Liquids @ Interfaces 2017

Laboratoire Interdisciplinaire de Physique (LiPhy)
Grenoble, France, October 23th-25th 2017
Organized by the CNRS research network (GDR) ‘Liquids at Interfaces’

140 Avenue de la Physique - BP 87
38402 Saint Martin d’Hères - FRANCE

Organization:
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Tuesday, October 24, 2017

Morning session

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Morning session

Chairpersons: Catherine Barentin and Lionel Bureau

9:00 am	-	9:45 am	**Invited talk:** "Friction at the interface between solid self-assembled monolayers and liquid polymers or solid metal nanotips"	Joshua McGraw
9:45 am	-	10:00 am	Experimental study of ice and snow friction	Luca Canale
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Abstracts

Talks

Monday, October 23, 2017

1:00 pm - 2:00 pm Arrival **- 140 Avenue de la Physique - 38402 Saint Martin d'Hères**

2:00 - 2:45 pm Invited talk "Vanishing droplets" François Boulogne

François Boulogne : Paris-Saclay University/Université de Paris-Sud Orsay

Drops can appear by condensation of water vapor on small dusts or on surfaces. The same drops can also disappear, often by evaporation in the ambient atmosphere. Although these phenomena are ubiquitous, the description of evaporation started about a century ago, and is still an active field of research with recent significant progresses that will be summarized. For example, under certain conditions, the convective flow of vapor has been revealed recently from observations on the evaporation kinetics compared to purely diffusive predictions. This situation requires some modeling and some progress can be achieved by using analogies with heat transfer. Evaporation also received a tremendous interest after Deegan's work on the so called "coffee stain effect", which is a transport of solute toward the contact line of the drop during its evaporation. Indeed, not only the evaporation can be used to remove a solvent and leave a deposit of particles as I will consider the absorption of the liquid in a substrate. Compared to evaporation, absorption leads to a different internal flow field carrying the particles, which forms a nearly uniform deposition pattern in constrast with the coffee stain effect. These results suggest that boundary conditions or environmental conditions can lead to interesting dynamics of vanishing droplets, crucial for a better understanding of climate change, coating processes, transpiration and cooling effects.

2:45 pm - 3:00 pm Life and death of a particle-ladden liquid sheet Pascal Raux

Pascal Raux, Anthony Troger, Pierre Jop, Alban Sauret : Surface du Verre et Interfaces, UPMC Paris6

Thin films of suspensions are involved in many industrial processes, such as surface coating or liquid transport in tubes. For dilute suspensions, it is well known that the particles increase the effective viscosity. However, this only holds in the continuum approximation, and should fail in a confined situation such as a liquid sheet. Here, we investigate the dynamics of a thin film of suspension, formed upon the impact of a suspension drop. We show that the atomization process varies when the thickness of the liquid film is smaller than the particle' size, leading to a loss of stability of the sheet. Our results highlight the influence of capillary effects in this confined flow.

3:00 pm - 3:15 pm Droplet breakup with in situ marangoni-induced elongational flow Margaux Kerdraon

Margaux Kerdraon : MMN, Gulliver, ESPCI Paris

Breaking unconfined droplets in an elongational flow has been investigated both theoretically [1] and experimentally [2]. However, it is extremely difficult to generate a saddle point within the droplet as, in these former studies, the elongational flow is generated in the external phase surrounding the droplet [3]. In this work, we experimentally investigate the breakup of a confined droplet in a microfluidic channel using in situ elongational flow generated by symmetric thermocapillary pumping. Mineral oil droplets with lengths ranging from 800-1600 µm are squeezed into a rectangular PDMS microfluidic channel (cross section: 200µm x 30 µm) with an aqueous solution containing SDS as the outer phase. A local chromium heating resistor of width 50 µm is located at the bottom of the channel and is electrically isolated from the solution by spin coating a 30 µm PDMS layer. The surface tension between the two working liquids increases with temperature such that switching on the heating resistors at the center of the droplet generates a Marangoni flow at the droplet interface from the tips towards the equator of the droplet, see Fig 1. The interfacial flow thus generates the pumping of the outer phase towards the equator, leading to the droplet's thinning, see Fig 2. Inside the latter, conservation of mass leads to an elongational flow propelling the two tips in opposite directions until the droplet finally breaks. A purely hydrodynamical model coupled with the conservation of mass is able to reproduce our experimental data in terms of droplet length and temperature gradient dependency. Interestingly, while the droplet is 3D in a non-axisymmetric geometry, our simple 2D model seems to capture the main features of droplet breakup.

3:15 pm - 3:30 pm Contact line rheology and reaction path approach for wetting dynamics over defects
Hugo Perrin

Hugo Perrin[1], Romain Lhermerout[1], Kristina Davitt[2], Etienne Rolley[2], Bruno Andreotti[3], Daniele Belardinelli[4], Mauro Sbragaglia[4]

1 : Departement of Chemistry, Physical & Theoretical Chemistry Laboratory, Oxford, United Kingdom

2 : Laboratoire de Physique Statistique de l'ENS, UPMC - Paris VI, Paris VII, ENS – Paris - France

3 : Physique et Mécanique des Milieux Hétérogènes (PMMH), Paris 7, UPMC, Paris 6 - France

4 : Department of Physics & INFN, University of Rome "Tor Vergata"

At the nanometer scale, the motion of a contact line separating a dry from a wet region is limited by the presence of surface heterogeneities that pin it. Such defects introduce morphological disturbances on the contact line and ultimately determine the force exerted on the wedge of liquid in contact with the surface. Here we revisit the seminal model proposed by Joanny and de Gennes, by including the influence of thermal noise and viscosity in a Langevin model with two degrees of freedom: the average position of the contact line and its distortion. We derive the response function of the contact line to identify the conditions under which the dynamics in a velocity driven experiment can actually be described by a constant forcing at small scale. We then relate the asymptotic properties of the relation between force and contact line velocity to the properties of the defects. In particular, we show that Kramers approximation misses the strong asymetry between advancing and receding directions. Finally, we show how to use the model as a way to fit experimental data and extract the salient features of the surface energy landscape.

3:30 pm - 4:00 pm Break

4:00 pm - 4:15 pm Molecular density functional theory of inhomogeneous fluids at interfaces
Maximilien Levesque

Maximilien Levesque : ENS Paris, France.

Liquids at interfaces, for instance close to a solid, are significantly organized at the molecular scale. Also, how the liquid behaves at the surface ultimately depend upon the atomic-scale interactions.

The large number of liquid molecules, for instance, water, that crowd the interface makes it hard for simulations to reach the space and time scales of real experiments. Several paths are offered to numerical experimentalists:

i. One can forget about the molecular nature of the solvent: no hydrogen bonding, no crowding effect, etc. These primitive methods focus on the macroscopic properties of the solvent like its dielectric permittivity. That's quite crude, but fast.

ii. Precisely, from all-atom simulations like molecular dynamics. Increase the numerical cost by 4 orders of magnitude with respect to solution (i) and you have the full molecular picture; If it fits in nowadays computers.

iii. In this presentation, I shall discuss a new paradigm, the molecular density functional theory. From rigorous statistical mechanics of inhomogeneous fluids, and for the same numerical cost as primitive models, MDFT aims at predicting the same equilibrium information as all-atom simulations.

The objective of this presentation is to confront and discuss whether MDFT can be useful to the community of this GDR.

For an illustration of the usage of the MDFT on solid-liquid interfaces, see [1]. For information about the most recent theoretical developments, see [2].

