Journées J3N Réseau National en Nanosciences et en Nanotechnologies
6 au 8 novembre 2006

Bottom-up approach for fluidics : nano-engineering of solid-liquid interfaces, fundamentals and applications to micro- and nano- fluidics

Project description

Control large scales liquid flows through nano-scale coupling within liquid-solid interfaces.

Amplitude and geometry of confined flows, characterized by the omnipresence of solid surfaces, crucially depend on the existing dynamical couplings between liquid flow at the interface and the intimate nature of this interface: surface charge and chemistry, wettability, topography.

Mastering the nano-interfacial structure and understanding such couplings therefore offers a mean to acquire active or passive control over large scales flows.

Methodology of achievement:

- **(i)** nano-engineering of the surfaces, *ie* the modification of nanometric properties, based on chemical functionalization and geometrical structuration of the interfaces;
- **(ii)** development of a specific instrumentation for nanoscale characterization of the dynamics at interfaces;
- **(iii)** development of a new generation of elementary microfluidic devices (for pumping, actuation or mixing) on the basis of the dynamical actuation of the nano-scale coupling.

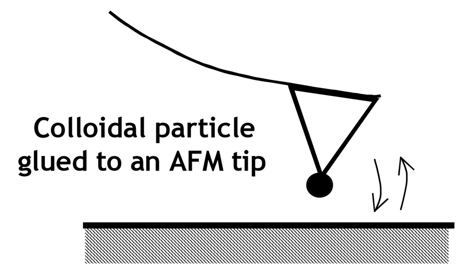
These three aspects will be complemented by a constant theoretical effort to predict and understand the measured effects (modelization and numerical simulations at the molecular scale).

Developing instruments to characterize flows at the nano-scale

AFM in colloidal probe configuration

We perform the analysis and characterization of the dynamical surface properties in controlled situations (known interfaces).

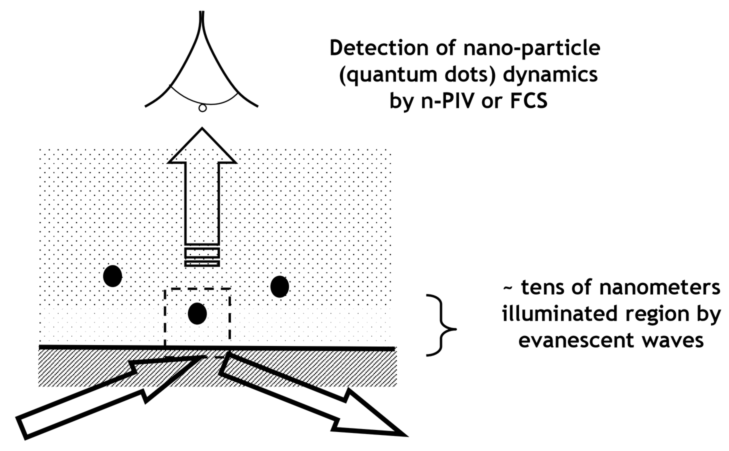
Final aim: develop a versatile tool for *local* mapping of the dynamical surface properties on addressable surfaces.

