Simulation Of Neurotransmitter Sensing By Cyclic Voltammetry Under Mechanical Motion Of A Neural Electrode

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Abstract

Neural electrodes for sensing neurotransmitters are embedded within the brain, detecting electrical signals produced by kinetic reaction of neurotransmitters in the brain. Sensing utilizes cyclic voltammetry (CV), which applies sweeping potentials to identify chemical kinetics of neurotransmitters. During in-vivo sensing, electrochemical sensing signals can be significantly disturbed by internal and external motion of the brain from a moving subject. This research assesses and analyzes the effect of dynamic motion of neural electrodes on its sensing capability using COMSOL Multiphysics™.

Electrochemistry module and structural mechanics module were coupled using the Nernst-Planck equation. In electrochemistry module, sweeping potentials for cyclic voltammetry were applied on a cylindrical carbon fiber electrode (8µm in length and 2µm diameter) with a triangular cone shape tip (3µm length). To represent the electrochemical interface between the electrode and brain, double layer capacitance is applied. In structural mechanics module, a sinusoidal waveform of mechanical motion was applied on the electrode, and periodic condition is applied for complete bonding between electrode and brain. Using parametric sweep setup, scan rate and double layer capacitance were changed in electrochemistry module, and mechanical frequency of motion on electrode were applied in structural module. The simulation results show that mechanical motion of neural electrodes significantly disturbs the current density of cyclic voltammetry. The motion effect become larger near peak potentials of oxidation and reduction compared to other region of sweeping. This simulation captures electrochemical-mechanical coupling of neurotransmitter transport and kinetic reaction on interface between brain and electrode.

In addition, when the scan rate and frequency are equal, the current density is fluctuated less than the one at low frequency. It is presumed that the temporal and spatial variation of depleted region is synchronized with the same scan rate of potential sweeping.

The simulation results showed electrochemical-mechanical coupling on interface between the brain and the electrode. Based on the simulation results, applying appropriate digital filter to sort out disturbance from mechanical motion would be necessary to obtain accurate sensing signals from neurotransmitters during in-vivo experiment.

Figures used in the abstract

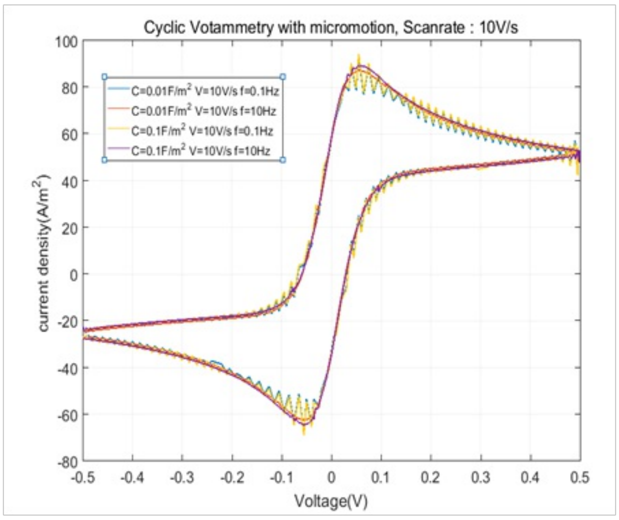

Figure 1 : Cyclic voltammetry with mechanical motion