(5) A General Bottom-Up Modeling Approach for BioFETs

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Biologically sensitive field-effect transistors (BioFETs) enable the integration of amplifying and analyzing circuits on the same chip. Microarrays consisting of BioFETs can be used outdoors to control the spread of diseases and environmental pollution, without the need of a lab thus allowing to save space, time, and equipment [1]. BioFETs consist of an electrical transducer, a dielectric layer, a biologically sensitive surface with immobilized biomolecule receptors, the analyte containing the biomolecules, and a reference electrode. When analyte biomolecules bind to the receptors, the surface charge changes. Thus the potential in the channel of the transducer changes and leads to a changed conductance of the fieldeffect transistor.

A BioFET device has been numerically analyzed for two biomolecule types. DNA due to the critical importance in medical, biological, and environmental studies and a Biotin-Streptavidin complex, which is used in purification and detection of various biomolecules have been chosen. The strong Biotin- Streptavidin binding can also be used to attach various biomolecules to one another or onto a solid support. The charge and the dipole moment of a single molecule were calculated from a protein data bank [2] using a bottom-up [3] approach.

The change of the charge happens at the Angstrom scale, while the FET dimensions are in the micrometer scale. Therefore, it is necessary to have an appropriate multi-scale model for the transducer-analyte interface. We employ homogenized interface boundary conditions [4], which connect the dielectric of the transducer and the analyte. In our simulations the analyte is described by the Poisson-Boltzmann equation. The device has a channel length of one micrometer. The model shows a strong dependence on surface charges and indicates a detectable shift in the threshold voltage depending on the orientation of the molecules related to the surface.

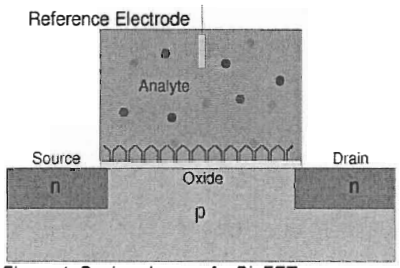

Figure 1: Basic scheme of a BioFET

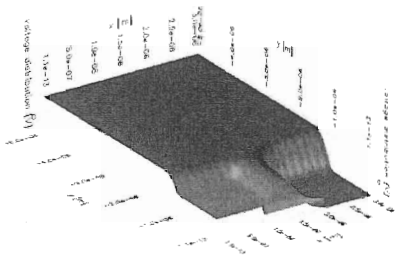

Figure 2: Potential profile for whole device

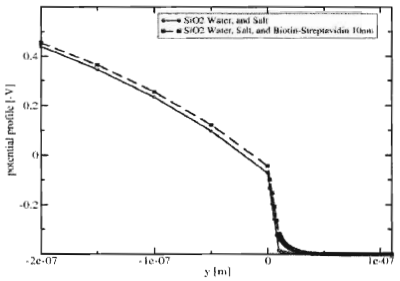

Figure 3: Cut through the potential profile

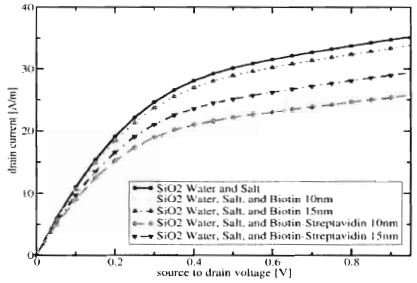

Figure 4: Output curves for different charge densities, bound (Biotin-Streptavidin) and unbound state (Biotin)

References
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