Design, Fabrication and Characterization of Electrochemical Devices:
Nanoscale Wet Transistor and Protein Devices

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Abstract

During the last four years, we have designed and manufactured different electrochemical device configurations. These are composed of metal/metal-oxide nanoelectrodes on Si-SiO_2 substrate in contact with different electrolytes, employing on-chip nano-technology.

Phenomena which have been addressed include water behaviour in strong electric fields. A particular phenomenon is vortex formation, due to rapid proton transport in an alkaline background, as modelled by the ambipolar transport equation. The physics behind the phenomenon is analogous to the transport of electrons in hole-doped semiconductors. A stirring function was predicted, and this property was applied in a subsequent study, demonstrating a Pure-Water Transistor (*PWT*).

The *PWT* relies on the controlled modification of the *p*H in pure water through the base electrode. Dependencies of the emitter-collector current responses on base *dc* voltage, bias, and distance between the base and emitter-collector electrodes are reported. The most sensitive electrode arrangement has the base as cathode and close to the emitter-collector electrodes with the emitter as anode. The life time of excess protons is quantified, i.e. prior to recombination with hydroxides to form water.

We have trapped single protein molecules of R-phycoerythrin in an aqueous solution by 10 V *ac* biasing between two sharp nanoelectrodes. In spatially non-uniform *ac* electric fields, the protein moves as a consequence of dielectrophoretic forces, i.e. the interaction of the dipole induced in the particle and the applied field gradient. Trapping of single protein molecules of R-phycoerythrin takes a place at the electrode tips due to the dielectrophoretic forces.

Fluorescence quenching of Enhanced Green Fluorescent Protein (EGFP) and wild type (wtGFP) was assayed using the Photoluminescence (PL) technique. The results under external electric field with gold electrodes showed that the PL intensity of GFP was decreased at small bias voltages. Biacore was used as supplementary measurement, showing a weak affinity between the voltages treated wtGFP and the immobilized antiGFP on the sensor chip of biacore than that of the EGFP treatment. These methods indicated that the wtGFP was able to bind gold metal solubilized from the electrode surface in an electrochemical cell, and that metal quenched the fluorophore function of GFP.

In a recent study, we administrated a droplet of Enhanced Green Fluorescent Protein EGFP molecules onto a chip consisting of Al-Al_2O_3 electrodes with 70 and 30 nm spacings and measured current-voltage I-V characteristics. UV-induced negative current produced at low voltages in the device with the electrodes 30 nm apart. The photoinduced current is discussed in terms of the properties of the thin Al-Al_2O_3 scale, the position of the Fermi level relative to the HOMO-LUMO gap, and dispersion of states of the GFP induced by varying dielectric constants as a function of applied electric field.