Internship / Thesis

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Capillarity of Soft Solids at the Nanoscale

What determines phenomena as varied as: the shape of a soap bubble, the spreading of a drop of dew on a leaf, the dewetting of a Teflon pan, the "tears" of wine, the meniscus around a fishing line, or the difficulty in extracting certain oils from the soil ? Capillarity. This force which tends to minimize the interfaces and whose origin is microscopic. Indeed, the molecules of a liquid have a certain affinity between them, and attract each other thus ensuring the cohesion of the whole. But now, add a boundary - an interface - and the molecules become less surrounded by their peers and thus frustrated ! The net result is a macroscopic force, surface tension, tending to reduce the interfaces.
If capillarity seems to be the prerogative of fluid interfaces at small scales (where it outweighs other forces such as gravity), the interfaces between solids and fluids also have an energy cost, which controls for instance the wettability of a given solid material. However, there is an essential difference between a solid and a liquid: the latter can rearrange under stress unlike a rigid crystal. Consequently, if a crystalline solid is stretched, its constituents can be "diluted" and the surface tension modified, which is impossible with an incompressible liquid. This effect, predicted by Shuttleworth in the 1950s, was extensively studied later.
There is however another class of solids. Non-crystalline solids, called amorphous solids. These are more and more studied since the rise of soft matter. They can be so soft (cosmetic and food gels or vesicles for example) that they sometimes behave like liquids and their surface tension outweighs their bulk elasticity. In addition, they are the source of a lively controversy following a pioneering experiment and an international conference in Leiden, the Netherlands, in 2015. In this emerging community, dedicated to the capillarity of soft solids, the existence of a Shuttleworth effect for amorphous materials is extensively debated due to the physico-chemical complexity and dual nature of soft matter. It therefore seems crucial to test these ideas by independent experiments and models. Ultimately, one could perhaps imagine controlling the wetting properties of a plastic material by simply stretching it ! From fog nets, or intelligent textiles, to surface treatments for optics, the number of potential applications is extremely large. But besides this, and the possible resolution of a lively controversy, this project could give us further fundamental insights about the fascinating properties of amorphous and soft matter.
Our group at LOMA, University of Bordeaux, has developed a growing expertise in precise atomic force microscope (AFM) measurements, combined with applied mathematics and statistical physics. Our goal in the present project, and with respect to this controversy, is to shed new light on the Shuttleworth enigma in soft matter, by providing a unique combination of direct AFM observations and theoretical modelling at the nanoscale.