[1] Maximilien Levesque, Virginie Marry, Benjamin Rotenberg, Guillaume Jeanmairet, Rodolphe Vuilleumier and Daniel Borgis, Solvation of complex surfaces via molecular density functional theory, J. Chem. Phys. 137, 224107 (2012)

[2] Lu Ding, Maximilien Levesque, Daniel Borgis and Luc Belloni, Efficient molecular density functional theory using generalized spherical harmonics expansions, J. Chem. Phys. 147, 094107 (2017)

4:15 pm - 4:30 pm Understanding the effect of wetting on thermo-osmosis using molecular dynamics
Li Fu

Li FU, Samy Merabia, Laurent Joly : Institut Lumière Matière (ILM), Université Claude Bernard - Lyon I (UCBL), Villeurbanne - France

The fundamental influence of thermal gradients on the flux has received scanty attention until only the past decades. Thermophoretic phenomena were firstly studied for numerous applications such as optothermal DNA trap [1] or disease-related protein aggregates [2]. On the other hand, thermo-osmosis at solid-liquid interfaces is the least studied among the osmotic phenomena. It is usually interpreted as a thermal gradient-induced Marangoni flow, but the molecular level understanding is still lacking. Using molecular dynamics simulations, we measured the thermo-osmosis coefficient by both mechanocaloric and thermo-osmosis routes, against different solid-liquid interfacial energies. We show that a modified Derjaguin's formula [3, 4] which takes into account the interfacial hydrodynamic conditions describes well the simulation results. For a non-wetting surface, thermo-osmosis transport is controlled and largely amplified by the existence of a slippage at the interface. Whereas for a wetting surface, the position of the hydrodynamic shear plane plays a key role in the determination of thermo-osmosis coefficient. The thermo-osmosis coefficient decreases for increasing wettability and a change of sign is clearly observed. A hydrodynamic backflow induced by hydrodynamic entrance effects is found in the thermo-osmosis route measurements, and is found to decrease significantly the amplitude of the thermo-osmotic effect.

1. Duhr, S. & Braun, D. Thermophoretic depletion follows Boltzmann distribution. Phys. Rev. Lett. (2006).
2. Wolff, M. et al. Quantitative thermophoretic study of disease-related protein aggregates. Scientific Reports 6, 22829 (2016).
3. Derjaguin, B. V., Churaev, N. V. & Muller, V. M. in Surface Forces 231–291 (Springer US, 1987). doi:10.1007/978-1-4757-6639-4_7
4. Fu, L. Merabia, S & Joly, L. submitted

4:30 pm - 4:45 pm Individual Swimming of Interfacial Swimmer Dolachai Boniface

Dolachai Boniface : Université Claude Bernard-Lyon I – France

An interfacial swimmer is a self propelled object which evolve at the interface between air and water and it uses the Marangoni effect for its own propulsion. Even if this system has been known since a long time, their interest in the field of active matter is relatively new and the characteristic of the individual swimming stayed mostly poorly studied.

Among those interfacial swimmers, camphor swimmers are disks of agar gel impregnated with camphor , the Marangoni effect is due to the dissolution of camphor into the water. The system's instability explains its mobility despite the circular symmetry. For this system, we have evidenced that the velocity exhibits some interesting dependency according to time, height water, swimmer's size...

4:45 pm - 5:00 pm Wettability study on natural rubber surfaces modified by incorporation of CaP particles and by exposure to biological environment Rodney Nascimento

Rodney Nascimento, Stella Ramos, Ivan Bechtold, Antonio Hernandes : University of São Paulo

This work reports an experimental study on phenomena that occur at the interface between surfaces and liquids, in particular, the wettability, a property that affects the cell response to implants. Five surfaces of natural rubber (NR) membranes (pure, polymer-bioceramic composite (NR-CaP) and three modified surfaces subjected to a simulated body fluid (NR-SBF)) were characterized by confocal Raman-spectroscopy, AFM, SEM and XPS and the results were correlated with the wetting properties. Seven liquids (water, formamide, di-iodomethane, ethylene-glycol, hexadecane, simulated body fluid and human blood droplets) were used in different experimental sections. Static and dynamic contact angle measurements were conducted to obtain the solid-liquid tensions, work of adhesion and depinning forces. The incorporation of CaP particles in the polymer decreases the roughness and increases the interfacial adhesion, and there was no dependence between the morphology and equilibrium contact angle. After exposure to a biological environment, the NR surfaces were considerably modified in terms of the chemical heterogeneity, decreasing the contact angle to values close to those associated with protein adsorption and cell adhesion. The study of evaporation dynamics of drops on the surfaces investigated revealed that the contact line behavior and blood ring stains are dependent on the effects of the modification of surfaces by the biological environment. The concepts applied, regarding different wettability aspects, should enable the evaluation of biomaterial surfaces and provide new insights allowing a better understanding of body fluid-material interfaces.

5:00 pm - 5:15 pm Silica nanoparticles / polymer hydrogel nanocomposite Elsa Perrin

Elsa Perrin[1,2], Anne Boutin[2], François-Xavier Coudert[3], Martin Schoen[1]

1 : Technische Universität Berlin (TUB) Berlin - Germany

2 : Processus d'Activation Sélective par Transfert d'Energie Uni-électronique ou Radiatif (PASTEUR) – UPMC, Paris VI, ENS - France

3 : Institut de recherche de Chimie Paris (IRCP), ENSCP-Chimie ParisTech-PSL – Paris - France

The design of nanocomposite materials is a fast-growing field with many novel and exciting materials with a wide array of mechanical, thermal, and catalytic properties, such as composite formed by polymer hydrogels and silica nanoparticles. In particular, the coupling between chemistry of adsorption and mechanical properties has been poorly explored. Recently a way was found to glue together two polymer gels using a dispersion of silica nanoparticles (NPs). Indeed, it is difficult to glue together polymer gels because it requires chemical reactions, pH changes or heating. Hence it is proposed for the first time that spreading a droplet of a silica NP solution on the surface of one gel and then bringing a second gel into contact with it leads to strong adhesion between the two gels of poly(dimethylacrylamide) (PDAM). Intriguingly, polyacrylamide (PAM) does not adsorb onto silica whereas PDAM adsorbs.

Through coarse grained molecular dynamics, based on inputs from quantum calculations and all-atom simulations, we characterize qualitatively and quantitatively the structure, dynamics and mechanical properties of such nanocomposite material. We focus particularly on an investigation of the different behaviour of PAM and of PDAM with regards to their adsorption on the silica surface. We look into the dynamics and the interaction energy of the polymer chains surrounded by water close to the nanoparticle's surface, compared to those of the bulk of the hydrogel.

5:15 -- 5:30 pm Molecular rheology of gold nanojunctions Jean Comtet

Jean Comtet, Antoine Lainé, Antoine Niguès, Lyderic Bocquet, Alessandro Siria : Laboratoire de Physique Statistique de l'ENS (LPS) - ENS Paris, Paris VII, UPMC - Paris VI – France

Despite extensive documentation of plastic deformation processes in micro-sized samples, there is up to now no clear understanding of the mechanisms governing plastic flow in nanoscale systems. Here, using a quartz-tuning fork based Atomic Force Microscope, we combine electrical and rheological measurements on nanoscale gold junctions, down to lateral sizes of several atoms, and study the onset of plastic flow in those model atomic-sized systems. By submitting the junction to increasing sub-nanometric deformations, we uncover a transition from a purely elastic regime to a liquid-like regime with plastic flow in the junction. We analyse and rationalize our results in the framework of a harmonically driven Frenkel-Kontorova model. Our measurements allow us to measure the critical yield force governing the onset of plastic flow in the junction, as a function of size. In those molecular systems, plasticity seems to be limited by the sliding of atomic planes under shear, as expected for dislocation starved systems.

5:30 pm - 5:45 pm Nanomechanics of ionic liquids at dielectric and metallic interfaces Léo Garcia

Léo Garcia : Laboratoire de génie chimique (LGC) - Institut National Polytechnique de Toulouse - Aubervilliers - France

Using a dynamic Surface Force Apparatus, we investigate the nano-mechanics and the nano-rheology of an ionic liquid at dielectric and metallic solid surfaces. On smooth dielectric Pyrex surfaces, we find an ordered interfacial phase extending over less than 3 nm away from the top of the layer, with a compression modulus of 15 MPa extracted from the profile of the oscillatory forces. We discuss the boundary flow of the Newtonian bulk phase on this ordered interfacial layer. On metallic platinum surfaces, our hydrodynamic measurements evidence an interfacial soft solid layer extending up to 20 nm away from the top of the layer. The elastic modulus of this interfacial layer, derived from elasto-hydrodynamic measurements, is similar to the one found on Pyrex surfaces. Both on the dielectric and on the metal surfaces, the thickness of the interfacial phases is not found to change upon approach of the opposite surface, and does not exhibit a capillary-freezing transition.

