility of the structures whereas nature can repair or re-grow if needed.

Contributions of the principal investigators. In previous work we have found that combinations of micro- and nanostructures significantly improve the stability of ultrahydrophobic surfaces, even after quite strong shear stress. The nanostructures that account for the wetting properties are placed between micron-sized pillars or cones which capture most of the shear stress and protect the fragile nanograss needles of the surface to a large extent (Freiburg). Micro- and nano-scratching machines have been developed in Strasbourg with the capability of in-situ observation capabilities and a JKR option so as to explore also the adhesion properties. A recognised expertise in Finite-Element modelling of contact mechanics will be also harnessed in this project.

Research project and collaborations. In this project, we want to continue exploring such surface architectures and evaluate the various physical and chemical principles that govern this stabilization, on the one hand, and to study the influence of thin liquid layers on rough surfaces on adhesion and friction, on the other hand. Micro- and nanostructured surfaces will be prepared by a combination of dry etching procedures and photolithographic techniques or by interference lithographical means. Important structural parameters are the size, shape and spacing of the protective structures as well as the surface chemistry of (or on top of) these structures that will be modified with monolayers of hydrophilic and hydrophobic polymers (Freiburg). Wetting, adhesion and friction properties can then be investigated. Friction properties can be explored as well in both dry and wet conditions as a function of shear load, liquid lubricant and shear duration. The results can then be correlated with the extent of damage at the micro-scale during loading (in-situ observation – Strasbourg) and at the nano-scale afterwards (post-mortem) to uncover promising strategies for the protective measures on micro- and nanostructured surfaces (Freiburg and Strasbourg). These studies will be complemented by finite element modelling (Strasbourg) to obtain a comprehensive picture of wetting, adhesion and friction between nano- and micro-structured surfaces.

Work plan. The doctoral researcher will work in Freiburg and Strasbourg on

- *Development of techniques for the generation of surfaces with micro- and nanostructures (Freiburg):* Based on our previous work, we will integrate DRIE techniques for the generation of nanostructures with photolithograpy and interference lithography to generate hierarchically structured surfaces (pillar geometries, shapes, sizes, and spacings). Polymer monolayers and networks will be deposited to adjust the surface chemistry of the samples.
- *Investigation of properties (Freiburg and Strasbourg):* Adhesion will be explored and friction properties of all samples (dry and wet conditions) will be determined for different compositions, loads and load duration. Each measurement will be accomplished with in-situ observation of the damage when possible and post-mortem using electron microscopy.
- *Modelling (Strasbourg):.* Finite-element calculations of contact mechanics will be achieved to study the influence of shear loading onto the resistance properties of the surfaces.