MIKADO, Nanofluidics inside an individual nanotube

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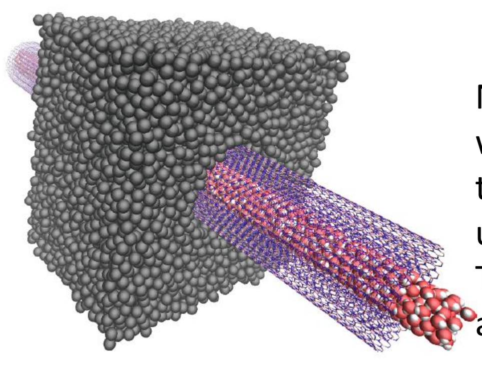
AGENCE NATIONALE DE LA RECHERCHE ANR

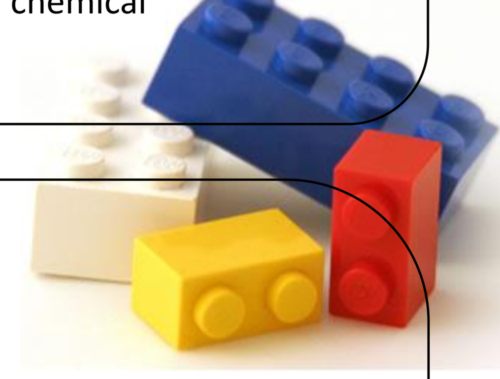


Project description

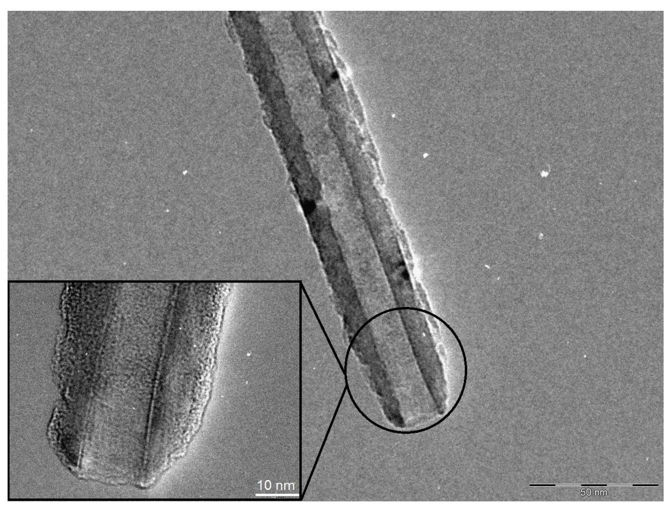
Probe the fluidic properties of an individual nanotube.

New paradigms for fluid transport are expected to emerge from the connement of liquids at the nanoscales, with potential breakthroughs in ultrafiltration, desalination, and energy conversion. Nevertheless, advancing the fundamental understanding of uid transport at the smallest scales requires mass and ion dynamics to be ultimately characterized across an individual channel so to avoid averaging over many pores.
To this end, a major challenge for nanofluidics consists in building distinctive and well-controlled nano-channels, amenable for systematic exploration of their properties

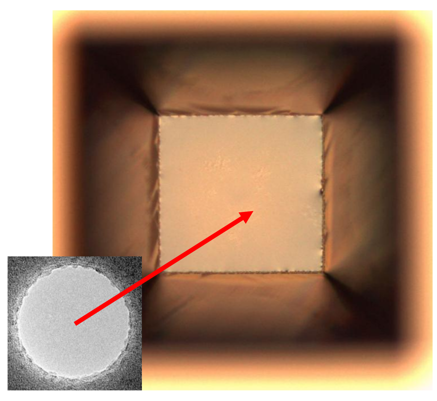
In this work, we describe the elaboration and exploitation of a new hierarchical nanofluidic device, made of a unique boron-nitride (BN) nanotube that transpierces an ultrathin membrane and connects two fluid reservoirs. Such a transmembrane geometry allows the versatile exploration of fluidic transport through a single nanotube under diverse forcings, including electric fields, pressure drops, and chemical gradients.