Tuesday, October 24, 2017

9:00 am - 9:45 am Invitated talk "Dynamics of hard and soft particles at liquid interfaces" Cécile Monteux

Cécile Monteux : Sciences et Ingénierie de la Matière Molle (SIMM), CNRS, ESPCI ParisTech – Paris - France

Solid particles can be used to stabilize foams or emulsions. Theoretically the spontaneous curvature of these materials is set by the equilibrium contact angle of the particles with the interface, which depends on the chemical nature of the particles. In practice, the particles may reach their equilibrium position very slowly and their adsorption dynamics can be quite complex. I will present several examples showing that the softness or agregation state of the particles can strongly influence their adsorption dynamics.

9:45 am - 10:00 am Cleaning Surfaces from Nanoparticles with Non Newtonian Fluid Adeline Lallart

Adeline Lallart[1,2], Philippe Garnier[2], Elise Lorenceau[1], Elisabeth Charlaix[1]

1 : Laboratoire Interdisciplinaire de Physique (LIPhy), Université Joseph Fourier - Grenoble 1, Saint Martin d'Hères - France

2 : STMicroelectronics - Crolles - France

In order to keep a high yield during integrated circuits production, a continuous improvement has been carried out in the particles cleaning area, switching from brushes and acoustic cleans to high velocity sprays. Moreover, Moore's law also applied to microelectronics devices, which typical dimension are getting smaller and smaller. Thus, with the shrinking of the device nodes, tinier and tinier particles have to be removed. Even though their adhesion and removal are well understood and documented for years, our industry still misses robust solutions to clean nanoparticles, keeping finest microelectronics features integrity, and extremely low material consumption.

It has been recently shown that new processes involving non-Newtonian fluid enable an excellent particles removal without material destruction. In this process, a thin layer of a well-chosen polymeric resist is deposited on the nanoparticles contaminated wafer. Then, the resist is removed either by peeling or chemical dissolution. To understand this remarkable ability, two mechanisms are postulated. In the peeling process, the removal capacity is based on a better adhesion between the particles and the resist rather than between the particles and the surface [1]. In the process involving chemical dissolution, the resist is return to a liquid state and is removed by a siphoning action and the particles are withdrawn from the surface thanks to the viscoelastic properties of the fluid [2].

In this talk, we will present results concerning a new process of resist dissolution using spray dispense rather than siphoning. Silicon wafers of 300 mm diameter are intentionally contaminated by 60nm silica particles or by polydisperse silicon nitride particles. Then, they are coated by a layer of well-chosen polymer resist with a thickness of 1,8 µm. This layer is eventually spray stripped with a chemical solution and the efficiency of the process is quantified by counting nanoparticles before and after the complete resist removal step thanks to a KLA Surfscan SP3 blue laser diffraction tool.

We show that with this process, both silica and silicon nitride particles of various sizes can be removed from the silicon wafer with a particle removal efficiency as high as 80%, thus showing that the process neither depend on the size nor on the chemical composition of the particles. Moreover, this remarkable efficiency is not due to the chemical solution used to dissolve the resist as the particle removal efficiency observed when performing only the chemical dissolution step is very low. Yet, we also observe that the surfaces are not homogenously decontaminated: quite surprisingly, the part exposed to the highest spray velocity are less decontaminated than the rest of the surface. We discuss this surprising result regarding the rheological properties of the polymer resist.

[1] P. Lin, S. Pi, H. Jiang, and Q. Xia, “Mold cleaning with polydimethylsiloxane (PDMS) for nanoimprint lithography,” Nanotechnology, vol. 24, no. 32, 2013.

[2] T. Walker and T. Hsu, “Enhanced particle removal using viscoelastic fluids,” J. Rheol. (N. Y. N. Y), vol. 58, no. 1, pp. 63–88, 2014.

10:00 am - 10:30 am Break

10:30 am - 10:45 am Cohesion and agglomeration of wet powder Anne-Laure Biance

Anne-Laure Biance, Pascal Raux : Institut Lumière Matière (ILM), Université Claude Bernard - Lyon I, Villeurbanne - France

Wet high shear granulation consists in mixing vigorously granules and a liquid binder to create agglomerates of various sizes. The process results from a balance between cohesion of the wet granular agglomerates and fragmentation due to the high mixing. By performing a simple test with glass beads and water, we focus on the cohesion of a wet granular media. On the contrary to previous works, we extend the study to larger value of liquid fraction w and we observe that, after the well documented plateau, the cohesive strength increases again with w, a behavior we capture by a simple model. We then design a novel agglomeration process that consists in vibrating at large amplitude a bead/liquid mixture. The vibrations induce not only to the fluidization of the wet granular material but also the formation of aggregates. As expected, their size increases with the liquid content, the frequency and the amplitude of the vibrations. However, the number of beads in an agglomerate does not depend on the bead size showing a self-similar mechanism of agglomeration. The role of cohesion strength in this process remains therefore ambiguous.

10:45 am - 11:00 am Freezing of dense colloids is packing Félix Ginot

Félix Ginot : Laboratory of Synthesis and Functionnalisation of Ceramics (LSFC) - SAINT-GOBAIN – France

The interactions between particles and a freezing front is key in many processes, from metal molding to cells cryopreservation.

Using a confocal microscope with two peltier modules, we investigate the freezing of dense colloids packing under a controlled temperature gradient.

We observe that smaller pores freeze later than bigger ones, according to Gibbs-Thomson equation.

If the freezing is slow enough, the particles can then reorganize around the ice seeds, and lead to ice lences.

Overall we show that small local variations in the pore size can lead to large heterogeneities in the freezing process.

11:00 am - 11:15 am Premelted films in solidification studies Sylvain Deville

Sylvain Deville[1], Dmytro Dedovets[1], Cécile Monteux[2]

1 : Laboratoire de Synthèse et Fonctionnalisation des Céramiques (LSFC) – Saint-Gobain, Cavaillon - France

2 : Sciences et Ingénierie de la Matière Molle (SIMM), CNRS, ESPCI ParisTech – Paris - France

Premelting describes the existence of liquid film at solid surfaces at temperatures below the bulk freezing temperature, a phenomenon common to all solids. Premelting has consequences in wide range of biological, geophysical, and technological processes, from the heaving of frozen ground to the mobility of particles in solid materials. Premelting provides a reduction of interfacial energy. When objects such as particles, droplets, or bubbles, are engulfed in a solidification microstructure, premelting occurs around the objects, because of the thermomolecular forces between the object and the matrix. Here we investigate by confocal microscopy the formation and dynamics of premelted films around oil droplets, during their interaction with a moving water/ice interface. Because of their small dimensions (nm), premelted films have been extremely difficult to investigate. Here, the premelted films are much larger, thanks to the solute effect, and we are able to follow the evolution of the 3D morphology, along with the concentration of solute. This opens exciting perspectives in the study of premelting and the investigations of the behaviour of wet boundaries in metals solidification and many other solidification systems.

11:15 am - 11:30 am Behaviour of a 2D cluster under compression Pierre Soulard

Pierre Soulard : Laboratoire Gulliver (ESPCI), PSL Research University – Paris - France

A crystal and a glass are different at a molecular level which leads to strong consequences at the macroscopic scale. Our Canadian close collaborators (K. Dalnoki-Veress group, McMaster University) have very recently developed an ideal experimental system to model such structures. The 2D clusters are made of an emulsion of lightly attractive, stabilized oil droplets (R around 10 micrometers) in water which are assembled droplet by droplet (tens of droplets). We study the response of the cluster when it is compressed between two thin glass rods (Rc around 10 micrometers). One glass rod is used as a force transducer in order to measure the forces as the droplets spatially rearrange under compression. Coupling the optical microscopy images of structural rearrangements within the 2D cluster with the direct force measurements provides insight into the failure mechanisms. Perfectly ordered crystals (highly monodisperse droplets) show well defined transitions. As the number of defects (substitution of a droplet by a smaller one) is increased in the crystal, we can study the transition toward a glassy system (bidisperse cluster). Additionally, the impact of the size of the cluster, the geometry of the initial aggregate, the relative size of a defect or even its position will be studied in the near future. The goal of the candidate will be to develop a theoretical model to understand this fascinating system.

11:30 am - 1:30 pm Lunch + Poster Session

1:30 pm - 2:15 pm Invited talk " An experimental approach to blood flows: lift, diffusion and clustering" Gwennou Coupier

Gwennou Coupier : Laboratoire Interdisciplinaire de Physique (LIPhy), Université Grenoble Alpes - Saint Martin d'Hères - France

Blood is a complex fluid, a property that stems from the presence of deformable cells, mainly red blood cells, and plasma proteins.The peculiar properties of blood comes from the complex mechanical response of the cells to external flow but also to their ability to migrate transversally to flow direction, which leads to an inhomogeneous structure of the suspension, at the local scale but also within the whole capillary network.

