Nanofluidic Ionic Devices

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Solid-state nanofluidic devices have proven to be ideal systems for studying the physics of ionic transport at the nanometer length scale. When the geometrical confining size of fluids approaches the ionic Debye screening length, a number of new transport phenomena occur, which have wide ranging implications to diverse areas such as biological ion channels, desalination, and energy storage and conversion. We have demonstrated a variety of nanofluidic ionic devices which utilize controllable ion selectivity, allowing us to realize ionic diodes and field effect transistors.[1] These devices have remarkable analogies to their semiconductor counterparts, but with some important differences.

One of the most intriguing implications of nanofluidic ionics is the ability to construct artificial ion channels. We have demonstrated[2] that we can create membrane potentials similar to cellular systems, with the additional ability to tune the ion selectivity ratio. The detailed dynamics of the transport allows us to identify relevant relaxation times and mechanisms, which could enable engineering of faster ionic and neural systems.

The study of nanofluidic ionic systems has primarily used monovalent ion systems. However, divalent ions comprise some of the most important ion channels in biological systems. We have investigated divalent nanofluidic ion transport, and have observed charge inversion at the channel/fluid interface.[3] The observation of charge inversion has important implications to the theory of a strongly correlated liquid (SCL) and biological permselectivity.

Finally, we will show some implications and applications. There are a number of naturally occurring systems which utilizes this physics for permselective ion transport, and engineered nanofluidic ionic systems can produce more efficient batteries.

[1]W. Guan, R. Fan, and M.A. Reed, *Nature Comm.* **2**, article # 506 (2011).
[2]W. Guan and M.A. Reed, *Nano Lett.* **12**, 6441 (2012).
[3]X. Li, W. Guan, B. Weiner, and M.A. Reed, *Nano Lett.*, **15**, 5046 (2015)