Friction, contact and elasticity of polymers films

PhD proposal – CIFRE - 2025-2028

SIMM Laboratory, 10 rue Vauquelin 75005 Paris

Contact: A. Chateauminois, antoine.chateauminois@espci.fr

E. Verneuil, emilie.verneuil@espci.fr

Industrial partnership: Saint-Gobain Research Paris

In many industrial processes or products, the manipulation of slender objects such as polymer films or fibers involves situations where friction could result in the development of instabilities which can then impact the process or the end-properties of the products. The formation and trapping of such instabilities basically depends on the interplay between the elastic energy stored in the folded part of the film and the frictional properties of the interface between the polymer film and the substrate.

While the interplay between capillary forces and elasticity - or adhesion and elasticity - has been widely investigated, a unifying physical description of the coupling between elasticity and friction suitable for a large class of systems is still lacking. Of particular importance is the roughness of the contacting surfaces which results in the formation of multi-contact interfaces consisting in a myriad of micro-asperity contacts. When dealing with viscoelastic materials, the statistical distribution of micro-asperity contacts may be time- or temperature-dependent which results in subtle and overlooked effects on the macroscopic friction force and on the related deformation of the objects.

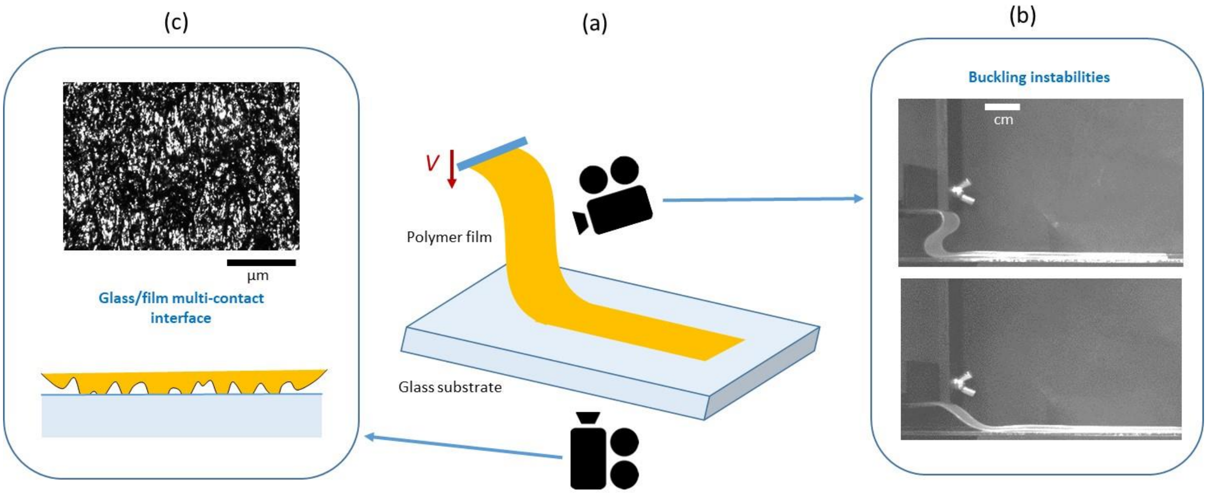

Figure 1: Deposition of a thin polymer film on a glass substrate: (a) a polymer film is deposited at imposed vertical velocity V on a glass substrate. (b) side view of the polymer strip showing either the development of a buckling instability (top, no slippage) or complete relaxation of the fold (bottom, slippage). (c) microscope observation of the rough contact interface where microcontacts appear as bright spots.

How does the interplay between deformation and friction affect the development and trapping of buckling instabilities in polymer films? What are the contributions of film roughness and polymer viscoelasticity? As a starting point to answer these questions, we will carry out experiments in which a viscoelastic polymer strip with a well characterized surface roughness is laid at imposed vertical velocity on a glass plate (Fig. 1a). In addition to the monitoring of the development of buckling instabilities (Fig. 1b), state-of-the-art microscope observations of the rough contact area at the glass/film interface will be performed in order to quantify the statistical distribution of micro-contacts in relation to macroscopic friction force (Fig. 1c). Using this approach, we will tackle the overlooked issue of the contributions of adhesion, viscoelasticity and topography to the development of multicontact interfaces between polymers and glass substrates. Additionally, we will explore how this contact surface evolves as a function of different parameters such as temperature, pressure, or film properties.

Hence, the interplay between friction and shape of slender objects will be broadly explored either by using slender objects with varied frictional properties, or varied viscoelastic properties, or by developing other experimental configurations.

Based on these observations, we will seek to develop a physical description of the role of friction in the formation and trapping of instabilities in slender polymer systems in relation to their mechanical and roughness properties.

Applicant skills We are looking for a PhD candidate motivated by experimental work involving custom-made friction experiments, analysis of buckling instabilities and statistical description of multi-contact interfaces, with a strong background in physics (soft matter, mechanics…).