Proposal for a M2 internship (spring 2025) and a PhD thesis starting in october 2025

Debonding of a microscopic fibril of soft polymer

Laboratoire de Physique des Solides, Laboratoire FAST
and Institut de Chimie Moléculaire et des Matériaux d'Orsay

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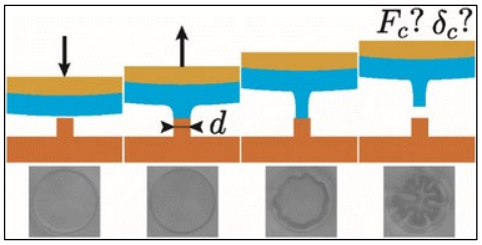
Omnipresent in the industry, both in advanced applications and in connection with our daily lives, adhesive tapes made of soft polymers remain only partially described. The quantitative prediction of their adhesion strength is a difficult fundamental problem, at the frontier between fracture mechanics, rheology, and polymer physics and chemistry. Besides, the possibility of this prediction is a strong industrial challenge that would allow manufacturers to reduce their development and production costs. During the detachment of a soft polymer adhesive, the unconfinement of the thin layer of adhesive material most often leads to a process of cavitation or fingering of the detachment front. The scenario then continues with the creation of microscopic fibrils of adhesive material followed by their stretching until they debond. The key theoretical element currently missing to build a predictive model for the adhesion strength is the understanding of the individual fibril detachment criterion.

The M2 internship (and the following PhD thesis) will be dedicated to the experimental understanding of the debonding process of micrometric fibrils of soft adhesive material. Adhesive layers will be brought into contact with a micrometric pillar before being separated at controlled velocity. During this separation, a single fibril of adhesive material with a diameter controlled by that of the pillar will be created and then stretched until it detaches (see figure). The project consists in an ambitious study of this process as a function of the geometrical, physical and chemical features of the system (adhesive rheology, pillar geometry, interfacial energy ...). These experiments, which follow a preliminary study [1], will involve commercial and homemade adhesives with controlled mechanical properties, the characterization of their rheology, the preparation of textured substrates by electronic and optical lithography, the chemical and physical tuning of their surface properties and, during the separation experiments, the measurement of low contact forces coupled with microscopic imaging.



A collaboration is planned with the Institut de Chimie Moléculaire et des Matériaux d'Orsay (ICMMO) where the chemical synthesis of adhesive materials with controlled rheology and chemical control of the surfaces of our substrates will be conducted.

The objective of the project is to identify the physical laws that control the debonding of a microscopic fibril of soft adhesive and their dependence on the rheology of the materials, their surface properties and the geometry. The ultimate objective is to establish and test a model, based on the identified fibril-debonding criterion, that allows to quantitatively predict the adhesion strength of the adhesive tape from the knowledge of the material properties.

The thesis will be mainly carried out at Laboratoire de Physique des Solides and Laboratoire FAST (in Orsay), where the experimental activities will be developed. The chemical synthesis of samples will be conducted at ICMMO.

[1] A. Duigou-Majumdar, P.-P. Cortet, C. Poulard, "Debonding of a soft adhesive fibril in contact with an elastomeric pillar", Soft Matter **18**, 5857 (2022), https://hal.science/hal-03758500v1/file/duigou.pdf