



UNIVERSITY OF
CALGARY

Optimizing Three-Dimensional Microelectrode Geometries for Neurostimulation

**Visualization of Electrochemical Species Distribution in
Neurological Systems**

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Neurological Disease

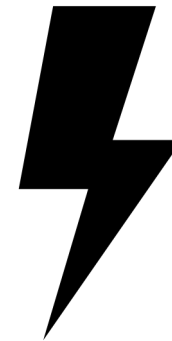
#1 cause of disability worldwide [1]

#2 cause of death worldwide [1]



Traditional Treatments:

Ineffective, only address symptoms of disease, costly



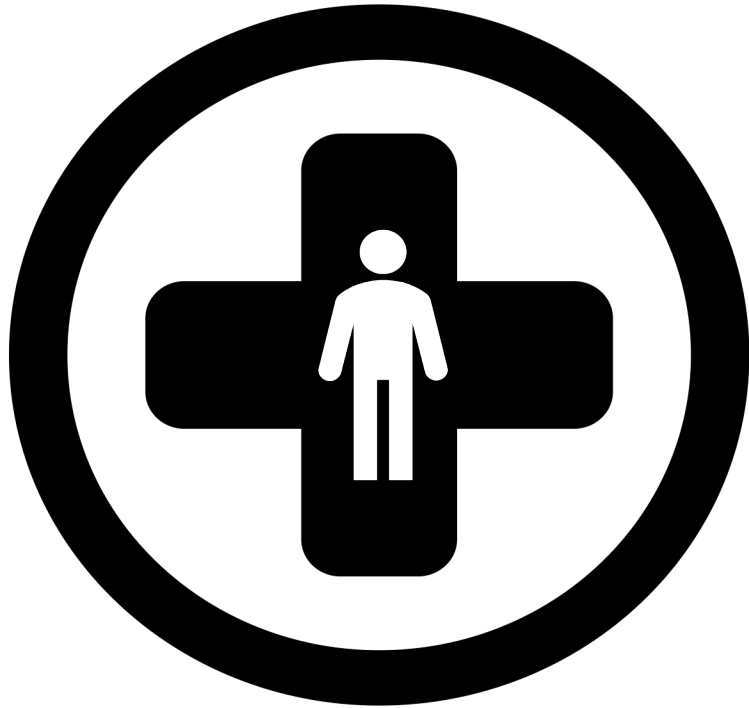
Neuromodulation:

The closed-loop recording and stimulation of neurons has shown promise in therapies for:

Epilepsy • Parkinson's • Neuropathic pain
Essential Tremor • Memory disorders
Depression • Obsessive compulsive disorder [2]



Patient Care First



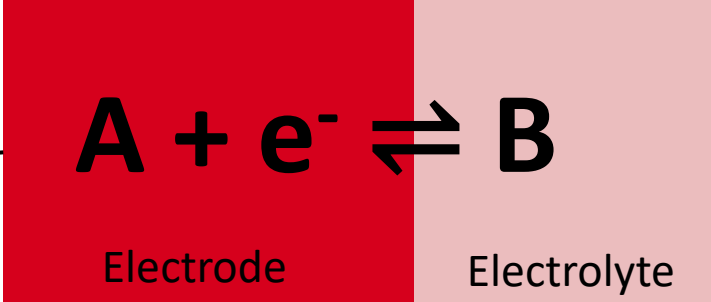
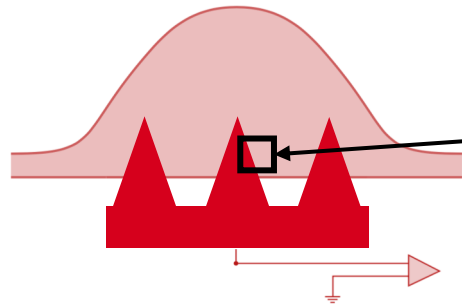
Selectivity