I will present a set of experiments that combine basic microfluidic approach with more specific techniques such as digital holography or microgravity environment. I will first describe how cells are lifted up far the channel walls. This results in concentrating the cells in the center of the channels, a phenomenon that is counterbalanced by hydrodynamic interactions between them. The cumulative effect of these interactions is a non-linear and anisotropic shear-induced diffusion. These hydrodynamic effects directly influence blood structure and rheology but also how it splits at bifurcations. I will finally discuss the contribution of the short-range adhesion forces between cells due to the presence of proteins in the plasma..

2:15 pm - 2:30 pm Soft biolubrication: lift at a vascular wall mimic Dephine Débarre

Delphine Débarre[1], Heather Davies[1], Claude Verdier[1], Ralf Richter[2], Lionel Bureau[1]

1 : Laboratoire Interdisciplinaire de Physique (LIPhy), Université Grenoble Alpes, St Martin d'Hères France - France

2 : School of Biomedical Sciences and School of Physics and Astronomy, University of Leeds

Interactions between circulating cells and blood vessel walls are central to many physiological processes such as the early stages of the immune or inflammatory response, gas exchanges with tissues, or vascular remodeling. Among these interactions, hydrodynamic forces play a key role, as they control the radial migration of the circulating cells towards or away from the vascular walls. A well-known example of hydrodynamics at play is the so-called cell-free layer, a near-wall region that is depleted in red blood cells, which is classically interpreted as resulting from the non-inertial repulsive force arising between the vessel surface and the deformable red cells flowing nearby [1]. A point that has been largely overlooked so far is the contribution of the wall deformability to such a repulsive hydrodynamic force, and in particular the role of the endothelial surface layer, a compliant meshwork of glycosaminoglycans lining the lumen of blood vessels.

In this context, we have developed an experimental setup allowing for the study of microparticles flowing past a surface bearing a macromolecular layer of hyaluronic acid mimicking the nature, thickness (a few hundreds of nm) and elastic properties (~100 Pa) of the endothelial surface layer. Combining parallel plate flow assays and 3D particle tracking based on interference microscopy, we show that:

i. non-deformable spherical microbeads traveling, in a controlled shear flow, close to the macromolecular layer, are repelled and lift away from the surface under strong enough (yet physiological) shear rates,

ii. the bead/surface distance increases with increasing shear rate and can reach up to several hundreds of nm,

iii. our experimental results can be quantitatively described in the theoretical framework of elastohydrodynamics accounting for the effect of substrate deformations [2].

This represents, to the best of our knowledge, the first experimental demonstration that a thin and compliant surface layer can contribute to the repulsive hydrodynamic interactions with flowing, cell-sized objects.

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2:30 pm - 2:45 pm Direct measurements of surface stress of stretched soft solids Qin Xu

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Surface stress, also known as surface tension, is a fundamental material property of any interface. However, measurements of solid surface stress in traditional engineering materials, such as metals and oxides, have proven to be very challenging. Consequently, our understanding relies heavily on untested theories, especially regarding the strain dependence of this property. Here, we take advantage of the high compliance and large elastic deformability of a soft polymer gel to directly measure solid surface stress as a function of strain by studying the wetting between liquid and gel. As anticipated by theoretical work for metals, we find that the surface stress depends on the strain via a surface modulus. Remarkably, the surface modulus of our soft gels is many times larger than the zero-strain surface tension. This suggests that surfaces stresses can play a dominant role in solid mechanics at much larger length scales than previously anticipated.

2:45 pm - 3:00 pm Elastocapillary levelling of thin viscous films on soft substrates Vincent Bertin

Vincent Bertin[1], Marco Rivetti[2], Thomas Salez[3,4], Chung-Yuen Hui[5], Christine Linne[2], Maxence Arutkin[1], Haibin Wu[5], Elie Raphaël[1], Oliver Bäumchen[2]

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A thin liquid film with nonzero curvature at its free surface spontaneously flows to reach a flat configuration, a process driven by Laplace pressure gradients and resisted by the liquid's viscosity. Inspired by recent progresses on the dynamics of liquid droplets on soft substrates, we here study the relaxation of a viscous film supported by an elastic foundation. Experiments involve thin polymer films on elastomeric substrates, where the dynamics of the liquid-air interface is monitored using atomic force microscopy. A theoretical model that describes the coupled evolution of the solid-liquid and the liquid-air interfaces is also provided. In this soft-levelling configuration, Laplace pressure gradients not only drive the flow, but they also induce elastic deformations on the substrate that affect the flow and the shape of the liquid-air interface itself. This process represents an original example of elastocapillarity that is not mediated by the presence of a contact line. We discuss the impact of the elastic contribution on the levelling dynamics and show the departure from the classical self-similarities and power laws observed for capillary levelling on rigid substrates.

3:00 pm - 4:30 pm Break + Poster Session

4:30 pm - 4:45 pm Ecoulements secondaires induits par des vagues de surfaces Jean Rajchenbach

Jean Rajchenbach[1], Didier Clamond[2], Enrica Saggese[1]

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We report the existence of steady recirculating eddies existing in the bulk of a liquid under the action of standing surface waves. This phenomenon results from the combined action of the nonlinearity and viscosity. The period of these secondary flows can be, say, one hundred times that of the wave, depending on the amplitude. Our experimental results reveal strong disagrements with theoretical predictions devised hitherto. In order to account for our data, we propose a new mechanism playing a major role in the formation of these rolls.

4:45 pm - 5:00 pm Viscoelastic Drag Forces and Crossover from No-Slip to Slip Boundary Conditions for Flow near Air-Water Interfaces Zaicheng Zhang

Maali Abdelhamid, Rodolphe Boisgard, Hamza Chraibi , Zaicheng Zhang, Hamid Kellay , Aloïs Würger

Laboratoire Ondes et Matière d'Aquitaine (LOMA), Université de Bordeaux, Talence - France

The “free” water surface is generally prone to contamination with surface impurities, be they surfactants, particles, or other surface active agents. The presence of such impurities can modify flow near such interfaces in a drastic manner. Here we show that vibrating a small sphere mounted on an atomic force microscope cantilever near a gas bubble immersed in water is an excellent probe of surface contamination. Both viscous and elastic forces are exerted by an air-water interface on the vibrating sphere even whenvery low doses of contaminants are present. The viscous drag forces show a crossover from no-slip to slip boundary conditions while the elastic forces show a nontrivial variation as the vibration frequency changes. We provide a simple model to rationalize these results and propose a simple way of evaluating the concentration of such surface impurities.

5:00 pm - 5:15 pm Conical deformation of a soft liquid interface induced by laser Antoine Girot

Antoine Girot : Laboratoire Ondes et Matière d'Aquitaine (LOMA), Université de Bordeaux, Talence - France

A century ago, Zeleny demonstrated that fluid interfaces may become unstable under sufficiently intense electric fields. When the electric pressure exceeds the Laplace pressure, the interface takes a conical shape and emits a fine jet that usually breaks up into a spray. Such conical menisci are now often termed as Taylor cones.

Here we extend this electro-hydrodynamic manifestation to the optical regime considering instead the optical radiation pressure of a continuous laser wave. It is already known that light can deform and even destabilize a soft liquid interface and gives birth to a jet. Here we demonstrate for different fluid systems that a conical shape

can also emerge from this instability. As for electrified interfaces, this conical shape is very stable and robust. We experimentally analyze the semi-angle of this liquid cone as a function of the incident beam power, the beam waist and the index contrast between the two liquid phases. A numerical investigation as well as an analytical model have been developed and they are able to account for the observed variations. For large index contrast and beam waist, we also show a hierarchical multiple jet formation for increasing beam power, as in strong field electro-hydrodynamics. This new optical manifestation suggests an analogy between electro- and opto-hydrodynamics.

