Effect of a High Frequency Field on the Electric Double Layer Surrounding a Biomolecule in a Fluid

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Abstract

Biosensors based on silicon nanowires are of great interest for ultrasensitive biomolecular recognition of disease specific markers for early stage diagnosis [1]. However, there are limitations on the performance of these nanosensors in solutions at high ionic strength. This is because the electric field induced by the binding of biomolecule is partially screened on length-scales larger than the Debye length. . Around a charged particle in electrolytic solution, ions position themselves in an electric double layer which screens the charged particle potential [2]. An approach to reduce the screening effect of the electric double layer involves application of a high frequency alternative current in the solution. In this study, simulation of the electric double layer behavior subjected to an alternating field is performed. The electric double layer is located around an array of charge particles placed on the top of a nanowire and surrounded by an electrolytic solution (Figure 1). In first approximation, the nanowire potential is considered constant. The alternating potential is applied by two metal electrodes placed in the solution. The electric double layer is simulated using COMSOL Multiphysics® software. The Poisson equation and Nernst-Planck equations are coupled to simulate the time-dependent potential and ion concentration in the solution [3]. The goal of this study is to simulate the frequency dependence of the alternating field on the electric double layer with a view to evaluate whether a high frequency RF field can disrupt the electric double layer (Figure 2).

Reference

[1]Yu Chen et al, Nanoelectronic detection of breast cancer biomarker, Appl. Phys. Lett., 97, 233702 (2010), Carsten Maedler et al, Detection of the melanoma biomarker TROY using silicon nanowire field-effect transistors, (2013), arXiv:1312.7532.

[2]J.N. Israelachvili, Intermolecular and Surface Forces, (Academic press: 2011).

[3]Guigen Zhang, Simulating the Electrical Double Layer Capicitance, Excerpt from the Proceedings of the COMSOL Conference 2010.

Figures used in the abstract

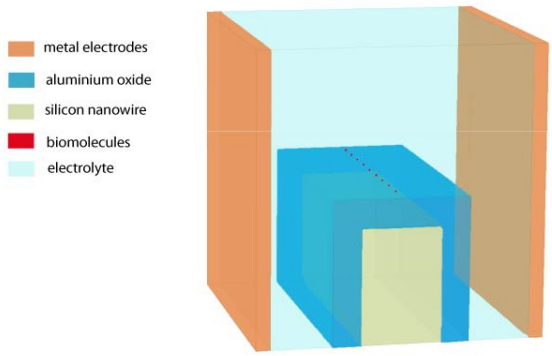

Figure 1: Geometry of the simulation.

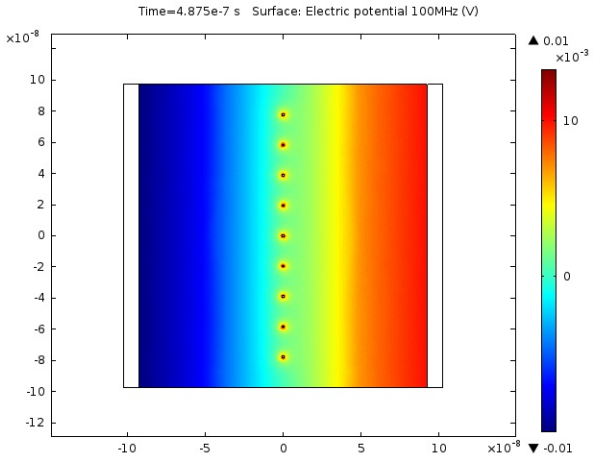

Figure 2: Electric potential in the electrolyte for a frequency of 100MHz.

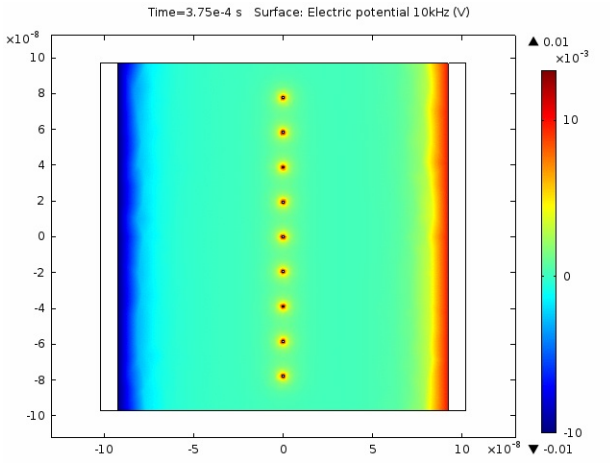

Figure 3: Electric potential in the electrolyte for a frequency of 10kHz.