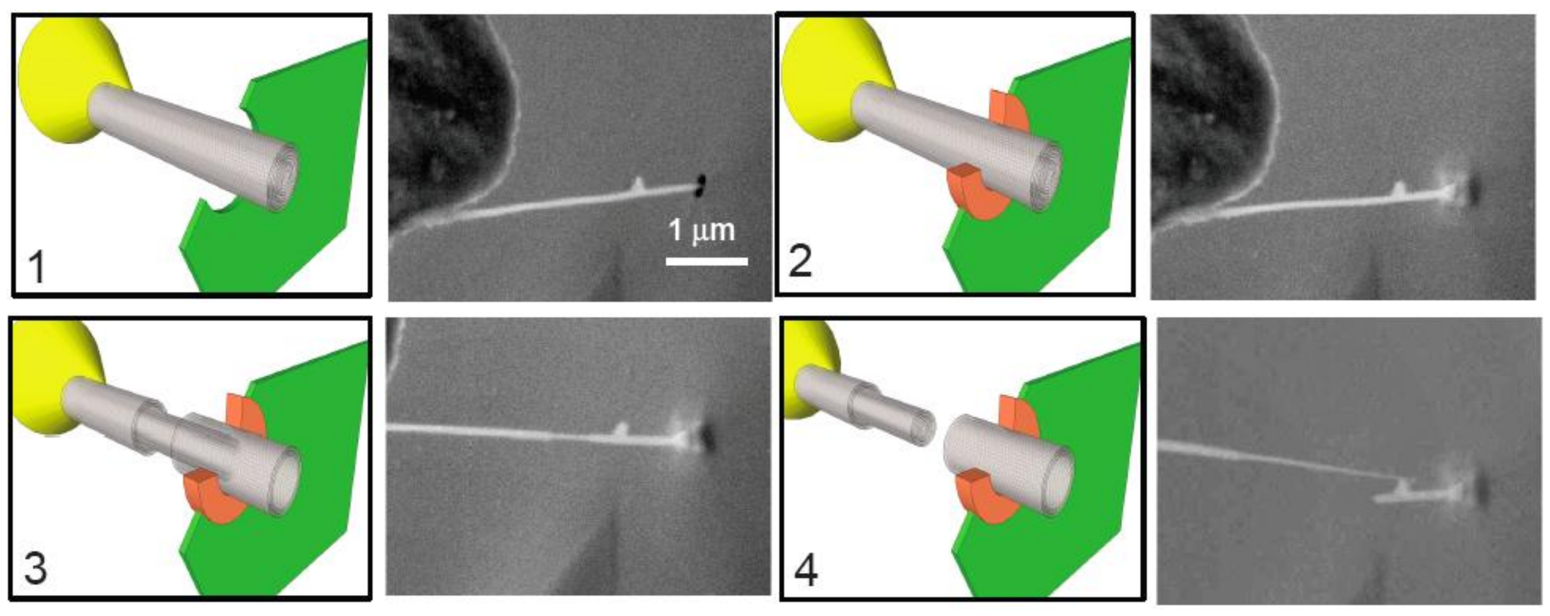
NT fabrication and nanomanipulation



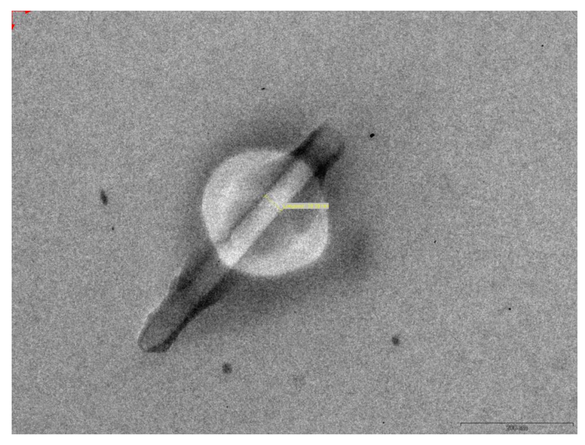
Fabrication, and opening of a specific nanotube. The nanotube is opened by desorption under a voltage bias [3].



