Development and Characterization of a High-Density Flexible Neural Recording Probe

Cedar Rose Leach[1], Nikolas Barrera[2], Emmanuel Ramirez[2], Ellis Meng[1,2]
[1]Ming Hsieh Department of Electrical and Computer Engineering, University of Southern California, USA
[2]Alfred E. Mann Department of Biomedical Engineering, University of Southern California, USA

Biomedical Microsystems Laboratory

Introduction

Goal: design, fabricate, and characterize a high-density, flexible, Si-polymer neural recording probe.

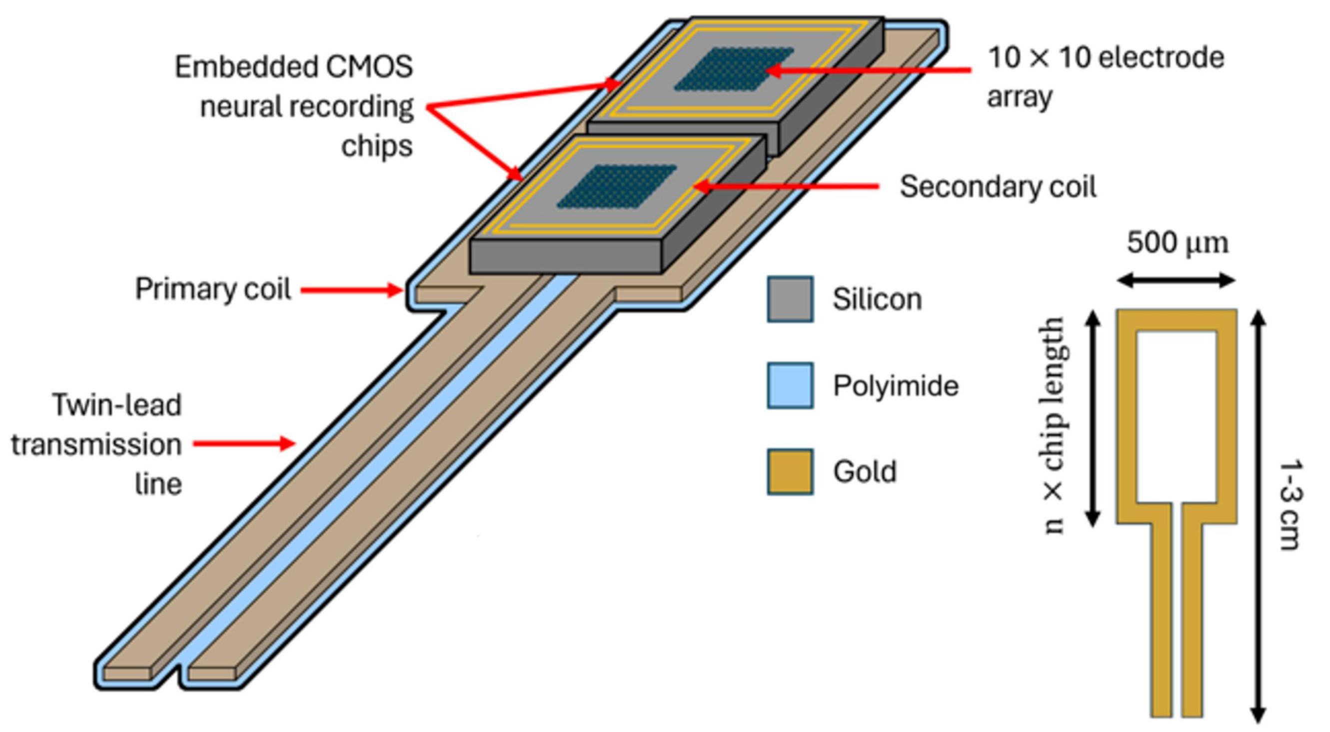

Fig. 1: Hybrid Si-polymer neural recording probe consisting of flexible shank and primary coil with embedded silicon ASICS. ASICS contain high-density electrodes and a secondary coil to couple with the primary coil.

- Hybrid approach combines **high spatial resolution** neural recordings from silicon with the polymer's lasting **flexible** mechanical properties and **biocompatibility** required for neural implants
- Flexible waveguide uses inductive coupling to wirelessly transmit GHz neural signals from the brain to an external system.