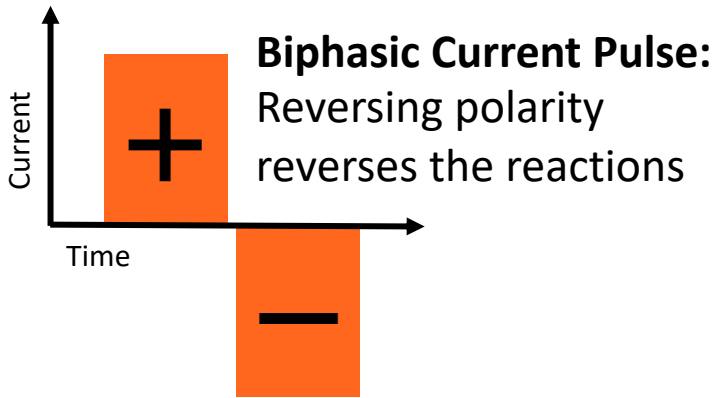
Safety



Neurostimulation Theory – Faradaic Charge Injection



Redox reactions transfer charge from electrode to electrolyte



Corrosion



Cytotoxic Products



COMSOL Multiphysics Set-Up

COMSOL Interface Used:
Secondary Current
Distribution coupled with
Transport of Diluted Species

