Characterization of Multi-Material Neural Interface Devices

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Introduction & Methods

- Clinical grid electrodes are routinely implanted directly on the surface of the brain in drug-resistant epilepsy patients and in patients with brain tumors.
- These clinical grids measure the electrical activity of the brain in a process called electrocorticography (ECoG) [1] to localize diseased and normal brain function to inform neurosurgical resection procedures.

Electrodes need to be characterized by electrochemical procedures to understand the nature of interaction between the metal electrode and the biological tissue.

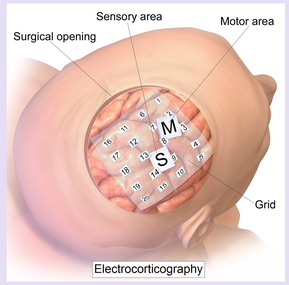


Figure 1. Clinical electrodes set up for ECoG [2]

- Comprehensive characterization of the electrodes involve 2-, 3-, & 4-point electrochemical experiments in saline solution (Figure 2) with Gamry software & instrumentation along with MATLAB to assess
  - Impedance
    - The effective resistance and capacitance in an electrode to measuring brain activity. A higher impedance means greater noise during recording (outcome of 3-point configuration).
  - Cyclic Voltammetry
    - Measurement of current through electrode to evaluate "water window" where reactions are still reversible.
  - Charge Injection Capacity
    - The maximum amount of charge that an electrode can sustain before breaching the redox threshold and oxygen/hydrogen is released.

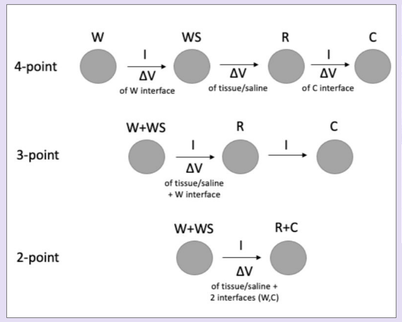


Figure 2. Electrode set up of different configurations.

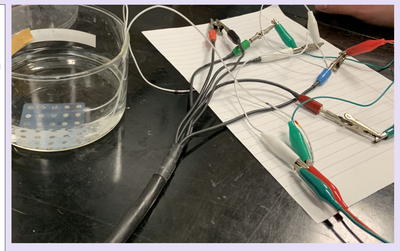


Figure 3. 4-point configuration set up for clinical platinum electrode.

Objectives

- Characterize different diameter electrodes (10 - 800 µm) made of Platinum (Pt), Titanium (Ti), and poly(3,4-ethylenedioxythiophene) (PEDOT) for:
  - Impedance, Cyclic Voltammetry, and Charge Injection Capacity.
  - To understand the influence of (i) diameter and (ii) material on the electrochemical properties that determine the quality of the recording and the safety of the electrical stimulation in the brain.

Experimental Design & Results

characterize clinical platinum electrode array → characterize multi-diameter & multi- material electrodes → Analyze Signal-to-noise ratio (SNR) in rats, analyze high gamma band responses/ recordings from the rat barrel cortex

1. Characterize clinical platinum electrode array

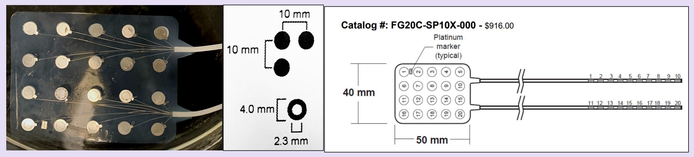


Figure 4. Picture and dimensions of clinical platinum electrode used in this experimentation.

2. Characterize multi-diameter & multi-material electrodes

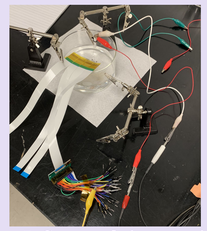


Figure 5. Setup of characterizing 64-channel microelectrodes.

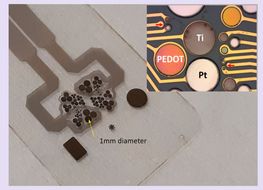


Figure 6. Variable diameter clusters.

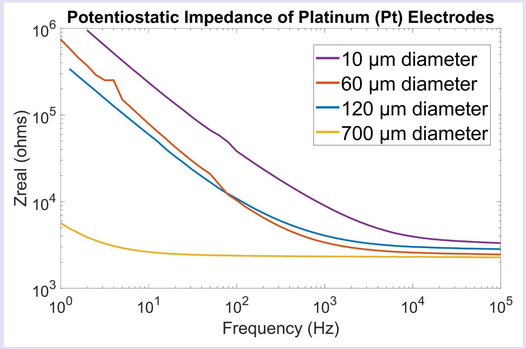


Figure 7. Impedance of Platinum Electrodes of selected diameters at 10-700 µm

- Impedance decreased as the surface area of the platinum electrode was increased.