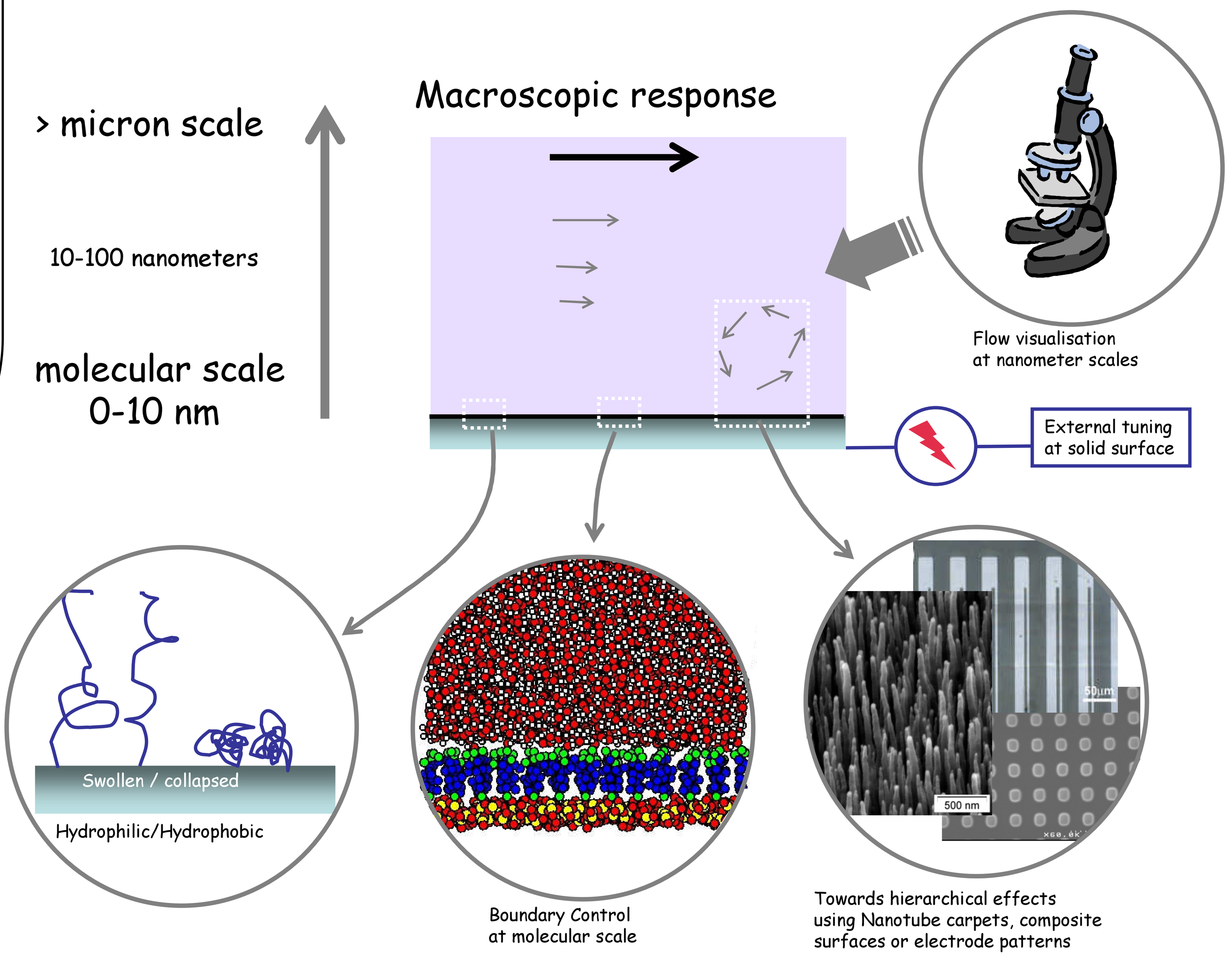


Nano- Particle Image Velocimetry

The already developed µ-PIV, based on standard fluorescence microscopy images, is limited to resolution in the micrometer range. By coupling a modified PIV analysis –to go beyond tracer's diffusion limits– with Total Internal Reflection illumination, the nano-PIV technique should give access to the 100 nm region in the vicinity of interfaces.

Final aim: liquid flow characterization within tens of nanometers from a solid surface.

