Simulation of Neurotransmitter Sensing by Cyclic Voltammetry under Mechanical Motion of a Neural Electrode

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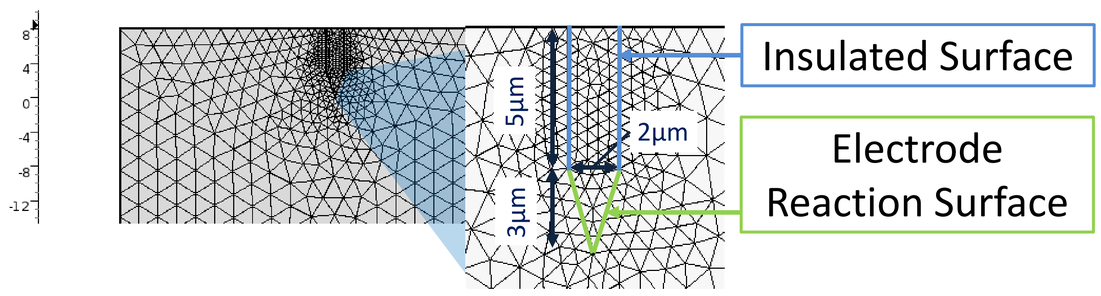
I. INTRODUCTION

- Real-time sensing of neurotransmitters has been enabled with cyclic voltammetry (CV). By applying sweeping potentials, cyclic voltammetry (CV) can detect the neurotransmitters and identify their chemical kinetics.
- Neural electrodes for electrochemical sensing of neurotransmitters are inserted into a brain, while in-vivo real time sensing is performed, These electrodes transmit electrical signals produced by kinetic reaction of neurotransmitters during CV.
- However, internal and external motion of a subject causes dynamic motion of electrode that can significantly disturb sensing signals.
- In this research, to assess and analyze the effect of dynamic motion, multiphysics simulation of cyclic voltammetry is performed with key mechanical and electrical parameter and variables.

II. SIMULATION CONFIGURATIONS & DESCRIPTIONS OF APPLIED PHYSICS

A. 2D Geometry and Mesh



B. Applied Physics

1. Diffusion and Transport

$$\frac{\partial c_i}{\partial t} + \nabla \cdot (-D_i \nabla c_i) = R_i \,, \; R_i = \frac{v_i i_{loc}}{nF}$$

< v_i : stoichiometric coefficient, n=number of electrons, F= Faraday constant>

2. Electrochemical analysis

$$i_{loc} = nFk_0 \left(c_{red} exp \frac{(n-\alpha_C)F\eta}{RT} - \; c_{ox} exp \frac{(-\alpha_C)F\eta}{RT} \right) (\eta = \phi_{s,ext} - E_{eq})$$

$$i_{dl} = (\frac{\partial \phi_s}{\partial t}) C_{dl}$$

< Butler-Volmer equation / double layer capacitance>

3. Solid Mechanics

Electrode : $\rho \frac{\partial^2 \boldsymbol{u}}{\partial t^2} - \nabla \cdot \sigma = \boldsymbol{F}\nu$ (ν = poisson's ratio)

