**Dramatic nano-fluidic properties of carbon nanotube membranes**

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Carbon nanotubes have three key attributes that make them of great interest for novel membrane [1] applications 1) atomically flat graphite surface allows for ideal fluid slip boundary conditions 2) the plasma cutting process to open CNTs inherently places functional chemistry at CNT core entrance and 3) CNT are electrically conductive allowing for electrochemical reactions and application of electric fields gradients at CNT tips. To explore the hypothesis of 'Gatekeeper' membrane selectivity, the entrances to CNT's cores were functionalized with aliphatic amines of different lengths, charged dye molecule and poly-peptides [2]. Anionic charged functional groups are seen to sharply increase flux of cationic permeates. This effect is reduced at higher solution ionic strength consistent with shorter Debye screening length screening attractive charge at the CNT core entrance. A hindered diffusion model with a geometry of CNT tip functionalization, not along the length of CNT core, was consistent with the experimentally observed selectivities. Functionality can be forced to occur at the CNT tip entrances by fast fluid flow of an inert solvent through the core during electrochemical functionalization. Changes in the flux and selectivity support a model where charged tethered molecules at the tips are drawn into the CNT core at positive bias hindering/gating flux across the membrane [3]. In general, the transport mechanisms through CNT membrane are a) ionic diffusion is near bulk expectation with no enhancement from CNT b) gas flow is enhanced by ~1-2 order of magnitude due to specular reflection off of flat graphitic surface c) and pressure driven flux of a variety of solvents (H2O, hexane, decane ethanol, methanol) are 4-5 ORDERS OF MAGNITUDE FASTER than conventional Newtonian flow due to atomically flat graphite planes inducing nearly ideal slip conditions [4]. This is a nearly ideal platform to induce electro-osmotic flow with high charge density at pore entrance and a nearly frictionless surface for the propagation of plug flow. Through diazonium electrochemical modification we have successfully bound anionic surface charge to CNT tips and along CNT cores. Both cationic and neutral fluxes through the CNT membrane are observed as a function of bias. High electro-osmotic flows of 0.05 cm/s at -300mV bias are seen. Use of these phenomena for transdermal drug delivery devices and micro-patterned fluidic systems are discussed.

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