5:15 pm - 5:30 pm Ultrasound transmission through model liquid foams generated by microfluidics Lorène Champougny

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3 : Matière et Systèmes Complexes (MSC), Université Paris Diderot - Paris 7, Paris – France

While the acoustic properties of solid foams, which are frequently used for soundproofing purposes, have been abundantly characterized [1], sound propagation in liquid foams remains poorly understood. J. Pierre and collaborators have recently investigated the transmission of ultrasound through polydisperse liquid foam samples [2, 3]. Their study showed that the mechanical coupling between the liquid network in the foam and the thin liquid films separating the bubbles could result in a large attenuation, associated to a resonant behavior [4].

The acoustic propagation in a foam strongly depends on its structural parameters (number, surface and thickness of the films, liquid fraction, among others), all of which were not well characterized in previous experiments. Further progress thus requires to investigate the acoustic response of well-controlled foam structures. We introduce a new experimental setup designed to study the transmission of ultrasound (frequencies in the range 70 – 1000 kHz) through model monodisperse liquid foam samples generated by microfluidics. We will present measurements of the acoustic transmission trough monodisperse bubble monolayers of various liquid fractions and bubble sizes. The analysis of these measurements will allow us to retrieve the sound velocity and attenuation in bubble monolayers as functions of their structural parameters.

Additionally, preliminary results on bubble bilayers already show a qualitative difference between the transmission through bubble monolayers and bilayers. This is likely a signature of the free liquid films separating the top and bottom bubbles in the bilayer. This discrete approach, allowing to isolate the signature of a single layer of free films in the acoustic response, will contribute to a better understanding of the dissipation in liquid foams. On the long term, this work could contribute to the design of optimized acoustic metamaterials created by solidification of liquid foams.

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5:30 pm - 5:45 pm Electroosmosis near soapy interfaces Oriane Bonhomme

Oriane Bonhomme, Baptiste Blanc, Christophe Ybert, Anne-Laure Biance : Institut Lumière Matière (ILM), Université Claude Bernard - Lyon I (UCBL), Villeurbanne - France

Even if liquid foams are commonly used in a large range of applications, their extensive use are still limited by drainage that implies eventually their destruction. We have shown in previous studies that the electroosmotic flow – namely the flow induced by an externally applied electric field – in a soap film can stabilize it through a film thickening effect [1]. In this work, we therefore experimentally investigate how an electrically driven flow can be generated closed to an air/liquid interface.

Application of an electric field to a neutral system (such as a surfactant solution) would not induce a liquid flow unless charge separation occurs. Indeed, in the case of ionic surfactants, a part of them are known to adsorb on the interfaces, and then the generation and the magnitude of an electroosmotic flow is possible and will depend on the molecular details of the surface. Although many studies have focussed on surfactant adsorption at equilibrium [2], many questions on the effect of the flow on the surfactant repartition (and vice et versa) still remains. How does the flow affect adsorption? Is there a Marangoni stress at the interface? What is the exact hydrodynamic boundary condition?

To adress these questions, we built a new experimental method to measure the zeta potential near a surfactant-laden interface. The experiment consists in measuring the fluid displacement under an electric field forcing via particle tracking in the liquid at selected distances of the surfactant-laden interfaces. We simultaneously investigate the surfactant distribution at interface during these flows by a nonlinear optical technique, namely second harmonic generation [3].

This first coupled measurement allowed us to prove that the surfactant layer remains homogeneously distributed, then immobile and that the interface remains stress-free. This result is for the first time an experimental proof that no force acts on the charged layer in EO phenomena [4].

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5:45 pm - 6:00 pm Level-set simulations of a 2D topological rearrangement in a bubble assembly: effects of surfactant properties Marie Le Merrer

Marie Le Merrer[1], Andrea Titta[1], François Detcheverry[1], Peter Spelt[2], Anne-Laure Biance[1]

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A liquid foam is a dispersion of gas bubbles in a liquid matrix containing surface active agents. Their flow involves the relative motion of bubbles, which switches neighbours during a so-called topological rearrangement of type 1 (T1). The dynamics of T1 events, as well as foam rheology, have been extensively studied, and experimental results point to the key role played by surfactants in these processes. However, the complex and multiscale nature of the system has so far impeded a complete understanding of the mechanisms at stake. In this work, we investigate numerically the effect of surfactants on the rheological response of a 2D sheared bubble cluster. To do so, a level-set method previously employed for simulating two-phase flow has been extended to include the effects of the surfactants. The dynamical processes of the surfactants —diffusion in the liquid and along the interface, adsorption/desorption at the interface— and their coupling with the flow — surfactant advection and Laplace and Marangoni stresses at the interface— are all taken into account explicitly. Through a systematic study in Biot, capillary and Péclet numbers which characterize the surfactant properties in the simulation, we find that the presence of surfactants can affect the liquid/gas hydrodynamic boundary condition (from a rigid- like situation to a mobile one), which modifies the nature of the flow in the volume from a purely extensional situation to a shear. Furthermore, the work of surface forces, resulting from surfactant and interface dynamics, can be interpreted as an effective dissipation, which reaches a maximum for Péclet number of order unity. Our results, obtained at high liquid fraction, should provide a reference point, to which experiments and models of T1 dynamics and foam rheology can be compared.

Wednesday, October 25, 2017

9:00 am - 9:45 am Invited talk "Friction at the interface between solid self-assembled monolayers and liquid polymers or solid metal nanotips" Joshua McGraw

Joshua McGraw : Département de Physique, Ecole Normale Supérieure (ENS), Paris - France

The friction between a solid and a liquid was historically assumed to be so large that fluid molecules in contact with a solid boundary were stuck. Thus, the classical no-slip boundary condition was applied. With the advent of micro- and nano-fluidics in the last decades, however, this boundary condition has been observed to fail in many instances. Particularly, as will be discussed here, a slip boundary condition is observed when unentangled polystyrene (PS) dewets from a hydrophobic, alkylsilane self-assembled monolayer (SAM). This boundary condition can furthermore be tuned over an order of magnitude by subtly changing the SAM [1], indicating that the friction between solid and liquid is highly sensitive to atomic level details. We have also investigated the friction between these same SAMs and a solid metal tip of nanoscopic dimensions. Remarkably, this apparent solid/solid friction is velocity dependent and exhibits a crossover from a linear to logarithmic scaling in the velocity [2]. The results can be described in terms of a distribution of nanocontacts with very weak stiffness compared to the expected one for metal/solid contacts. The work presented here has been done in collaboration with the authors of refs. [1, 2].

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9:45 am - 10:00 am Experimental study of ice and snow friction Luca Canale

Luca Canale[1], Axel Laborieux[1], Jean Comtet[1], Antoine Niguès[1], Caroline Cohen[2], Christophe Clanet[1], Alessandro Siria1, Lydéric Bocquet[1]

1 : Laboratoire de Physique Statistique de l'ENS (LPS) – Paris - France

2 : Laboratoire d'hydrodynamique (LadHyx), Ecole Polytechnique, Palaiseau - France

Ice and snow friction have been an important subject of study in the last century: if ice friction has been considerably investigated , very little is available about snow. Indeed, because of it's nature, experiments on snow are more difficult to achieve. Even for ice nevertheless, many questions remain unsolved: in particular, the link between the measured macroscopic friction coefficient and the behaviour of the interface is still unclear. A lubricating liquid layer has been predicted but neither its origin (frictional melting) nor its dynamics have ever been proved or observed properly. Furthermore, the strategies adopted to reduce friction are very different for snow (waxing, polyethylene,) and ice (no wax, steel) even though regulating this water film thickness is always claimed as the ultimate goal.

To investigate these aspects we have two setups: a classical tribometer made of a rotating disk is filled with a 5cm thickness of snow or ice. We measure the friction force exerted on a slider mounted on top of the disk via a torque sensor. The tribometer is placed in a cold room whose temperature can be varied between -30°C and 0°C. Snow is fabricated and kept in the chamber. By varying the materials of our sliders, we study the influence of the thermal conductivity and hardness over friction for different speeds.

To study the dynamics at the interface, we have developed an in-house macroscopic aluminum tuning fork AFM based : when the tuning fork shears the ice, the shift in its resonance frequency and the broadening of the quality factor give quantitative informations about conservative and dissipative forces at stake. We use a 3mm radius PMMA bead glued on the prong of the tuning fork to shear the ice surface. Because of the tuning fork high resonant frequency (~ 800 Hz) and high stiffness (~10^5 N/m), we can measure elastic and dissipative forces over three speed decades. Furthermore, we can see the interface evolution with a microscope camera: we observe the formation of capillary bridges depending on the speed regime. We perform the experiment in a cold chamber in order to look also at the influence of temperature. Interestingly, snow and ice present different velocity responses, maybe due to their different structure.