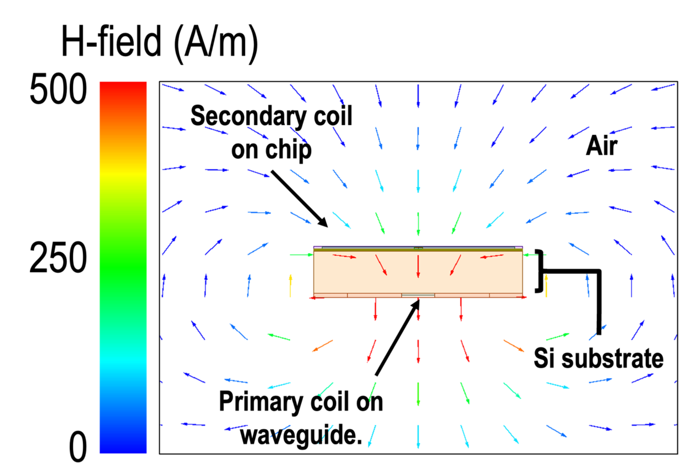

Fig. 2: Cross-section of probe. Magnetic field lines represent the inductive link. Demonstrates how energy is transferred wirelessly through electromagnetic induction.

Development

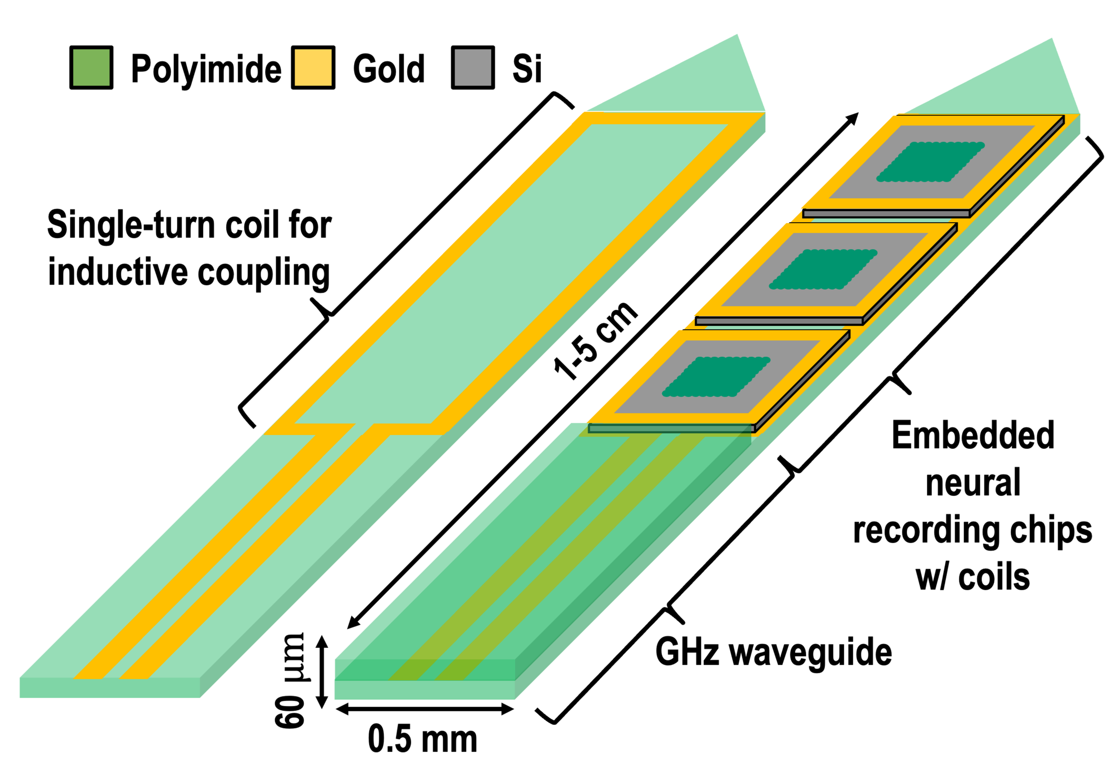

Fig. 3: Flexible shank with resonant inductive coupling to embedded silicon neural recording chips.