Fabrication of SiN membrane (lithography and sputtering) and direct drilling (FIB).

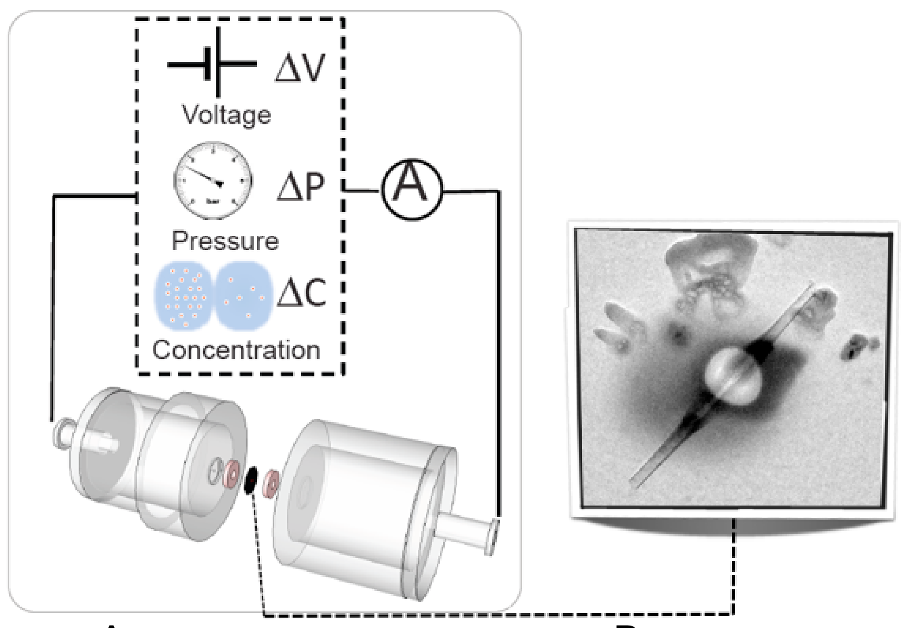


SEM in situ nanomanipulation of a nanotube: The inner part slides inside and ensures that the tube is open both ends. All manipulations have been performed via stick-and-slip motors.

