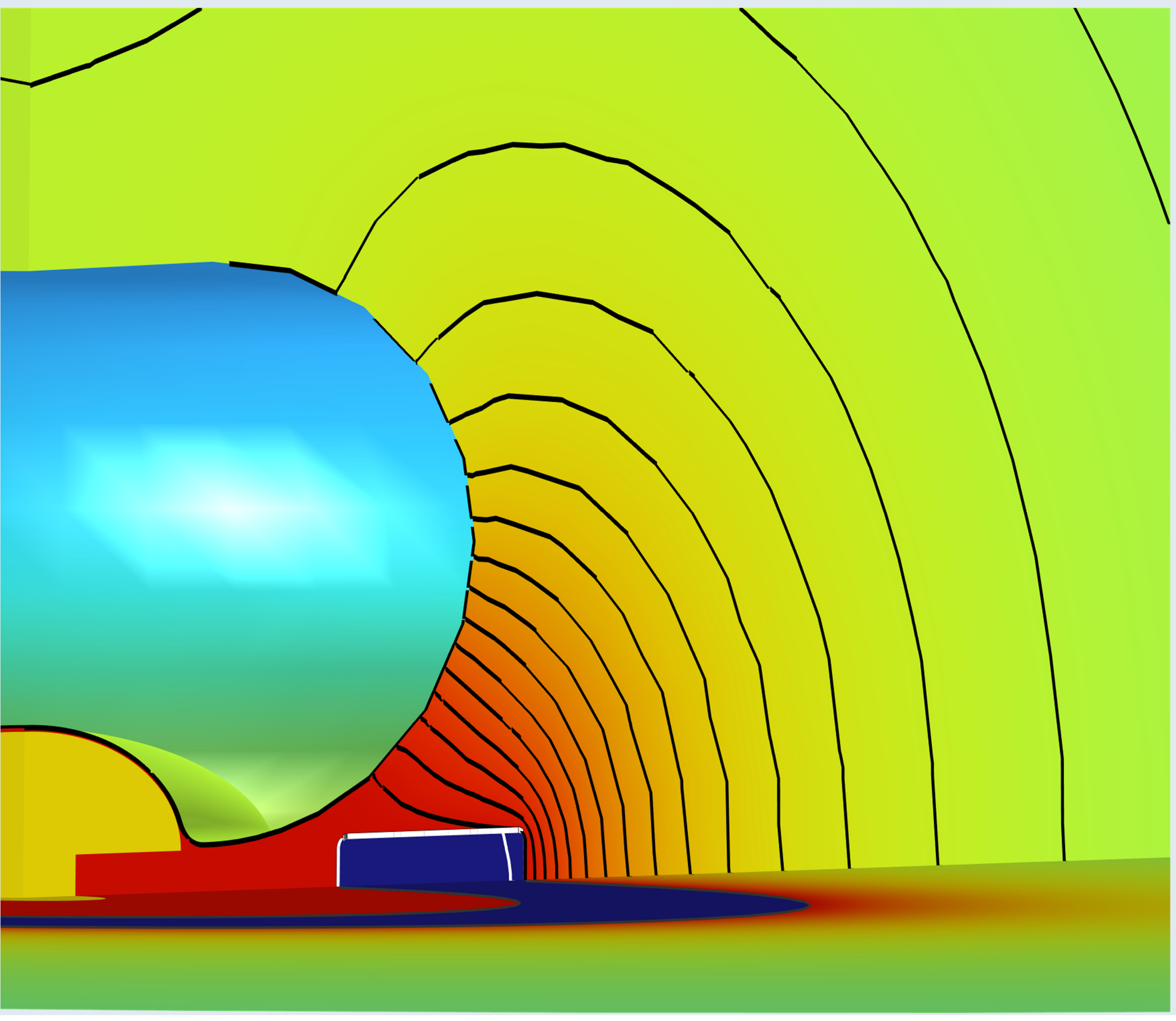

Ionic Neuromodulation and Neurosensing Platform for In-Vitro Studies

Assess the viability of localized, coordinated, ionic stimulation and sensing for modulating the neuron response with mitigated electrical cross-talk.

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Abstract

Unveiling the complex biophysics of neurons, neuron tissues and brains can unlock countless possibilities ranging from the treatments of disorders, to the replica of neural networks behavior in hardware or software.
Our work aims at supporting neuron/brain studies by providing a tool to design novel in-vitro platforms for closed-loop neuromodulation and neurosensing.

The novelty of our simulation platform is the co-integration of microelectrode-array sensors with conductive polymer-based (CP) ionic actuators, which enables a "more physiological" (w.r.t. electrical stimulation) ionic modulation of the neural activity.

