A modified Hodgkin–Huxley model for nanoelectronics

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A modified Hodgkin–Huxley model for nanoelectronics

In the Hodgkin–Huxley model[1], bioligcal ion pumps push current through a membrane until is the electrical capacitance of the membrane is charged up, at which point it generates a voltage which turns off the ion channel pumps. When a lipid bilayer is brought into close proximity to a nano-electronic device (such as a 1d carbon nanotube[2], quasi-1d silicon nanowire, 2d graphene sheet[3], or any other of the many classes of nanoelectronics devices), a similar phenomenon occurs: The current through the ion channel charges up the electrical capacitance of the lipid bilayer. However, because the nano-electronic devices have capacitance of their own (including both classical electrical capacitance as well as quantum capacitance[4] due to the Pauli exclusion principle), these also get charged by the ion channels, and ultimately turn off the ion channels, even for simple ion channels that are not voltage dependent. This modified Hodgkin–Huxley model can account for the electrical behavior of nanoelectronic interfaces to a electrically active ion channels, a growing interest with applications from neurons and cadiomyoctyes to even smaller, electrophysiologically active organelles such as chlorplasts and even mitochondria[5].

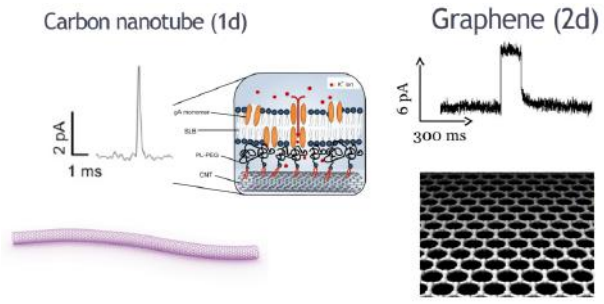
[1]A. L. Hodgkin and A. F. Huxley, “A quantitative description of membrane current and its application to conduction and excitation in nerve,” J. Physiol., vol. 117, no. 4, pp. 500–544, Aug. 1952.

[2]W. Zhou, Y. Y. Wang, T.-S. Lim, T. Pham, D. Jain, and P. J. Burke, “Detection of single ion channel activity with carbon nanotubes,” Sci. Rep., vol. 5, p. 9208, 2015.

[3]Y. Y. Wang, T. D. Pham, K. Zand, J. Li, and P. J. Burke, “Charging the quantum capacitance of graphene with a single biological ion channel.,” ACS Nano, vol. 8, no. 5, pp. 4228–4238, Apr. 2014.

[4]C. Rutherglen and P. Burke, “Nanoelectromagnetics: Circuit and Electromagnetic Properties of Carbon Nanotubes,” Small, vol. 5, no. 8, pp. 884–906, 2009.

[5]K. Zand, T. Pham, A. Davila Jr., D. C. Wallace, and P. J. Burke, “Nanofluidic platform for single mitochondria analysis using fluorescence microscopy,” Anal Chem, vol. 85, no. 12, pp. 6018–6025, 2013.



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