Common Models

Neglect redox products

Ohmic resistance

This Work

Electrolyte as movement of
diffusing charges

Visualizes redox products

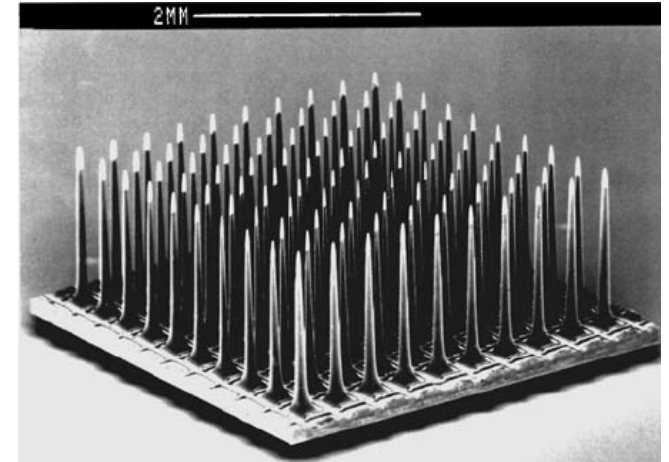
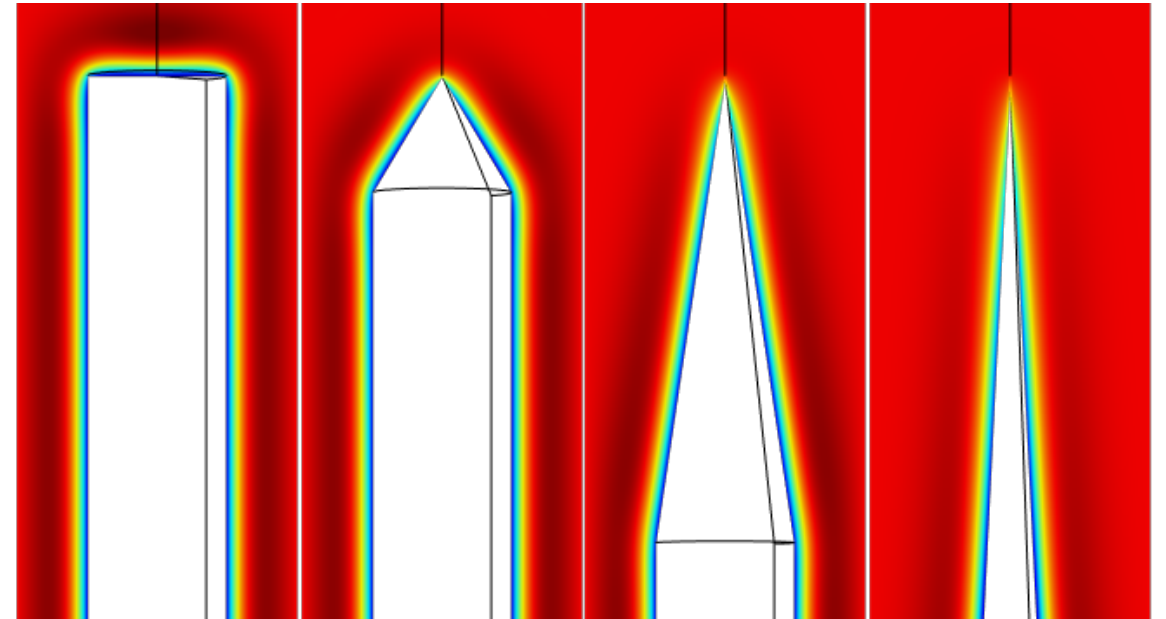
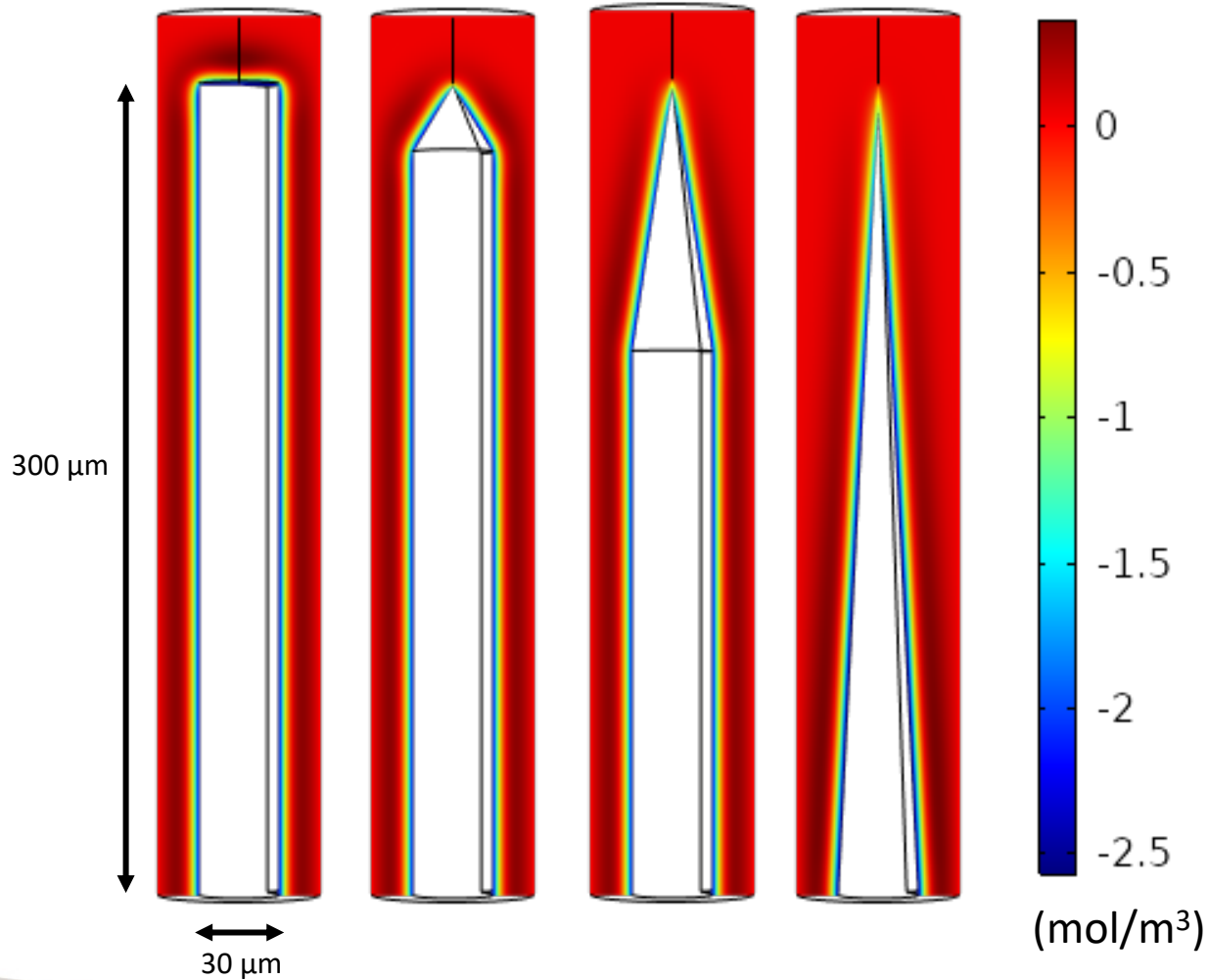