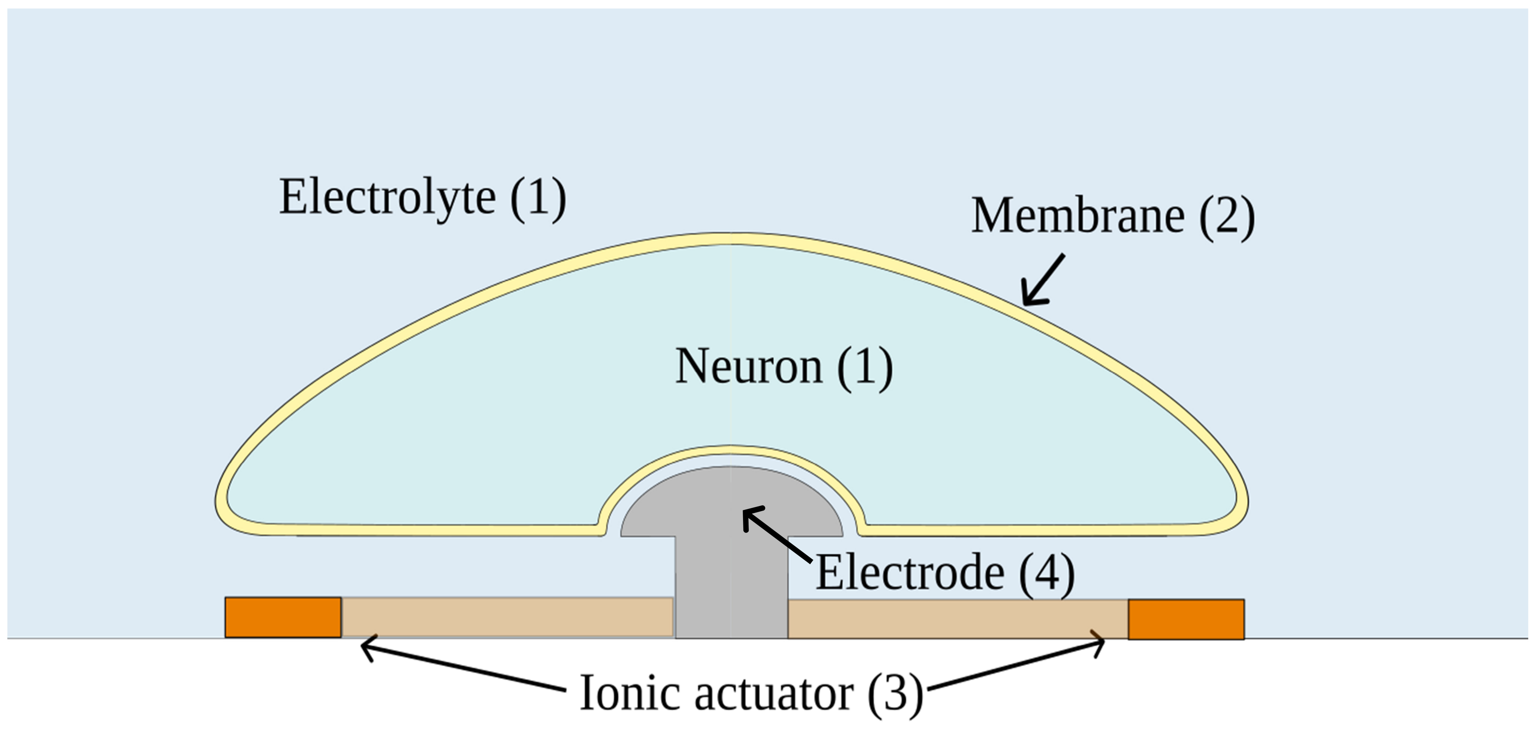

FIGURE 1: Sketch of the system cross-section composed of a neuron engulfing a mushroom sensing microelectrode and over a polymer-coated electrode disc for ionic stimulation.

Methodology

The neuromodulation-neurosensing system is shown aside and is solved in 2D-axisimetric coordinates to save simulation time. The system elements are bathed in a physiological electrolyte containing the relevant mobile physiological ions and lowly mobile organic molecules. The main physical model are as follows:

1. Poisson-Nernst-Plank for the Neuron and Electrolyte (tcd+es)
2. Augmented Hodgkin-Huxley (Refs. 1,2) for the Membrane (bode)
3. Two-phase model (Ref. 3) for the Ionic Actuator (2es+tcd)
4. Dynamic site-binding for the Electrode surface (bode)

Results

The controlled release of [Ca2+] during an ionic neuromodulation (right y-axis in panel b), exerted by the electrical stimulus (right y-axis in panels b and c) effectively stops the bursting activity of the neuron (panel a), bringing it back to tonic firing (panel b).

The sensed biphasic potential on the electrode appears both without (panel c) and with (panel d) the actuation signal. Fine control of the actuation signal mitigates the cross-talk artifacts superimposed to the useful signal (panel d), thus enabling to discriminate recording during actuation.