- Gold shank and coil insulated with **polyimide**
- Embedded silicon neural recording chips, 100 electrodes/chip for **high special resolution**
- Wireless transfer of data between the embedded chips and primary coil via **inductive coupling** and **load modulation**.

How do we fabricate this hybrid Si-polymer coil + shank?

Fabrication Approaches

- Femtosecond laser ablation to pattern titanium sheets + parylene deposition for insulation
- 3D Resin coil molds for platinum wire
- Femtosecond laser-patterned silicon wafers
- 100μm parylene deposition over coil in silicon wafer mold

- Femtosecond laser-patterned glass slide to form wire into coil and shank. Insulated with Kapton and cured epoxy. Flattened by top glass slide.

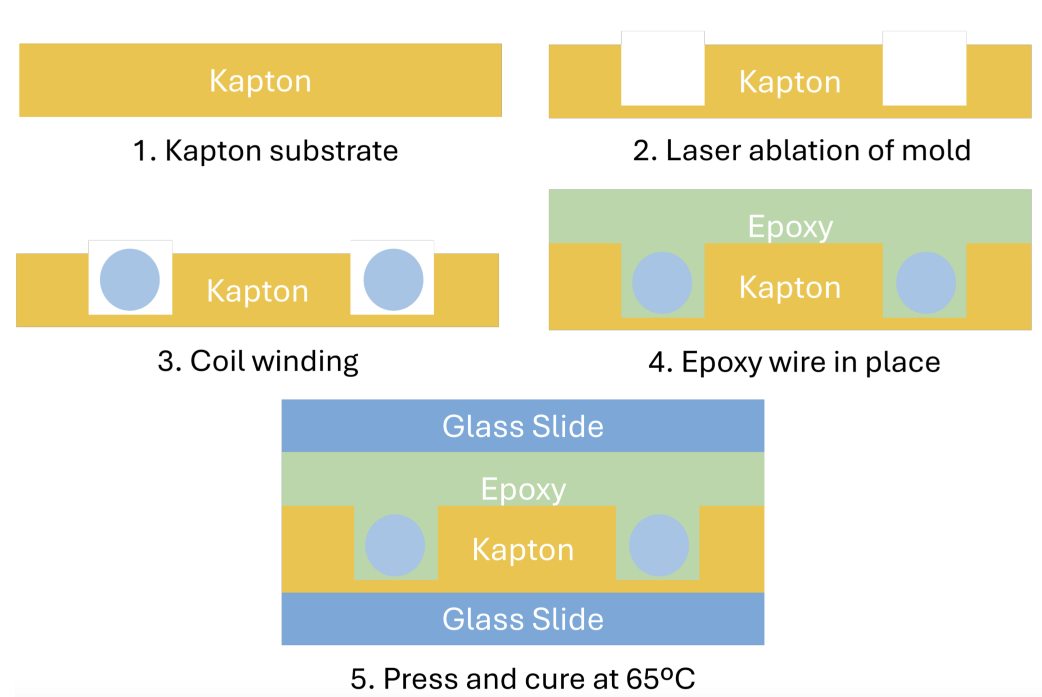

Fig. 4: Coil + shank fabrication procedure with engraved glass slide as coil mold with Kapton and epoxy as flexible substrate.

Fig. 5: Patterned wire-bending mold with coil in the polyimide substrate.