Results (continued)

3. Recording whisker barrel cortex activity in rats:

We placed the electrode on the surface of the rat barrel cortex during whisker stimulation by air puff with a small air tube.

Figure 8. Electrode placed on rat whisker barrel cortex.

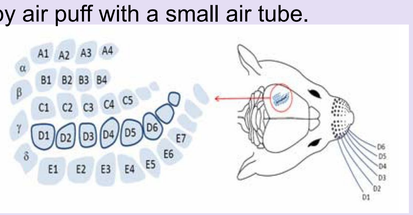


Figure 9. rat barrel cortex and schematic of whisker stimulation [3].

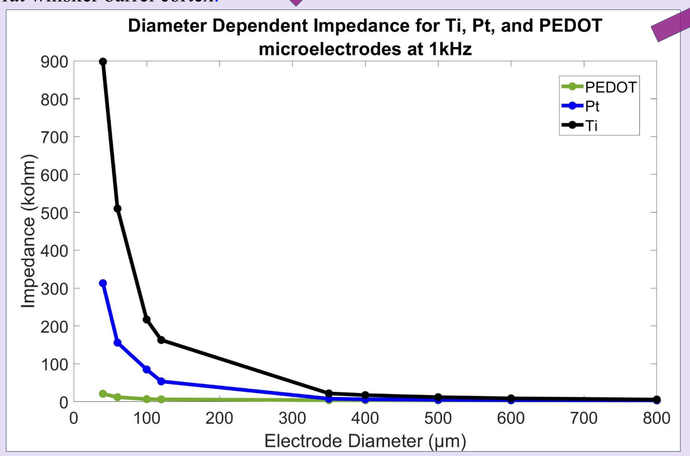
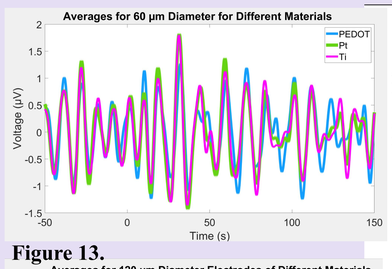


Figure 10. Diameter Dependent Impedance was evaluated



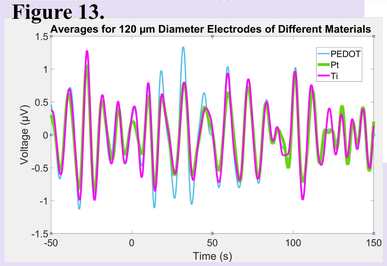


Figure 13.

Figure 14.

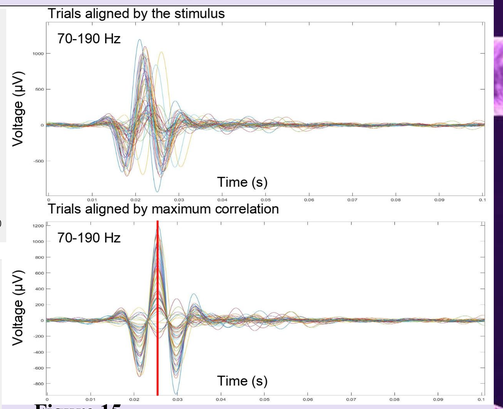


Figure 15.

The average plots (Fig. 13-14) had a lower amplitude compared to the expected data (Fig. 15) indicating that data was collected for this experimentation may have been noise.

Discussion & Conclusion

Our future steps consist of more animal case study experiments using electrodes which generate less noise. With such categorization of electrodes in this experiment, potential treatment and therapy options can be devised to study neural disorders when these electrodes are utilized.

Acknowledgements

Thanks to Integrated Electronics and Biointerfaces Laboratory and GEAR program

[1] Koubeissi, Mohamad Z, and Patricia O Shafer . "Video EEG Monitoring with Invasive Electrodes." *Epilepsy Foundation*, Oct. 2018, www.epilepsy.com/learn/treating-seizures-and-epilepsy/surgery/tests-surgery/video-eeg-monitoring-invasive-electrodes.

[2] Blausen.com staff (2014). "Medical gallery of Blausen Medical 2014". WikiJournal of Medicine 1 (2). DOI:10.15347/wjm/2014.010. ISSN 2002-4436.

[3] Valente, Sabrina & Ringwood, John & Mcloone, Violeta & Lowry, John. (2012). Investigation of events in the EEG signal correlated with changes in both oxygen and glucose in the brain. 1-6. 10.1049/ic.2012.0220.