Beyond the slip length –Explaining high flow rates in carbon nanotubes

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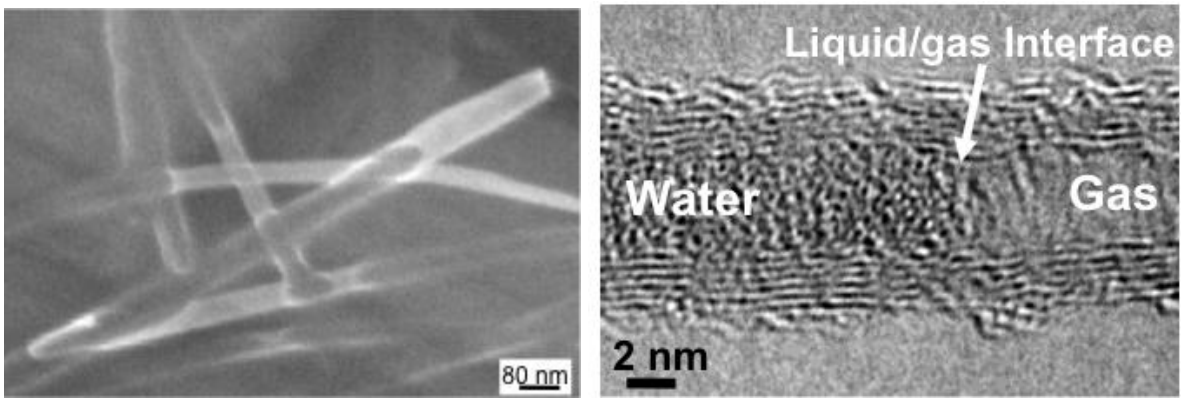
Experimental results of liquid flow through carbon nanotubes [1-3], showing orders-of-magnitude higher than expected flow rates, have generated an intense debate about the underlying physical phenomena and whether such flow can be explained within the continuum model on which traditional fluid mechanics is based [4, 5]. These results also hold great promise for filtration applications in general and water desalination in particular.



Water plugs in 40-60 and 2-5 nm diameter carbon nanotubes,

Attempts so far to explain these results have focused on the slip length at the wall and its possible dependencies on a wide range of parameters, from contact angle to roughness, viscosity and shear rate. All these solutions are somewhat unsatisfying when slip values in the order of tens of micrometers for CNTs with diameters of only few nanometers are obtained. Moreover, no model has been yet capable of explicitly relating the flow enhancement with solid-liquid molecular interactions occurring at the channel walls.
A different approach is presented here with an explicit dependence of the velocity at the wall on the solid-liquid molecular interactions via the adhesion energy. A comparison with published experimental results showing good agreement will be presented and insight on how to extend this model beyond the specific case of water-CNTs will be offered.

[1] Majumder, M., et al., *Nanoscale hydrodynamics: Enhanced Flow in Carbon Nanotubes.* Nature, 2005. **438**(7064): p. 44.
[2] Holt, J.K., et al., *Fast Mass Transport Through Sub-2-Nanometer Carbon Nanotubes.* Science, 2006. **312**(5776): p. 1034-1037.
[3] Whitby, M., et al., *Enhanced Fluid Flow through Nanoscale Carbon Pipes.* Nano Letters, 2008. **8**(9): p. 2632-2637.
[4] Whitby, M. and N. Quirke, *Fluid Flow in Carbon Nanotubes and Nanopipes.* Nature Nanotechnology, 2007. **2**: p. 87-94.
[5] Mattia, D. and Y. Gogotsi, *Review: static and dynamic behavior of liquids inside carbon nanotubes.* Microfluidics and Nanofluidics, 2008. **5**(3): p. 289-305.