Characterization

1) Device packaging for coil measurements

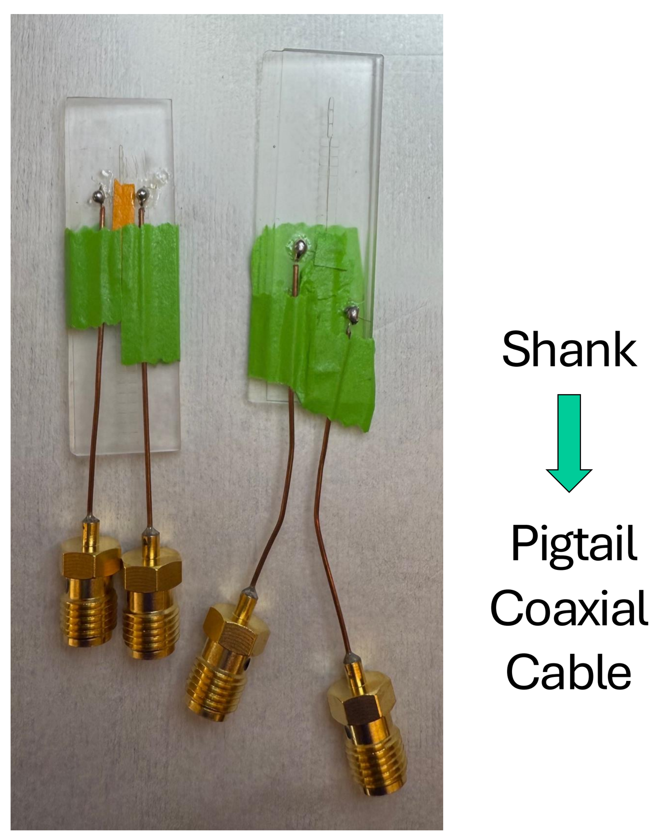

Fig. 6: Packed initial rendition of neural probe to collect shank + coil measurements.

2) COMSOL Multiphysics simulation to analyze characteristics across different frequencies

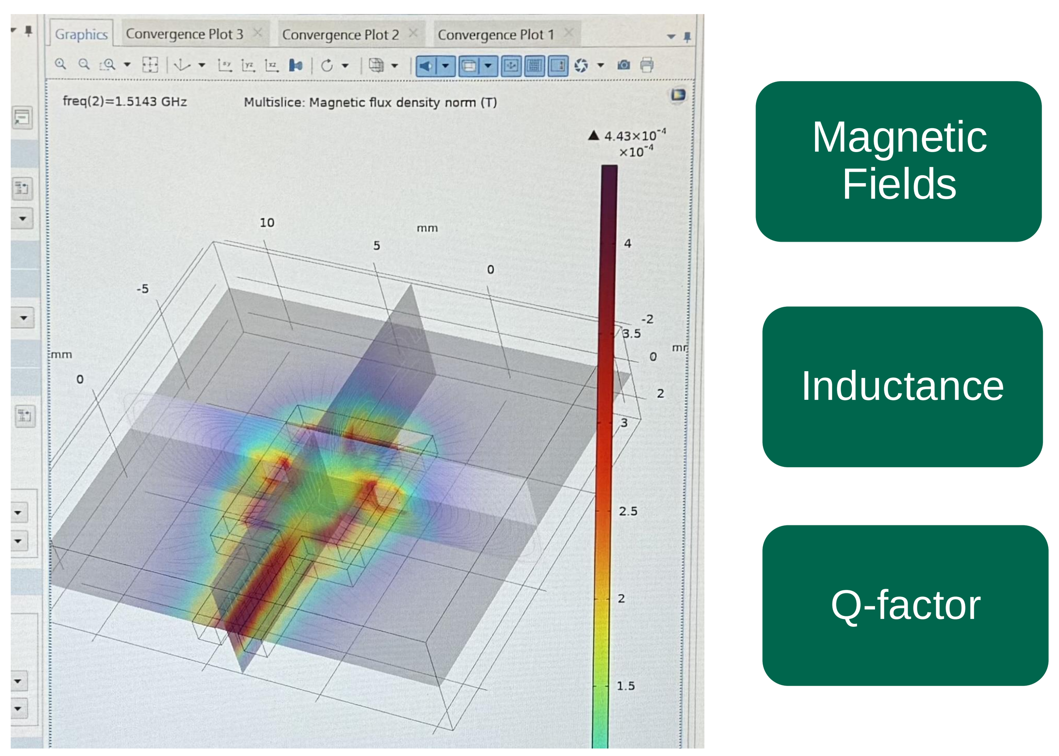

Fig. 7: Using COMSOL Multiphysics to simulate the magnetic fields, inductance, and Q-factor of the primary coil, across various frequencies.

