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.
- 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
  - Cyclic Voltammetry
  - Charge Injection Capacity
- 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).
- Measurement of current through electrode to evaluate “water window” where reactions are still reversible.
- The maximum amount of charge that an electrode can sustain before breaching the redox threshold and oxygen/hydrogen is released.

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

1. Characterize clinical platinum electrode array
2. Characterize multi-diameter & multi-material electrodes
3. Record 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.

Results (continued)
- Recording whisker barrel cortex activity in rats:
  - 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).

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

References

Figure 1. Clinical grid electrodes set up for ECoG [2]
Figure 2. Electrode set up of different configurations.
Figure 3. 4-point configuration set up for clinical platinum electrode.
Figure 4. Picture and dimensions of clinical platinum electrode used in this experimentation.
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
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 of Ti, Pt, and PEDOT microelectrodes at 1kHz
Figure 11. Average plots (Fig. 13-14) had a lower amplitude compared to the expected data (Fig. 15).
Figure 12. 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.

Figure 13.
Figure 14.
Figure 15.