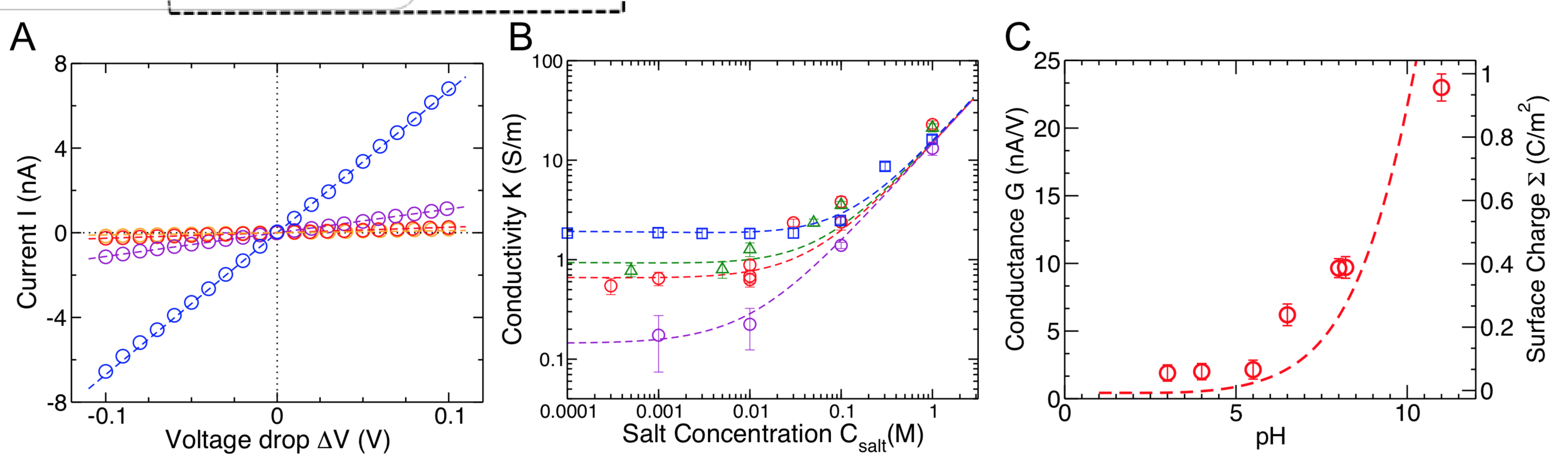


TEM image of final device, open nanotube and sealed membrane hole.

Measuring ion transport in a individual channel



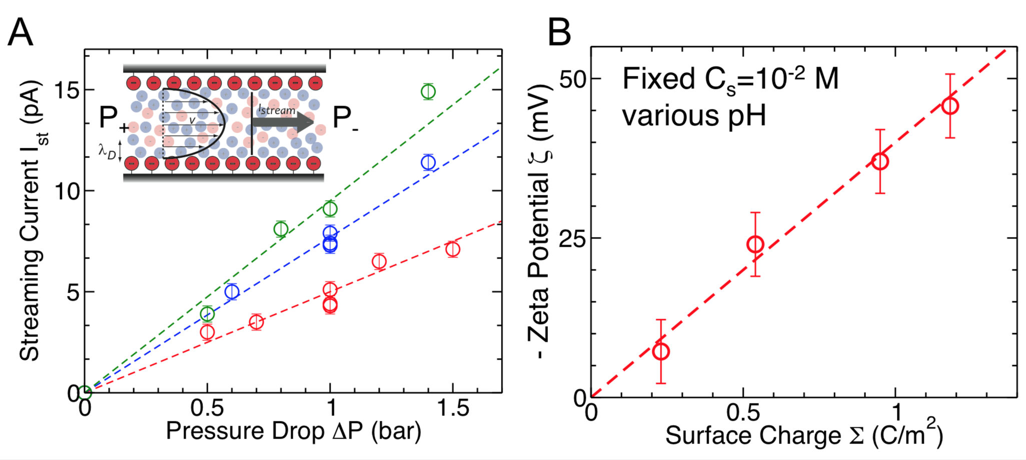
Sketch of the fluidic experimental set-up. The membrane based on an individual Boron Nitride nanotube is squeezed between two reservoirs filled with a solution of KCl in water. Two Ag/AgCl electrodes are connected within the reservoirs allowing to apply a voltage difference and measure the induced ionic current. In parallel an excess pressure drop can be applied, as well as a salt concentration gradient.



