Molecular and ionic transport in 2D nanochannels and nanopores

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The molecular transport phenomena within nanometer-scale confinements are critical for understanding basic biological and physical processes, as well as the rational design of materials for energy and water technologies. With atomically clean interfaces, sub-nanometer control of geometry, and exquisite control of surface charges and functionalization, 2D materials make an excellent model system.

In this presentation, I will discuss the transport of water and molecules across nanopores in 2D membranes, atomically smooth 2D nanochannels, and laminar graphene-based membranes. Employing a novel micro-pervaporation chamber, we could measure nanoscale transport of liquids and mixtures through individual nanopores and nanochannels with varying height, and we could detect differential fluxes of each component. Comparing different 2D materials, and different liquids and binary mixtures, we could discern the effects of geometry vs. materials properties, and the explore the coupling of molecules with the solid surfaces. Next, I will focus the mechanical coupling of the liquid with the walls of the nanochannels, leading to elastocapillary-driven collapse of channels, i.e. switching. After developing theoretical framework and exploring the switching dynamics, we used such accumulated knowledge to design an active nanofluidic components: nanoswitch and nanocapsule (Figure 1). We demonstrate that nanocapsule could reversibly seal off zepto-liter volumes of liquids – comparable to the volume encapsulated in viruses. Nanocapsules could become elements of integrated nanofluidic circuitry, and could allow us to controllably explore biochemical and biophysical processes in crowded environments.

Figures

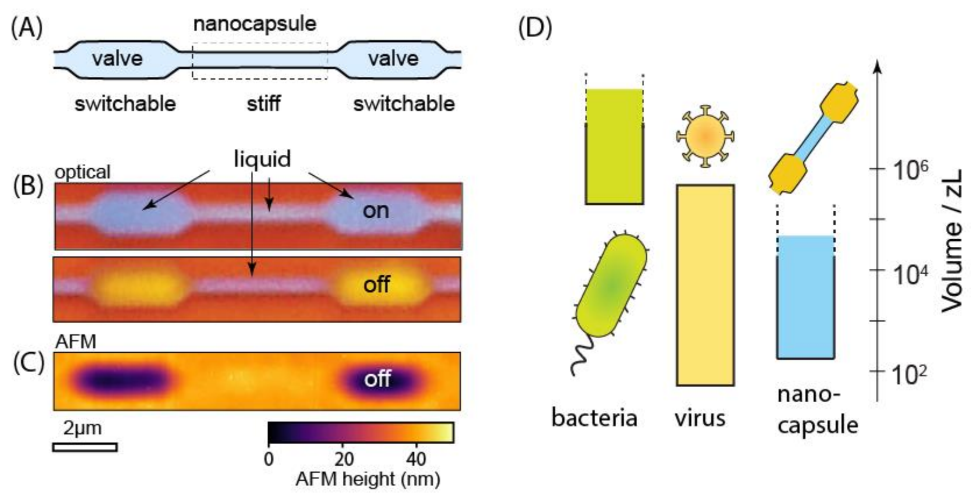

Figure 1: a) Sketch of a nanocapsule based on nanochannels in 2D materials (top view), consisting of a collapsible valve (switches), with a narrow channel section between them (nanocapsule). Elastocapillarity collapses the top walls of the valves during the drying process, capturing a zepto-litter volume of liquid in the stiff capsule. B) Optical image of a nanocapsule in open (top) and closed position with captured water (bottom). C) AFM image shows collapse of top wall of the walls. D) Comparison of volumes enclosed by different structures.