3) Designing PCB to characterize inductive coupling efficiency of primary coil

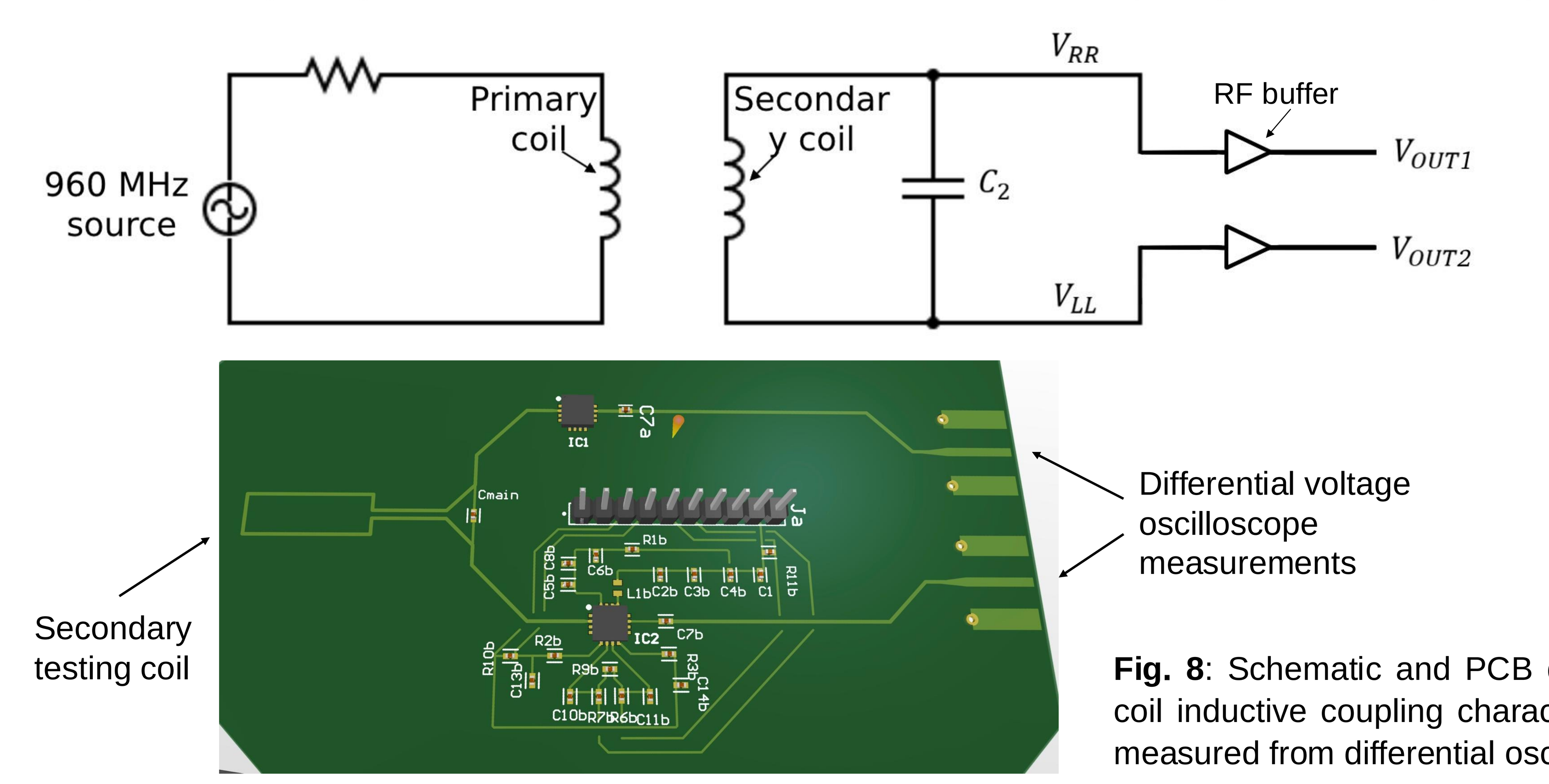

Fig. 8: Schematic and PCB design for primary coil inductive coupling characterization. Signals measured from differential oscilloscope probes.

Conclusions

Fabrication Method

- Engraved glass slide
- Wrapped wire
- Kapton tape + cured epoxy as the flexible substrate

Next Steps

- Continue characterization
- Method to embed ASICS

Acknowledgements

Work led by Nikolas Barrera who created Fig. 1-5. Extended gratitude towards Nikolas Barrera, Emmanuel Ramirez, and Ellis Meng for their mentorship and support.

This work was supported by the USC Provost's Fellowship and the National Science Foundation (NSF Award ECCS-2133138).