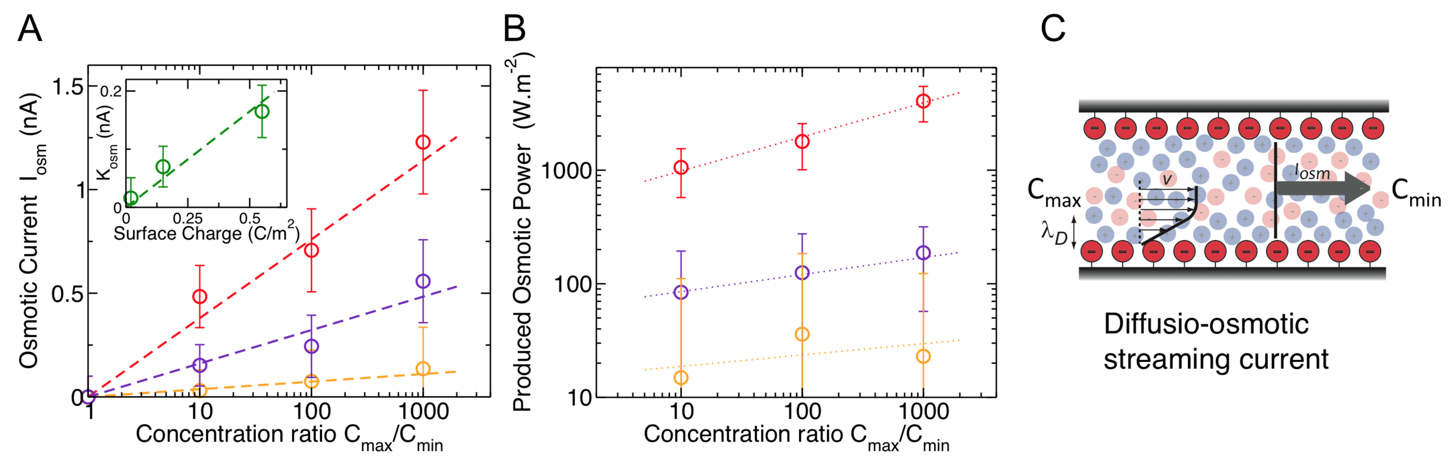
Conductance measurement BN nanotubes for various salt concentration and tube radii (in the range 15-40 nm. A very large surface charge, up to 1 C/m^2, is measured for the BN nanotubes.

Streaming current measurements under pressure drop for various pH.