10:00 am - 10:30 am Break

10:30 am - 10:45 am Electro-Responsive Polyelectrolyte-Coated Surfaces Vincent Sénéchal

Carlos Drummond, Vincent Sénéchal, Hassan Saadoui : Centre de Recherche Paul Pascal (CRPP), Université de Bordeaux, Pessac – France

Most of the studies in friction control have been devoted to improve lubricant design based on novel chemistry or better formulations, combining engineering, know-how and trial-and-error methods. Customarily, walls are considered as confining inert boundaries, with invariable interactions among themselves and with the lubricants. However, considering the surfaces as active components of the system may open avenues for novel functions; appealing applications can be foreseen if the control of the composition and morphology of the surfaces can be tuned in a reasonable time scale. Polyelectrolytes are convenient elementary bricks to build responsive surfaces, given that the polyion chain conformation is very sensitive to different environmental variables. Thus, the state of a typical polyelectrolyte can be controlled by external stimuli or environmental changes, allowing for reversible modifications of the intimate structure of the surface. In this way, active control of the surface properties is possible by adjusting the local molecular conformation of a responsive polyelectrolyte layer. Conformation of polyions can be manipulated by variations in pH or ionic strength. However, chemical variables are in general difficult to control. In addition, the characteristic time of response of molecules to changes of these parameters can be long. In this work we discuss how surface properties can be controlled following a completely different strategy, based on physical methods. We verified that conformation of adsorbed polyelectrolytes can be manipulated using and external electric field, as a consequence of their ionic charge. By dynamically tuning the conformation of the lubricant, fast variation of friction, adhesion and wettability can be achieved. The strong points and limitations of this method of surface properties control will be discussed.

10:05 am - 10:35 am Coffee break (Concordia)

10:45 am - 11:00 am A quantitative comparison of the solid-polymer melt or solid-elastomer friction: a proof of the Navier interfacial equation Marceau Henot

Marceau Henot, Liliane Leger, Frédéric Restagno : Laboratoire de Physique des Solides (LPS), Université Paris-Sud - Paris 11, Orsay - France

If the Navier-Stokes equation is often considered as one of the most difficult mathematical equations for a physicist or a mathematician, the question of the boundary conditions to describe the flow of a liquid in a pipe is often considered as trivial. It is usually assumed that the tangential velocity of a fluid close to a surface at rest is equal to zero. Nevertheless, already in his treatise on the movement of fluids, Navier introduced a more general equation, assuming a linear boundary condition: the shear stress at the solid-liquid interface is proportional to the component of the fluid velocity tangent to the surface V:

$$\sigma = k\,V \quad (1)$$

where k is a solid-liquid friction coefficient independent of the shear rate. Indeed, the shear stress at the interface being related for a Newtonian fluid to the shear rate, the friction coefficient is usually converted to a slip length b, where b is the so-called Navier slip length. If for simple liquids, the slip length is small, it can becomes millimetric in the case of polymer melts. In 1979, de Gennes proposed a simple and elegant explanation of the huge slip length observed in the case of polymer melts [1]. The physical idea is that for non-adsorbing surfaces, k should be independent of the entanglements, which control the polymer melts viscosity and thus one should observe a slip length proportional to the polymer viscosity for a set of homopolymer of different degrees of polymerization:

$$b(N) = \eta(N)/k \quad (2)$$

Using a velocimetry technique based on fluorescent photobleaching [2,5], we systematically measured the slip length of different PDMS polymeric liquids on a non-adsorbing surface made of non-entangled short chains of PDMS grafted to the surface. As predicted by eq. (1), we observed a constant slip length, independent of the shear rate. Moreover, we observed a linear variation of the slip length with the fluid viscosity, as predicted by eq. (2) allowing a precise determination of the solid-liquid coefficient. We showed that the friction coefficient is equal to the one we previously measured by studying the solid friction of an elastomer of PDMS on the same surface [3,4]. This allowed to directly connect for the first time solid-solid friction to solid-fluid friction in a direct measurement [6]. Finally, a molecular prediction of the solid-fluid or the solid-liquid friction coefficient is possible by using the monomer-monomer friction that can be extracted from a rheology experiment.

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11:00 am - 11:15 am Wall slip of polymer microgels in microfluidic channels Justin Péméjà

Justin Péméja, Baudoin Geraud, Marie Le Merrer, Catherine Barentin : Institut Lumière Matière (ILM), Université Claude Bernard - Lyon I (UCBL), Villeurbanne - France

Jammed polymer microgels like polyacrylate-based Carbopol are complex yield stress fluids widely used in applications like cosmetics or oil extraction: solid-like at rest, they become liquids under a sufficient stress. Besides, their flow properties are very dependent upon wall properties, as they can exhibit significant slip, which can drastically affect flow rates under confinement like in porous rocks or in microfluidic channels.

We will present wall slip measurements performed on Carbopol in glass microfluidic devices. These are combined with a microscopic characterisation through fluorescent imaging of the polymer structure. In particular, we vary the yield stress, the solvent viscosity and the microstructure size.

We show that the wall stress-velocity relation behaves either as a Stokes-like friction, or as a non-linear friction predicted by the elasto-hydrodynamic model of Meeker et al. (PRL 2004). The transition between both regimes is tuned not only by the confinement of the microgel suspension (as in Divoux et al. PRE 2015) but also by the wall stress, which was not reported before.

11:15 am - 11:30 am Wall slip of soft-jammed systems: a simple lubrication process Elise Lorenceau

Elise Lorenceau[2], Xiao Zhang[1], Philippe Basset[3], Tarik Bourouina[3], Florence Rouyer[1], Julie Goyon[1], Philippe Coussot[1]

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Various materials, such as foams, emulsions, concentrated suspensions and colloids, are soft-jammed systems: they can flow only when submitted to a stress larger than a yield stress and otherwise they behave as solids. In many situations it is observed that such materials glide along smooth solid surfaces, in the sense that the bulk material apparently moves as a rigid block for a stress lower than the yield stress. This effect is called wall slip. Its impact on flow characteristics is dramatic since it may make such materials, otherwise at rest, flow at a high velocity under small stresses. Thus wall slip can overturn the standardcontinuum mechanics description assuming adherence.

By removing artefacts due to edge effects during long creep tests with soft-jammed system we can determine the stress solely associated with steady state wall slip below the material yield stress. This stress is found to vary linearly with the slip velocity for a wide range of materials whatever the structure, the interaction types between the elements and with the wall, and the concentration. Thus wall slip results from the laminar flow of some given free liquid volume remaining between the (rough) jammed structure formed by the elements, and the smooth wall. This phenomenon may be described by the simple shear flow in a Newtonian liquid layer of uniform thickness. Quite surprisingly, this equivalent thickness varies in a narrow range (between 20 and 50 nm) for various systems.

Posters

Interdigitation between polymer chains in solution and polymer brushes: impact of shearing

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2 : Laboratoire Léon Brillouin (LLB), CEA Saclay, GIF SUR YVETTE - France

Polymer brushes have been actively studied for their importance in many fields such as assisted oil recovery, biology or lubrication. Depending of the chemical properties of the polymers tethered to the surface, such modified surfaces may exhibit an adhesive behaviour thanks to the entanglement of the polymer chains, or an anti-adhesive behaviour, as for antifouling treatment.

The static properties of polymer brushes are well understood both theoretically and experimentally thanks to neutrons reflectivity measurement between other techniques. However, the evolution of the conformation of polymer brushes under a flow is still an open question.

Shearing polymer melts on polymer brushes is known to change the conformation of polymer brushes. An indirect evidence of this change of conformation is the existence of different regimes of slippage depending on the shear rate [1]. More precisely, a transition from a marginal to a large slip regime have been reported. For low shear rates, the polymer chains of the melt stretch the grafted chains, but the grafted chains relax rapidly enough so that the number of entanglement between grafted chains and melt remains constant. Therefore, the force friction between melt and brush is high and there is a small slippage close to the brush. For higher shear rates, the polymer chains of the melt can disentangle from the grafted chains, the force friction decreases and the slippage increases. A more direct proof of this change of conformation of the grafted chains have been exhibited by neutron reflectivity measurements, a technique that permits to know directly what is the conformation of the brushes [2].

