Nanofluidics insights into the water carbon interface

Lydéric Bocquet

Laboratoire de physique statistique, UMR CNRS 8550 Ecole Normale Supérieure 75005 Paris, France

**lyderic.bocquet@lps.ens.fr*

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 raised fundamental questions on the specificity of the water-carbon interface, its structure, reactivity and dynamics. We tackle this question by exploring the transport across individual nanotubes, which allow to adress systematically the fundamental 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 an experimental study of ionic transport and current fluctuations inside individual Carbon Nanotubes (CNT). The conductance is found to exhibit a power law behavior at low salinity, with an exponent close to 1/3 versus the salt concentration in this regime. This behavior is rationalized in terms of a salinity dependent surface charge at the water-CNT surface. These results suggest hydroxide adsorption at the (hydrophobic) carbon surface. This is in contrast to its boron nitride analogue, which exhibits a pH dependent - and very high - surface charge. These results are confronted to ab initio simulations. Then, we explore the water friction at the CNT interface. This is done experimentaly by exploring nanoscale water jets emerging from single CNT. The jets' peculiar hydrodynamics enable us to passively measure pressure-driven flow rates with unprecedented sensitivity and without dyes. Our experiments reveal diameter-dependent surface slippage in carbon nanotubes, with giant flow enhancements in the smallest tubes. In contrast, their boron-nitride analogues, which have the same crystalinity as CNT, exhibit no slippage. This shows that water-solid friction and interfacial slippage originates in subtle and even sub-atomic details of the solid-liquid interface.

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[3] Scaling behavior for ionic transport and its fluctuations in individual carbon nanotubes, E. Secchi, A. Niguès, L. Jubin, A. Siria, L. Bocquet, Phys. Rev. Lett. 2016.