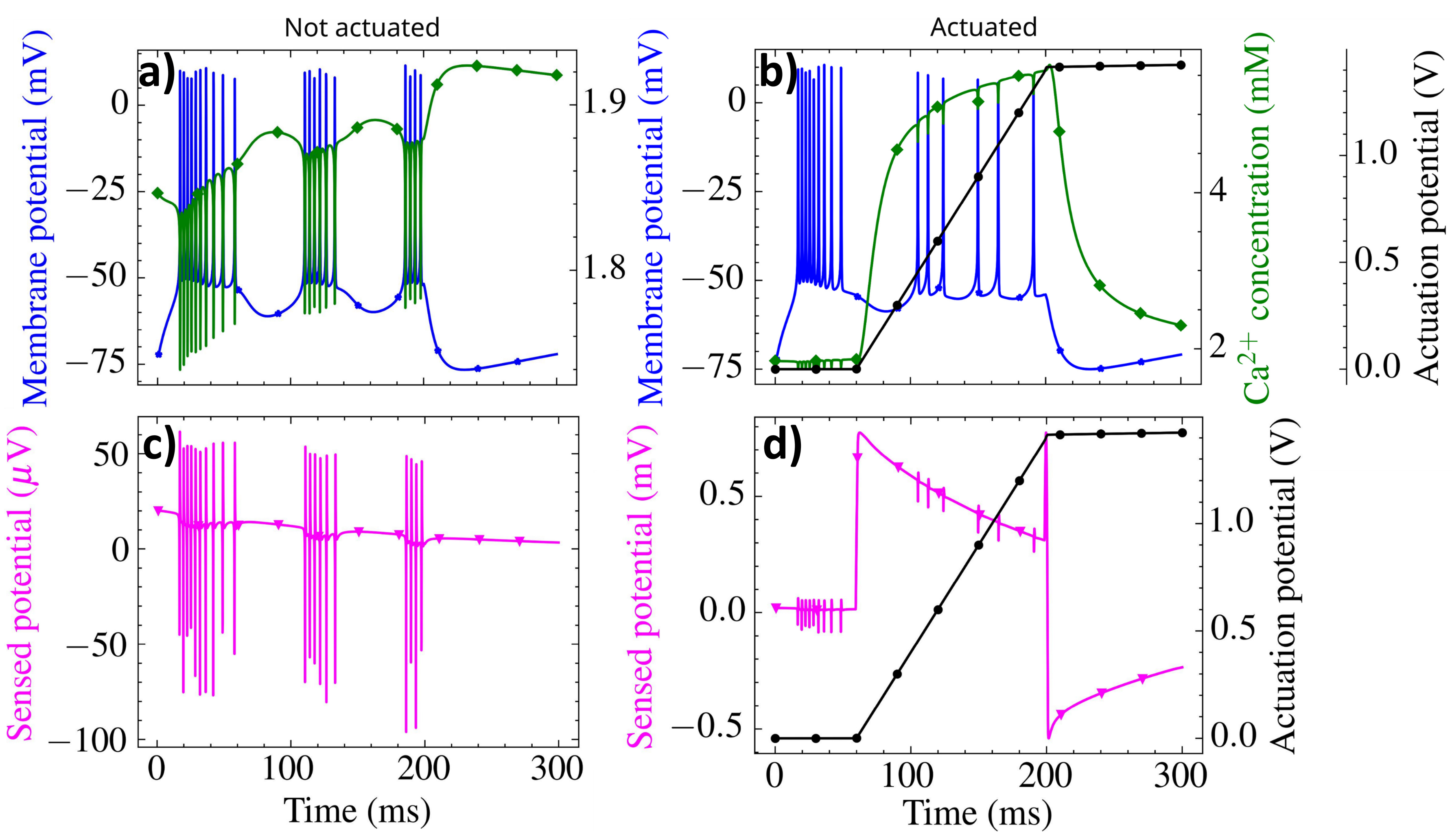

FIGURE 2: Signals with/without actuation of neuron activity.

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REFERENCES

1. Hodgkin, A. L., Huxley, A. F., (1952), A quantitative description of membrane current and its application to conduction and excitation in nerve. The Journal of Physiology, 117 doi: 10.1113/jphysiol.1952.sp004764.
2. Golomb, David et al. "Contribution of persistent Na+ current and M-type K+ current to somatic bursting in CA1 pyramidal cells: combined experimental and modeling study." Journal of neurophysiology vol. 96,4 (2006): 1912-26. doi:10.1152/jn.00205.2006
3. Klas Tybrandt et al. Chemical potential–electric double layer coupling in conjugated polymer–polyelectrolyte blends.Sci. Adv.3,eaao3659(2017).DOI:10.1126/sciadv.aao3659

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