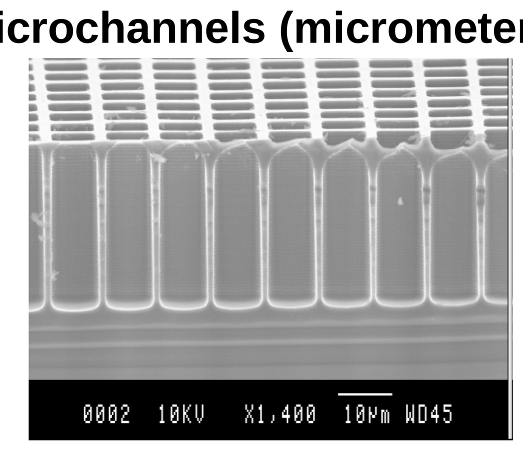




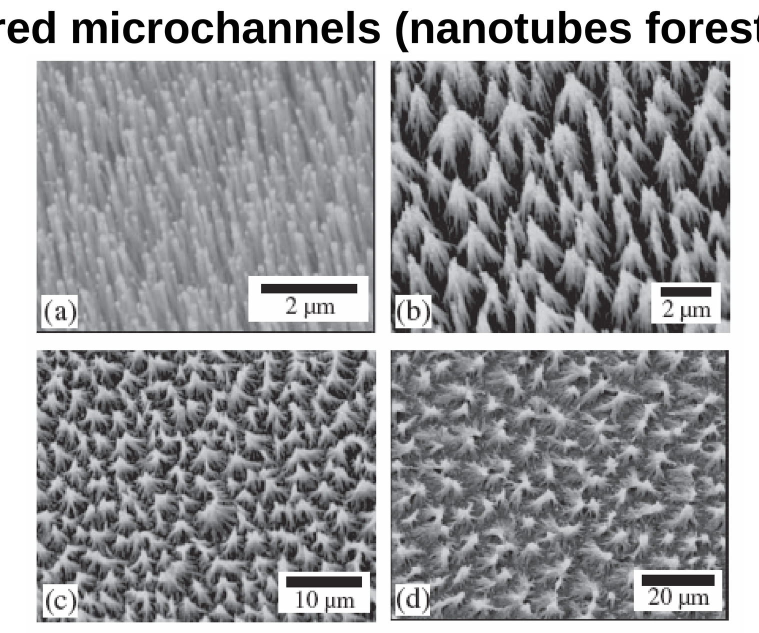
Surface tailoring: structuration

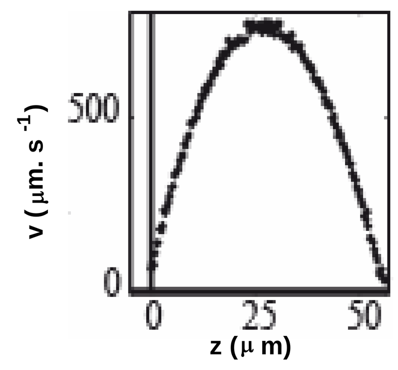
Structured microchannels (micrometer scale):

RIE

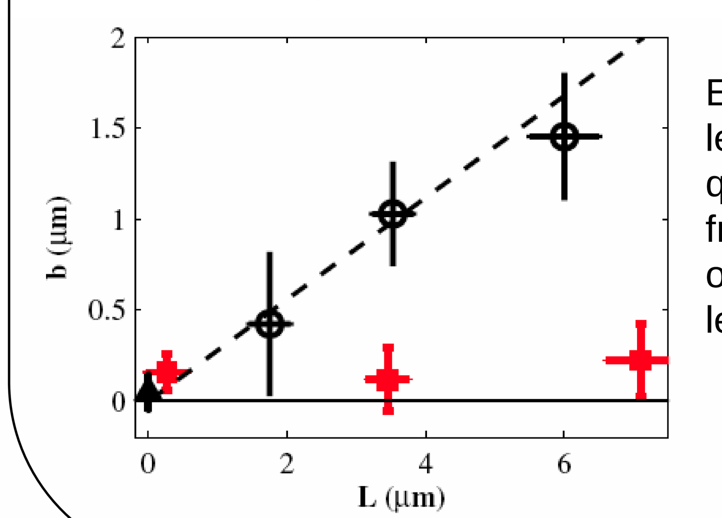


Structured microchannels (nanotubes forest):





Typical velocity profile obtained in a microchannel covered with nanotubes. From such a profile friction at the interface can be determined.

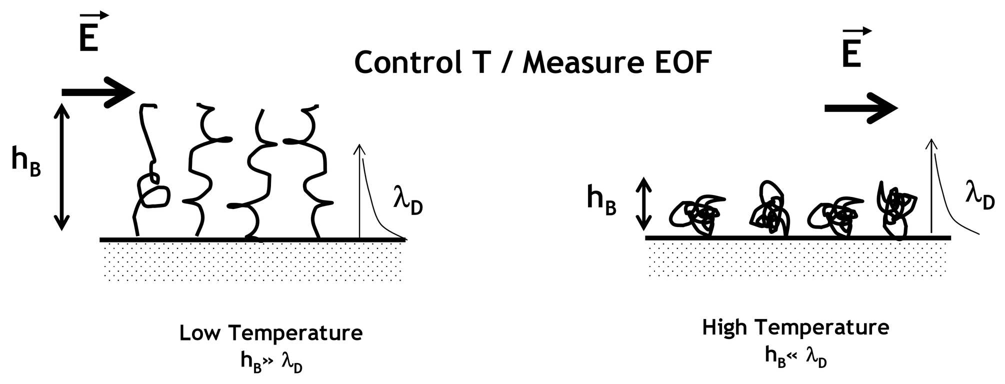


Evolution of the slip length parameter b, quantifying the surface friction, as a function of the lateral rugosity length scale L.