Brain : Kelvin-Voigt viscoelastic with a relaxation 12.5 ms time

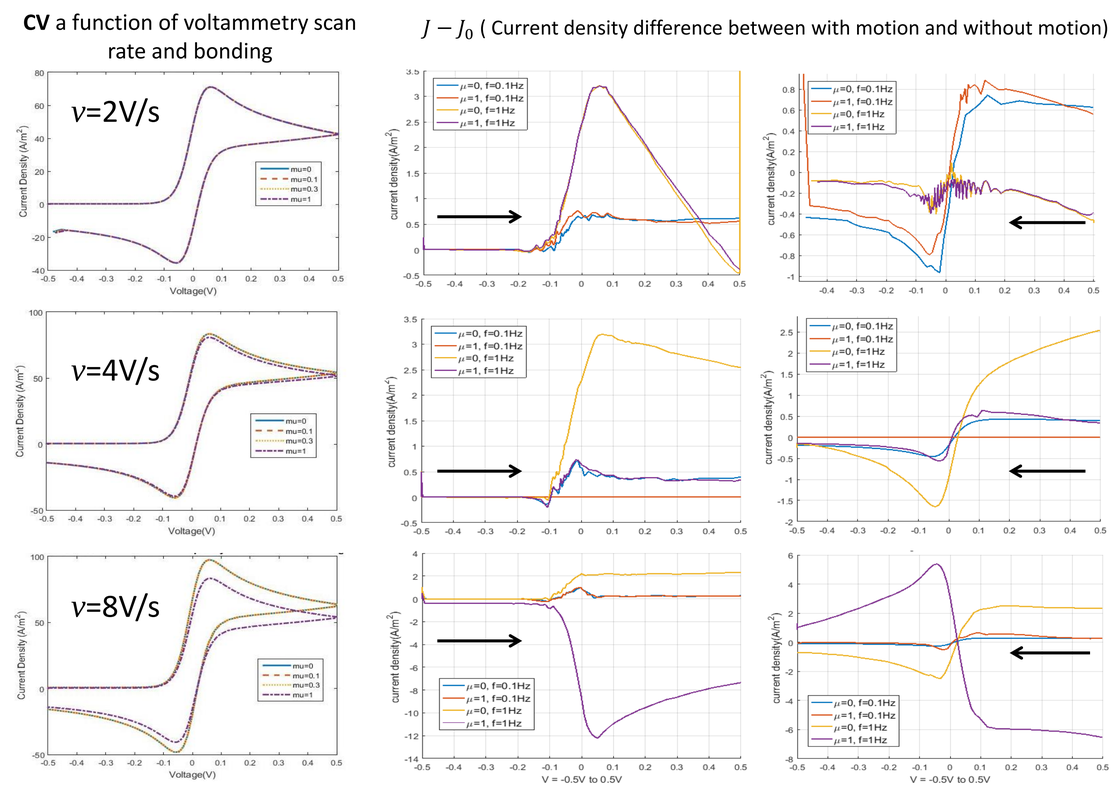
C. Simulation Variables and Parameters

	Variables	Notation	Values(unit)
Electrochemistry	Double Layer Capacitance	C	0.01, 0.1(F/m^2)
	Scan rate	v	2, 4, 8 and 400 (V/s)
Dynamics	Amplitude	A	1(μm) sinusoidal
	Frequency	f	0.1, 1 (Hz)
	Friction Coefficient	μ	0, 0.1, 0.3, 1

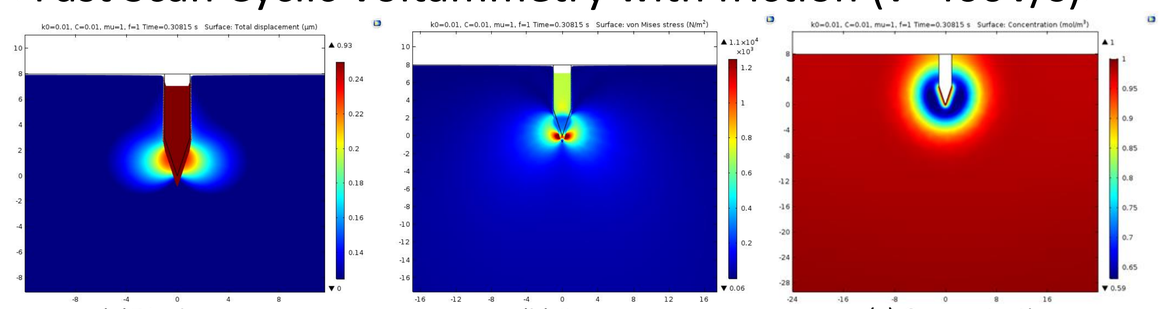
III. SIMULATION RESULTS AND DISCUSSIONS

CV a function of voltammetry scan rate and bonding

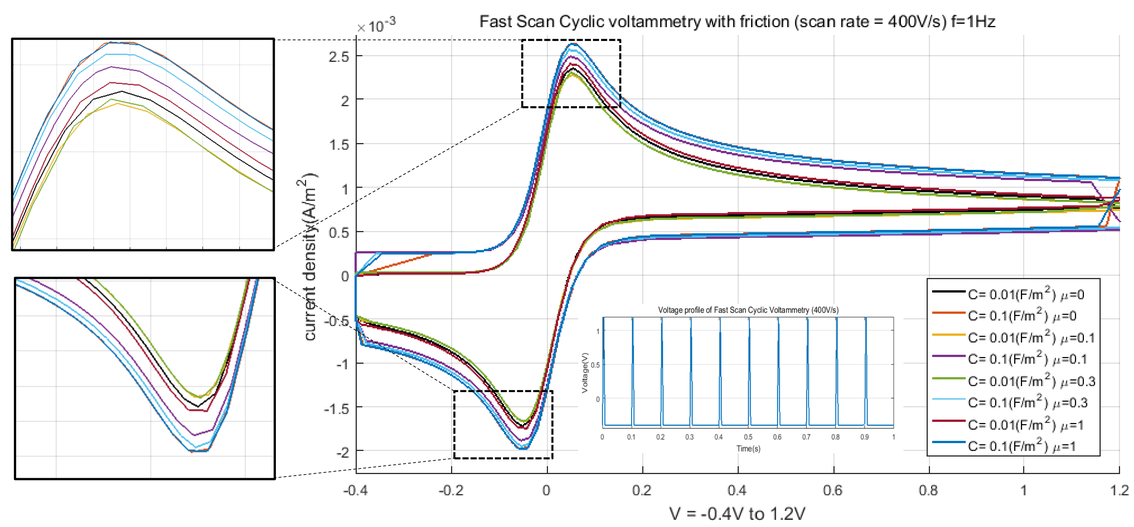
$J - J_0$ (Current density difference between with motion and without motion)



< Fast Scan Cyclic Voltammetry with friction (v=400V/s)>



(a)Displacement (b) Stress (c) Concentration



IV. CONCLUSION

While neurotransmitters are detected with electrodes implanted in the brain, mechanical impact can significantly disturb the sensing signals from neurotransmitters.

A multiphysics simulation was newly developed, and the electrochemical-mechanical coupling is well captured with varied double Layer Capacitance, scan rate and mechanical frequency and friction .

Acknowledgement

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