



12-month post-doctoral position (to begin ASAP)

Hydrodynamic boundary condition of polymer solutions on simple and complex surfaces

Contacts

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Many natural spaces such as porous media or biological environments are crowded by confining interfaces and are filled with complex fluids. These spaces are home to flow with characteristic dimensions on the scale of nanometres. At such length scales the fluids may behave in a completely different manner as compared to those encountered at more familiar scales. One example is the idea that, in the fully liquid state, molecules may slide along a solid confining boundary. This effect, called slip, was proposed by Navier in the early 19th century, but it was not until more than a century later, with the push for device miniaturization giving rise to micro and nanofluidics, that slip has become an essential ingredient to the understanding and prediction of such small-scale flows. As it turns out, however, little is understood about the slip boundary condition of complex fluids, and the central aim of this post-doctoral project will be addressing this lack. In order to mimic the aforementioned complex fluids, polymer solutions with controlled concentration and chain length will be used.

One example of confined polymer solution specificity is that of a depletion zone in the first few nanometres near the substrate, where relatively few polymers are found due to a preference for interaction between the solvent and the wall. Such a depletion zone may give rise to apparent slip because of a lower concentration of polymer near the walls, this lower concentration being associated with a local depletion in the viscosity. These depletion effects and their coupling to flow are complex, but they are now fairly well understood for the case of dilute solutions where individual polymer molecules do not overlap in space. The same, however, is not true for the case of more concentrated solutions and we wish to know in particular how such a depletion zone may change under flow; again, much is known with respect to equilibrium, but the situation in flow is still mysterious.

Polymer depletion near the wall is only one possibility, and in the opposite case of an attractive interaction polymers may instead adsorb to confining walls. The impacts of such an adsorbed or grafted layer are important to colloidal stabilization, fouling, and smart surfaces. Much is known about the statistics and equilibrium properties of such so-called “polymer brushes”. Similarly, slippage of polymer melts (i.e. with no solvent) along chemically grafted brushes is by now fairly well understood^{1,2}. However, yet again, there is a substantial lack of knowledge about



hydrodynamic flow past polymer brushes in solution. While many simulations and much theoretical work have been done, experiments are lacking.

Among the different techniques available to measure the slip length of polymer solutions, dynamic Surface Force Apparatus (dSFA)³ or Photobleaching based techniques⁴ have been used in the past. The dSFA allows to measure at different frequencies with a resolution close to 1 nm, but requires a complex preparation of the surfaces due to its high sensitivity to dust. Recently, we used the photobleaching experiment (PE) to measure the slip of concentrated polymer solutions. The resolution is limited to 1 μm and requires photobleachable polymer.

During this post-doc financed by the ANR (ENCORE), we will study hydrophilic and hydrophobic surfaces, along with polymer decorated walls and combine our results with the dSFA and PE experiments. In the first part, we will address how polymer molecules in solution react at a boundary when subject to a pressure driven flow; do they stick or slip, and how much? The effect of the polymer concentration, chain length and degree of confinement by one or two walls will be investigated; a complete fundamental understanding of these dependencies is currently lacking. Experiments will be conducted using the lately developed and high precision surface probe: total internal reflection fluorescence, near-wall nanovelocimetry (TIRF-NWN) that measures particle position thanks to an evanescent light wave. Further development of this technique using tagged polymers will be necessary, and the flow experiments will be conducted in microfluidic environments tailored to the nanoscale using infrastructure provided by the host institution, the Institut Pierre-Gilles de Gennes pour la Microfluidique.

Highly motivated candidates are encouraged from the present to send an application package including: a CV; a letter of intentions that also outlines the applicant's expertise and relevant experience; and, the names of references. Applications will be accepted until the position is filled.

1. Hénot, M., Drockenmuller, É., Léger, L. & Restagno, F. Friction of Polymers: from PDMS Melts to PDMS Elastomers. *ACS Macro Lett.* **7**, 112–115 (2018).
2. McGraw, J. D. *et al.* Nanofluidics of thin polymer films: Linking the slip boundary condition at solid–liquid interfaces to macroscopic pattern formation and microscopic interfacial properties. *Adv. Colloid Interface Sci.* **210**, 13–20 (2014).
3. Barraud, C. *et al.* Boundary flow of viscoelastic polyelectrolyte solutions. *ArXiv180303440 Cond-Mat Physicsphysics* (2018).
4. Hénot, M., Chennevière, A., Drockenmuller, E., Léger, L. & Restagno, F. Comparison of the Slip of a PDMS Melt on Weakly Adsorbing Surfaces Measured by a New Photobleaching-Based Technique. *Macromolecules* (2017). doi:10.1021/acs.macromol.7b00601