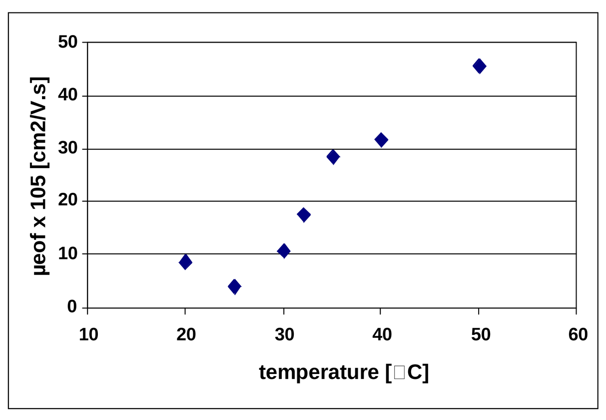
Surface tailoring: functionalisation

Active polymer brushes:

pNIPAM coatings undergo a swollen-to-collapse transition as function of temperature. This strongly affects the flows within the Debye length λ_D



⇨ active control of the dynamics of the liquid close to the solid substrate, which will lead to a control of the overall flow geometry.



Evolution of the mobility of electro-osmotic flow as a function of the temperature in a fused-silica capillary grafted with pNIPAM

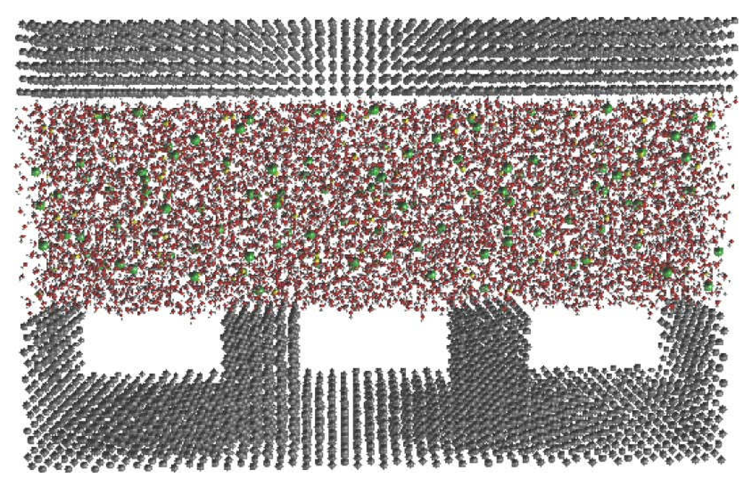
Future work:

- Optimisation of the polymer that will enlarge its potentialities
- Local activation

Modeling

Implementation:

MD simulations
Realistic model for water SPC/E

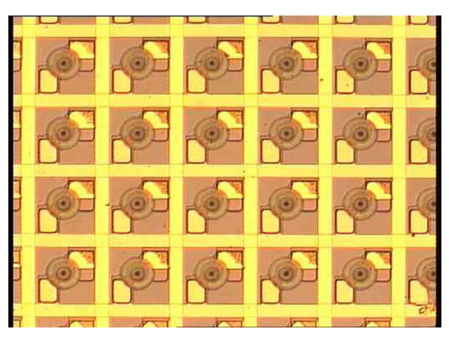


Future work:

Molecular description of interfacial transport on:
- functionalized surfaces;
- and/or textured surfaces.

Final objectives

- **Achieve fundamental understanding and characterization of nanometer scale couplings at a liquid solid interface;**
- **Develop local addressing method to tune spatially and temporally the surface properties (surface temperature or electric potential control);**
- **Use the combination of the above mentioned skills to develop new functionnalities for microfluidic devices.**



micro array (4000/cm^2) of annular independent heating resistances

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