Even though the impact of shearing of melts on polymer brushes have been observed, shearing of polymer solutions on polymer brushes has not been studied in much detail. With solutions, the concentration of the solutions is an important parameter since it can change, even at rest, the interdigitation between the chains anchored to the surface and the solution.

In this poster, we will present a setup built to shear polymer solutions into a beam of neutrons in order to use the neutron reflectivity technique to have access to the conformation of polymer brushes. We will present preliminary results obtained for different shear rates of polystyrene solution over polystyrene brushes.

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Polymer bridging on p-NIPAM polymer brushes

Erik Abegg, Elisabeth Charlaix, Joel Chevrier : Laboratoire Interdisciplinaire de Physique (LIPhy), Université Joseph Fourier - Grenoble 1, Saint Martin d'Hères - France

Polymer brushes of Poly(N-isopropyl acrylamide) (p-NIPAM) are a well-studied system, finding application as a functional polymer due to its thermally activated transition from an expanded to a collapsed state at 32oC. Performing conventional “static” AFM force spectroscopy in water on a p-NIPAM brush using sharp probes reveals distinctive behavior characterized by two phenomena: rupture events and adhesion on the length scale of the polymer chain. This indicates the formation of a tether consisting of multiple polymer chains between the probe and the substrate: a “polymer bridge”. Through further investigation of its force response, we intent to explain the mechanical behavior of this polymer bridge.

Nanoconfined ionic liquids: disentangling electrostatic & viscous forces

Romain Lhermerout, Susan Perkin : Departement of Chemistry, Physical & Theoretical Chemistry Laboratory, Oxford - United Kingdom

Ionic liquids (ILs) are of interest due to their promising physico-chemical properties for a range of applications. A series of reports over the past few years have revealed the existence of an anomalously long-ranged surface force across pure ionic liquids and concentrated electrolytes, although the origin of this force is not yet fully resolved [1]. Ionic liquids are viscous liquids and therefore it was important to inspect rigorously whether the observed repulsive forces are indeed equilibrium forces or, rather, arise from the viscous force during drainage of the fluid between two confining surfaces. In this poster we present our SFB measurements performed with [C2C1Im][NTf2] confined between mica surfaces, exploring 3 orders of magnitude in approach velocity. Trajectories are systematically fitted by solving the equation of motion, allowing us to disentangle the viscous and equilibrium contributions. First, we find that the drainage obeys classical hydrodynamics with a negative slip boundary condition in the range of the structural force, meaning that a nm-thick portion of the liquid in the vicinity of the solid surface is composed of ordered molecules that don't contribute to the flow [2]. Secondly, we show that a long-range, static force must be invoked, in addition to any viscous force, in order to describe the data quantitatively. The range of this equilibrium interaction is in agreement with the screening length reported for the same system in previous studies. In those studies the decay was simply checked to be independent of velocity and measured at low approach rate, rather than explicitly taking account of viscous effects: we explain this by noting that the viscous force is linear to very good approximation over a wide range of distances and therefore neglecting it did not alter the measured screening length.

References

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Lubricated friction: insight into weakening mechanisms

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We study the onset of friction for rough contacting blocks whose interface is coated with a thin lubrication layer. As in dry friction, the transition from static to sliding friction is mediated by interfacial shear cracks. These cracks break the solid contacts that form rough frictional interfaces and are quantitatively described in term of fracture mechanics.

We show that even though the frictional strength of the system is reduced by the lubricant, surprisingly, the fracture energy (the amount of energy dissipated per unit area) is an order of magnitude higher than in the case of dry friction. Moreover, lubricant viscosity affects the onset of friction but has no effect on the fracture energy. Our macroscopic experiment cannot, however, differentiate between different scenarios responsible for the high dissipation: the strengthening of the liquid layer under high compression or the elastic coupling between the liquid layer and the solid asperities.

Linking nanoscale pairwise force profile to macroscale rheology in suspensions

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The process by which sheared suspensions go through a dramatic change in viscosity is known as discontinuous shear thickening. Although well-characterized on the macroscale, the microscopic mechanisms at play in this transition are still poorly understood. Here, by developing new experimental procedures based on quartz-tuning fork atomic force microscopy, we measure the pairwise frictional profile between approaching pairs of polyvinyl chloride and cornstarch particles in solvent. We report a clear transition from a low-friction regime, where pairs of particles support a finite normal load, while interacting purely hydrodynamically, to a high-friction regime characterized by hard repulsive contact between the particles and sliding friction. Critically, we show that the normal stress needed to enter the frictional regime at nanoscale matches the critical stress at which shear thickening occurs for macroscopic suspensions. Our experiments bridge nano and macroscales and provide long needed demonstration of the role of frictional forces in discontinuous shear thickening.

Comtet, J., Chatté, G., Niguès, A., Bocquet, L., Siria, A., & Colin, A. Nature Communications (2017)

Experimental study of confined bubbles dynamics submitted to a temperature gradient

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Two-phase flows are involved in many industrial processes (cosmetics, food, new materials, enhanced oil recovery) and are largely studied since several decades. These study strongly benefit from the emergence of microfluidics, offering building block experiments or models systems for both single bubble/droplet system or foam/emulsion. These studies lead to both important fundamental questions and to a wide spectrum of applications. The question we address is the influence of the boundary condition at the interfaces on the global dynamics of these objects. We propose to study model systems starting from a building block experiment: a single droplet. The results should have a significant impact for both the droplet-based microfluidics, and more generally to the soft matter community.

Démouillage de film mince au sein d'une matrice immiscible : une étude modèle pour une meilleure compréhension des instabilités interfaciales dans les films multinanocouches coextrudés

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La coextrusion multinanochouches est un procédé innovant qui apparait comme une solution encourageante pour obtenir des matériaux aux propriétés améliorées sous forme de films constitués de milliers de couches alternées de deux polymères différents à l'état confiné (épaisseurs de couches nanométriques) [1]. Cependant, la réduction de l'épaisseur dans ces multicouches à l'échelle nanométrique provoque d'éventuelles irrégularités d'interfaces qui peuvent conduire à des ruptures de couches. La compréhension complète des causes de l'instabilité de ces couches à cette échelle est donc primordiale pour la maitrise du procédé afin d'obtenir les couches stables les plus fines possible.

Les ruptures observées dans ces films semblent présenter un certain nombre d'analogies avec le phénomène de démouillage de films minces, largement étudié dans la littérature. Ainsi, les polymères amorphes déposés sur un substrat pour lequel ils ne présentent pas d'affinités et chauffés au-dessus de leur température de transition vitreuse, finissent par se rompre en petites gouttelettes. Si pour des systèmes monocouches ou bicouches (deux films de polymères immiscibles superposés) les études tant théoriques qu'expérimentales sont nombreuses, les effets d'interface dans les systèmes multicouches (i.e. nombre de couches supérieur à 2) n'ont à ce stade que très peu été étudiés. Une étude préliminaire menée dans notre équipe a consisté à mesurer des cinétiques de démouillage de films minces de polystyrène (PS) entre deux couches de polyméthacrylate de méthyle (PMMA) dans des conditions statiques, i.e. sans écoulement forcé. Il a été montré que dans le régime des épaisseurs typiquement supérieures à 100 nm, la vitesse était bien décrite par un modèle simple balançant tension interfaciale et dissipation visqueuse [2].

En diminuant l'épaisseur du PS, une transition vers un régime dépendant de l'épaisseur a été observée pour les épaisseurs inférieures à 100 nm. Les mécanismes possibles seront discutés.

Cette étude constitue une approche prometteuse vers une compréhension des phénomènes de rupture de couches observés dans le procédé de mise en œuvre cité plus haut.