$$I_{stream} = -\frac{\epsilon\zeta}{\eta}\mathcal{A}\frac{\Delta P}{L}$$



Huge osmotic energy conversion

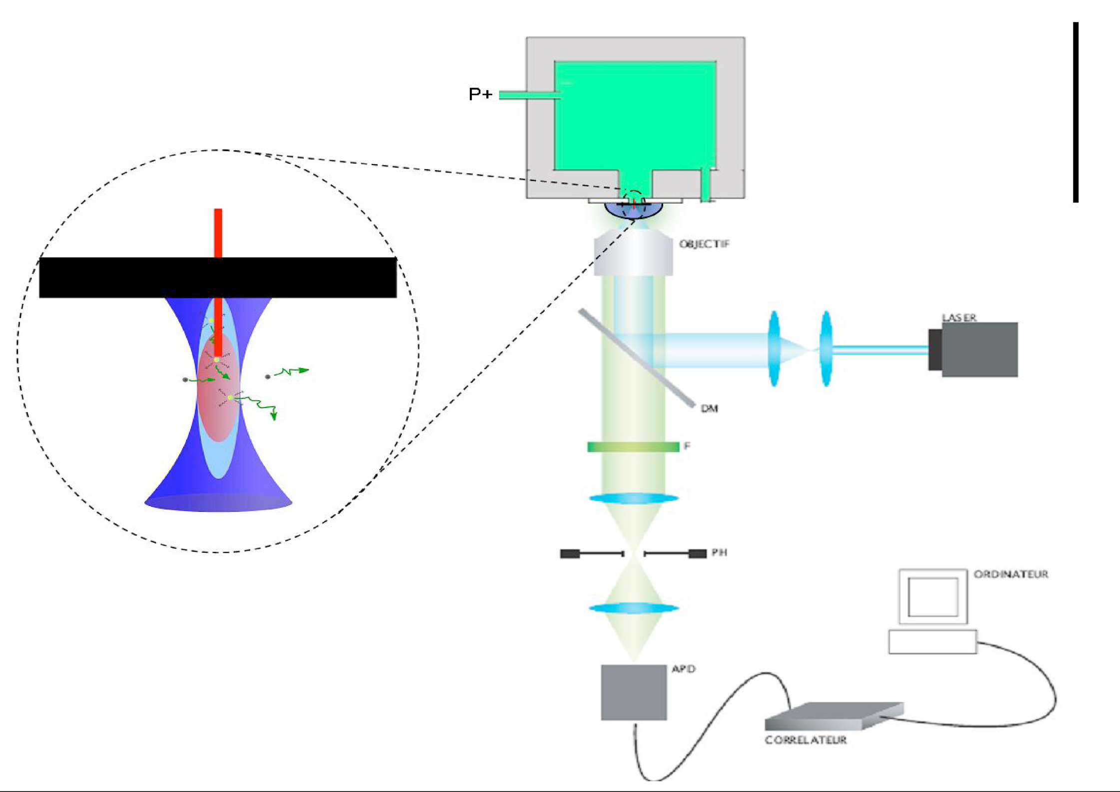


Osmotic current generated by a gradient in salt concentration. This corresponds to huge produced osmotic energy, 3 orders of magnitude larger than the state of the art.

$$I_{osm} \approx \frac{2\pi R}{L} \times \Sigma \times \frac{k_B T}{\eta\,\ell_B} \times \Delta \log[C_{\rm salt}]$$

Measuring mass transport in a single NT

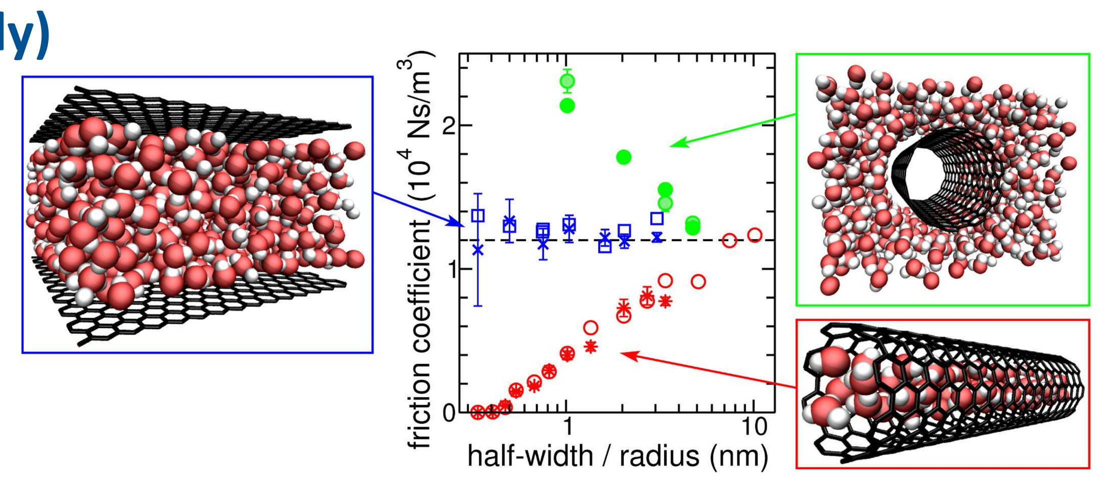
The already developed FCS set-up consists in the detection of fluorescent molecules in a confocal volume at timescales below 1 µs. By aligning the confocal volume at the top of the NT, one can count the number of fluorescent molecules passing through the NT.



Modeling (Collaboration L. Joly)

Molecular description of transport in CNT.
Testing the effect of extreme confinement.

Dependence of friction on surface curvature revealed by first results for CNT [4]



[1] Holt, J. K. *et al*. Science 2006, **312**, 103.
[2] Majumder,M.; Chopra, N.; Andrews, R.; Hinds, B.J. Nature 2005, **438**, 3, 44
[3] Poncharal P. *et al*, Nanotechnology, 2010, **21**, 215303
[4] Falk, K.; Sedlmeier, F.; Joly, L.; Netz, R.; Bocquet, L. Nano Lett. 2010, **10**, 4067; *ibid* Langmuir 2012, **28** 14261
[5] CY Lee, L. Joly, A. Siria, A.L. Biance, R. Fulcrand, L. Bocquet Nano Lett. 2012, **12**, 4037−4044
[6] A. Siria, P. Poncharal, A.-L. Biance, R. Fulcrand, X. Blase, S. Purcell, L. Bocquet, paper submitted (2012)

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