Iontronics: towards neuromorphic computing with tapered microfluidic channels

René van Roij[a]

[a] *Institute for Theoretical Physics, Utrecht University, The Netherlands*

We recently explained theoretically [1] why and how a micrometer-sized tapered channel between two aqueous electrolytes is not only a diodic current rectifier but actually even a transistor. Interestingly, this iontronic transistor is pressure-gated rather than the ordinary voltage-gated solid-state transistor: the electric conductivity of the channel can be tuned by an applied pressure drop (that induces a Poiseuille flow next to the electro-osmotic flow). More recently we showed [2] that the application of a periodic (AC) voltage causes these tapered channels to respond as memristors (resistors with a memory). These memristors can be used to construct iontronic circuits that exhibit neuromorphic responses upon a stimulus above a critical threshold, not unlike action potentials and spike trains in living neuronal cells and synapses [2]. In this talk we will explain the rich underlying physics of these iontronic devices that hold the prospect of applications in neuromorphic computing on the basis of the same material that our brain is made of: aqueous electrolytes. After briefly discussing the electric double layer on the basis of solutions of the Poisson-Boltzmann equation, we will discuss the electrokinetic transport of water, charge and salt on the basis of Poisson-Nernst-Planck-Stokes equations, and the Hodgkin-Huxley-like (Kirchhoff) equations for iontronic circuits of memristors that exhibit neuromorphic responses. If time permits we will also touch upon ongoing work on reservoir computing with tapered channels [3], acoustic signaling with pressure pulses [4], and chemical signaling using ion concentration shocks that affect the surface charge (and hence the conductivity) of the channel [5].

Referencias

[1] Willem Boon et al., Phys. of Fluids 34, 101701 (2022); arXiv 2205.02002v1.
[2] Tim Kamsma et al., Phys. Rev. Lett. 130, 268401 (2023); arXiv 2301.06158.
[3] Tim Kamsma et al., manuscript in preparation.
[4] Alexander Barnaveli et al., manuscript in preparation.
[5] Willem Boon et al., Phys. Rev. Lett. 130, 05800 (2023)..