Figure 1: Typical Commercial Utah Array from Blackrock Microsystems [3]



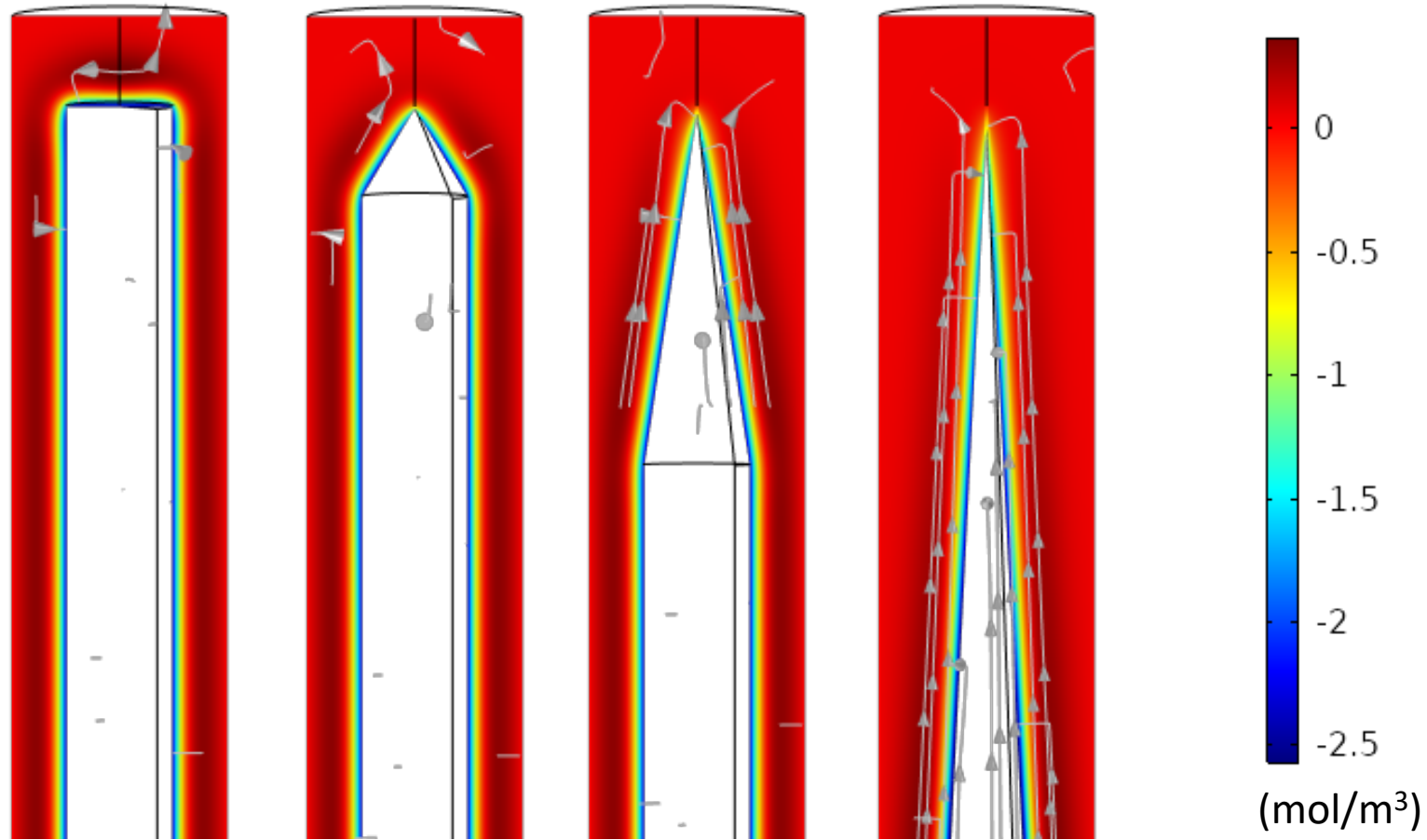
Redox Species Concentration By Geometry



Faradaic reactions and double layer capacitance redistribute current density to be more uniform on conical electrodes [4]