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Electro-responsive polymers for controlling surface properties

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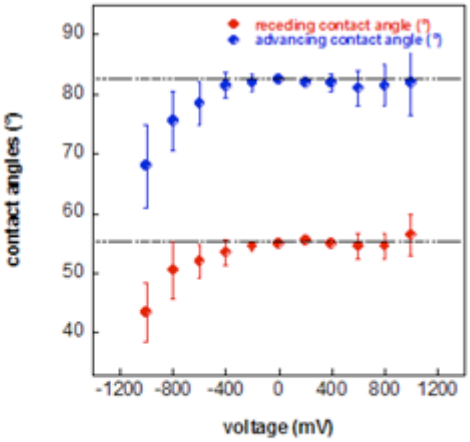
In nature, there exist many examples of stimuli-responsive materials, like Mimosa pudica leaves which fold when touched. Different alternatives have been proposed to mimic the behavior of such natural smart materials, which can change their properties in response of a changing environment. Stimuli-responsive polymers are good candidates for design of smart materials, as their properties can often be reversibly tuned by the variation of some external variables like temperature, pH or solvent quality. Changing the conformation of polymers by applying external stimuli makes it possible to control the properties of polymer-based materials. Our aim is to develop new strategies to create polymer-based smart materials suitable to operate in aqueous environment. Instead of using chemical stimuli, we have applied an electrical voltage to polyelectrolyte(PE)-based surfaces, because the response of polymer chains to physical stimuli is usually faster and the electric signal is easier to control. In this work we discuss the effect of an electrical voltage on the wetting and adhesion properties of PE surfaces due to electric-field-induced changes of macromolecular conformation.

Diblock PS-b-PAA coatings were prepared using the Langmuir-Schaeffer method [1-2], which is very useful to control the molecular density at the surface. Wetting properties were studied with the dynamic contact angle experiment. Adhesion forces were measured using the AFM with a colloidal silica probe in the aqueous media. Small voltages between -1V and 1V were applied between the aqueous media and the PE surfaces. Several pH and salt conditions were investigated, to maximize the responsiveness of the material.

We have shown that by applying small negative voltages it is possible to continuously decrease the contact angle of PS-b-PAA coated surfaces whereas by applying positive voltages the contact angle comes back to its original state. This effect was more efficient when in presence of a small salt concentration. Moreover, AFM force curves showed that the application of the electrical voltage is responsible for the reversible changes of PE conformation: PE chains are expanded by negative voltages and collapsed under the action of positive voltages [3]. As a consequence, the adhesion between the colloidal probe and the PE surface can be tuned by changing the applied voltage. The adhesion forces can also be controlled by controlling the density of PE on the surface.

In summary, in this poster we will show that it is possible to manipulate PE conformations with small electrical voltages in order to create smart materials: pH values close to the surface pKa and a small amount of salt are necessary to obtain the best response of the material.



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Adsorbed water on nanopore surfaces in a Metal Organic Framework

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Metal organic frameworks (MOF) are crystalline structures with well defined nanopores. Their extraordinarily high adsorption capacity for methane has attracted interest for storage of this high energy:carbon ratio fuel.

HKUST-1 is a MOF synthesized from copper nitrate and benzene-1,3,5-tricarboxylic acid benzene-1,3,5-tricarboxylate in a water-ethanol mixture.[1] Its crystal structure (cubic space group Fm3m) contains two bound water molecules and three pore sites, of diameter 5Å, 9.6 Å and 12.4 Å respectively. The open pore volume space describing the pore surfaces is inactive, i.e., adsorption sites have negligible binding energy [2], as confirmed by the reversibility of the methane adsorption isotherms [3].

After drying in air the resulting MOF crystals were investigated by small angle neutron scattering (SANS) and by wide angle X-ray scattering (WAXS). The SANS results show that in the low temperature (110ºC) treated samples the pores remain populated by water molecules. The condition of the water in the pores is revealed by the WAXS measurements: its state is amorphous and close to that of bulk water (Figure 1).

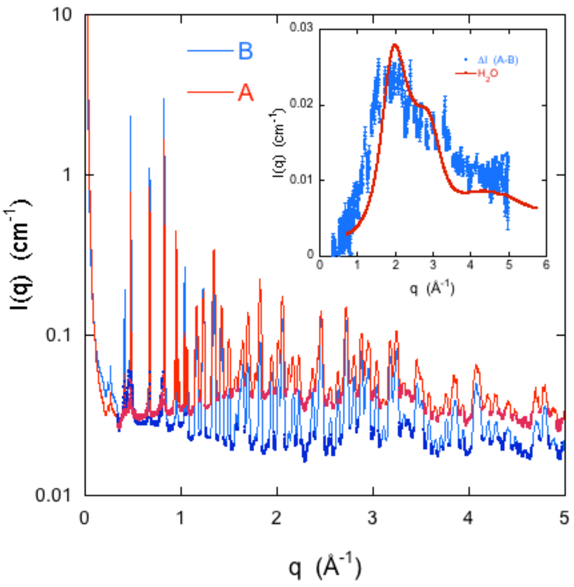

Figure1. WAXS response of samples A (before evacuation) and B (after evacuation); regions free of crystallographic reflections highlighted. Inset: Data points (blue): amorphous scattering component in sample A intensity difference DI=IA(q)-IB(q) from highlighted regions in main figure. Continuous curve (red): SAXS response of pure water, reduced by factor 7.

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Force measurements on a plate in a foamy bath

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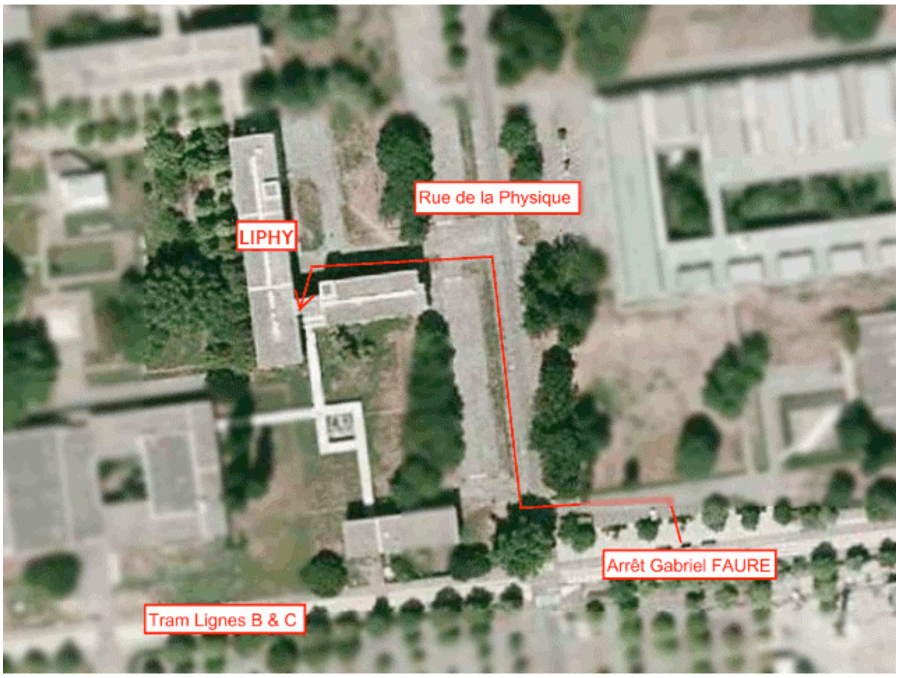
Withdrawing a solid out of foam leaves a thin layer of bubbles on its surface. Experimental observations show that both solid surface properties and mechanical foam properties have significant effects on the coating thickness. To predict this thickness, we performed an experimental study. Our setup allows us to measure the force exerted on a vertical plate during its controlled displacement in and out of a foam. We varied systematically the withdrawing velocity and the surface roughness of the plate. The simultaneous measurement of force and position leads to two different methods to determine the foam yield stress. The first one is an extrapolation towards the static regime during the immersion of the plate, and the other one focuses on the relaxation of the foam at the end of the immersion. The obtained yield stress values are in good agreement with the theoretical prediction for the studied foam. From the characterization of the foam properties, we expect to get the flow field during the plate motion and to predict the coating thickness. This study of the solid/foam interaction has applications in the food and cosmetic industry, where foam is always in contact with a solid to be manipulated.

Access Map



Address: University domain of Grenoble
140, avenue de la Physique - BP 87
38402 Saint Martin d'Hères, France

GPS coordinates: 45.19325 / 5.76227

Directions:

- **from the train station**, B tramway towards « Gières-Plaine des sports » ; stop at « Gabriel Fauré ».
- **from the hôtel**, B tramway at « Victor Hugo » (200m from the hotel) towards « Grenoble Presqu'île » ; stop at « Gabriel Fauré ».