Anomalous transport of water in nanotubes

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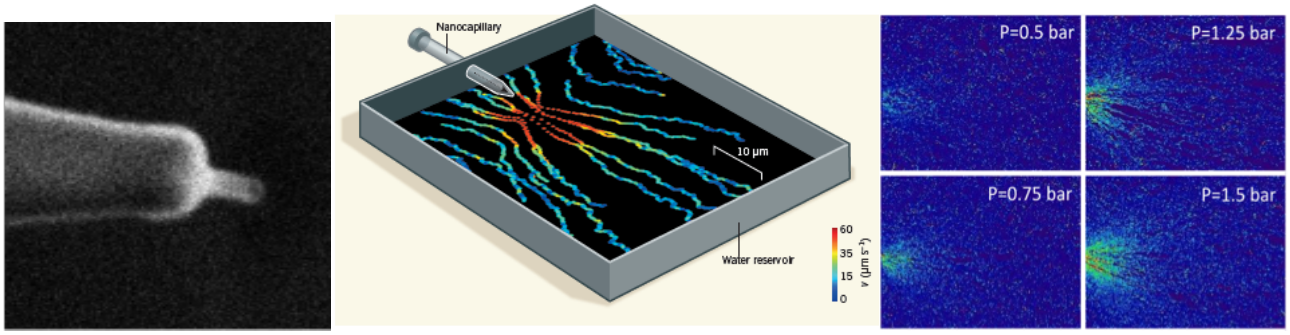
Nanofluidics is the frontier where the continuum picture of fluid mechanics confronts the atomic nature of matter. Recent experiments reported exceptional transport properties of water when confined in carbon nanopores. This has stimulated interest in carbon-based membranes for desalination, nano-filtration, and energy harvesting. But these works also raised fundamental questions on the specificity of the water-carbon interface, its structure, reactivity and dynamics.

We tackled these questions by exploring experimentally the transport across individual nanotubes, which allow to adress systematically the fundamental hydrodynamic properties at the nanoscales. To this end, we have developed new methods based on the manipulation of nano-scale building blocks which allow to fabricate original fluidic and mechanical systems involving single nanotubes.



I will first discuss experiments of ionic transport across carbon and boron-nitride nanotubes, which exhibit contrasting responses for these twin materials with the same crystallography but different electronic properties. This points to a strongly different chemical reactivity of BN versus carbon surfaces.

More recently we explored water friction at the nanotube interface, thanks to Landau-Squire nanojets experiments. Our experiments reveal diameter-dependent surface slippage in carbon nanotubes, with giant flow enhancements in the smallest carbon nanotubes. In contrast, their boron-nitride analogues, which have the same crystalinity as CNT, exhibit no slippage. These drastic differences in permeability point to a hitherto not appreciated link between hydrodynamic flow and the electronic structure of the confining material.

Finally I will discuss non-linear transport across such nanochanels and how these properties can be harnessed to fabricate "ionic machines" on the basis of active nanofluidic transport. This opens new avenues to develop dynamical selectivity, ionic pumps for uphill transport, etc. The implication for water filtration, desalination and energy will be discussed.

References:
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