Mass transport in nanocapillaries

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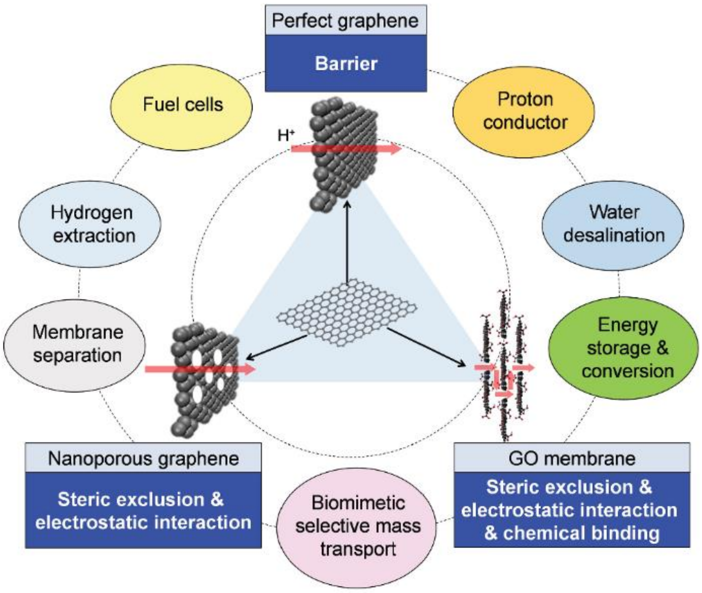
In condensed matter physics a lot of attention has been on electronic transport, but much less work is done on mass transport which is often considered to be more related to engineering. However, due to the recent fabrication of nanotubes and two dimensional atomic thin layers transport of protons and liquids have been studied where, due to the small dimensions, quantum effects are becoming important.

In this lecture I will give an overview of recent research on proton and water transport through nanotubes and nanocapillaries fabricated from graphene and other 2D materials. I will discuss fabrication issues and the novel interesting physics one has recently unveiled with those systems.



Schematic diagram illustrating the structure of (nanoporous) graphene and GO membrane, the mechanism for selective mass transmembrane transport and possible uses. Fig. taken from Adv. Mater. **28**, 2287 (2016).

A monolayer of graphene was initially considered to be impenetrable. However, recent experiments have shown that *protons* are able to be transported through graphene with a potential barrier of about 1 eV. Other membranes (hBN, MoS_2, ….) will also be considered and investigated for proton transport.

A second part of the lecture will be on water and ion transport between a stack of two layers in which the slit opening is Angström scale. When confined between graphene layers, water behaves differently from bulk and exhibits unusual properties such as fast water flow and ordering into a crystal. The hydrogen-bonded network is affected by the limited space and by the characteristics of the confining walls. Water confined between such layers crystallize into 2D ice with a strongly modified dielectric constant. The effect of an electric field on layers of ice will be considered. Water flow was found to be strongly enhanced. Although hBN has the same hexagonal structure as graphene the flow between a slit of hBN layers was found to be strongly hampered.

Such narrow slits can be used to separated water from ions and other contaminants. Recent experiments and related theoretical insights will be discussed.