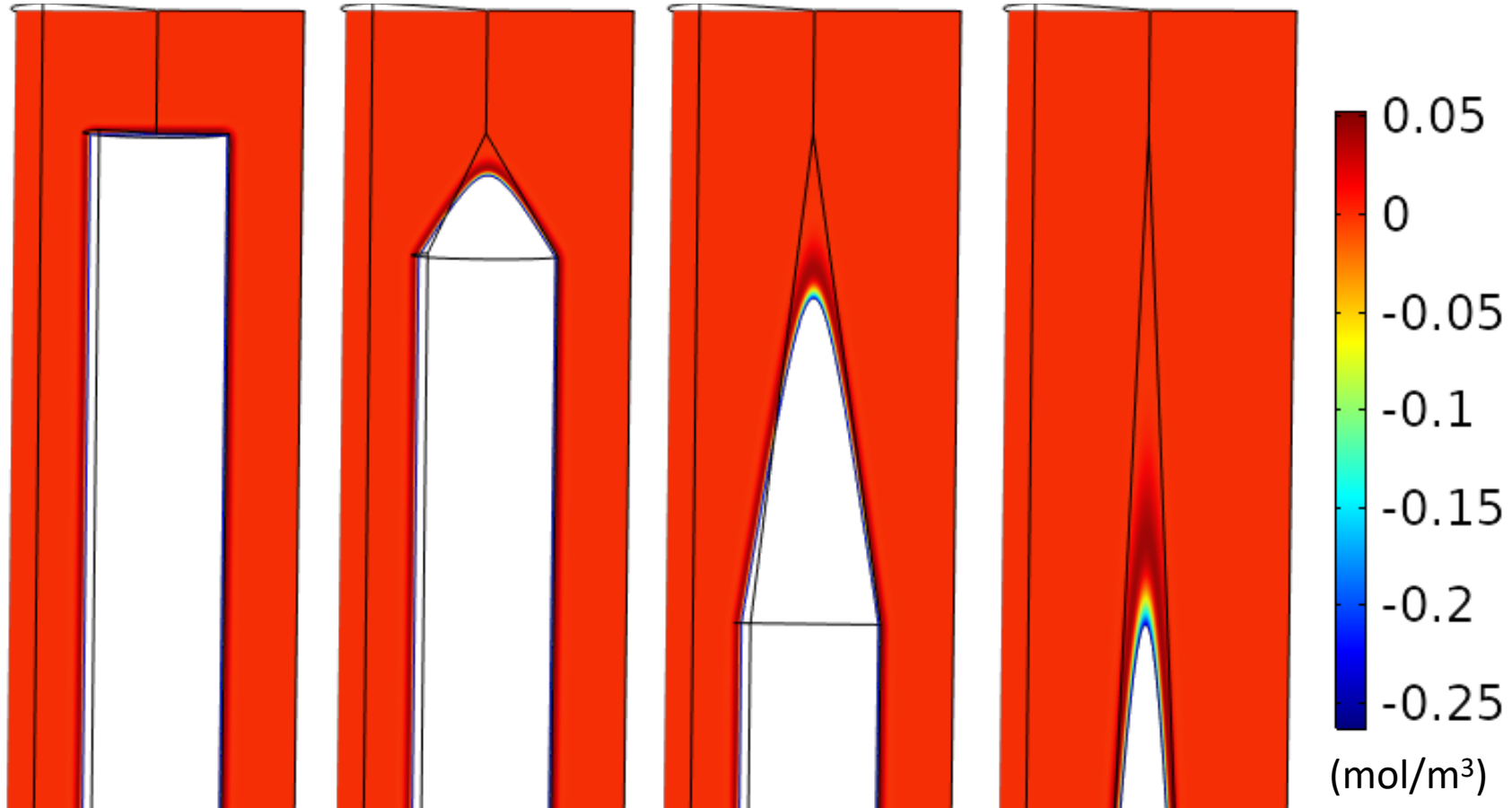


Diffusion – Non-Uniform Distribution of Products



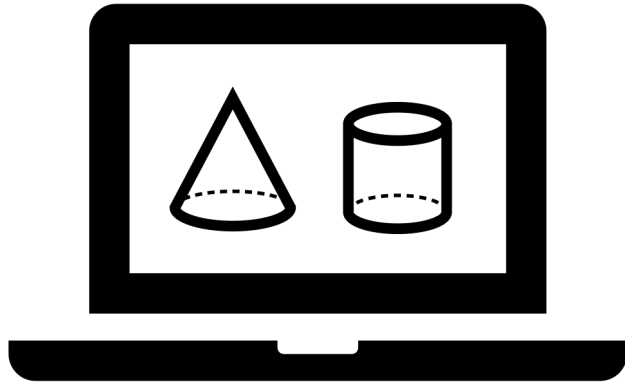


Redox Species Concentration - Off-Center Vertical Slices





This Work



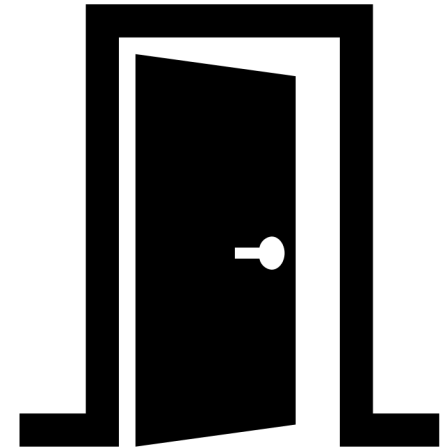
- Visualization of redox species distribution around stimulation microelectrodes

Key Results



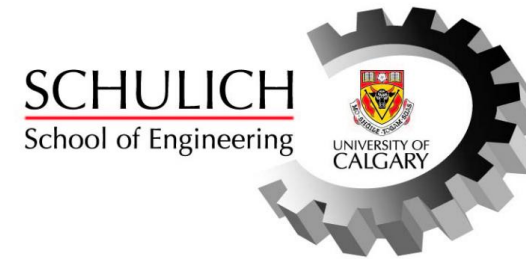
- Uneven redox species distribution as caused by varying geometries potentially affect safety and selectivity

Future Research



- Long-term corrosion effects
- Tissue damage

Acknowledgements



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References

- [1] Carroll W. M. (2019). The global burden of neurological disorders. *The Lancet. Neurology*, 18(5), 418–419. [https://doi.org/10.1016/S1474-4422\(19\)30029-8](https://doi.org/10.1016/S1474-4422(19)30029-8)
- [2] Sun, F. T., & Morrell, M. J. (2014). Closed-loop neurostimulation: the clinical experience. *Neurotherapeutics : the journal of the American Society for Experimental NeuroTherapeutics*, 11(3), 553–563. <https://doi.org/10.1007/s13311-014-0280-3>
- [3] Kim, Seung-Jae & Manyam, Sandeep & Warren, David & Normann, Richard. (2006). Electrophysiological Mapping of Cat Primary Auditory Cortex with Multielectrode Arrays. *Annals of biomedical engineering*. 34. 300-9. 10.1007/s10439-005-9037-9.
- [4] Cogan, S. F., Ludwig, K. A., Welle, C. G., & Takmakov, P. (2016). Tissue damage thresholds during therapeutic electrical stimulation. *Journal of neural engineering*, 13(2), 021001. <https://doi.org/10.1088/1741-2560/13/2/021001>