Towards a Distributed, Chronically-Implantable Neural Interface

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KEY FEATURES
• Niobium microwires for observing local field potentials along cortical column
• Ultra-low power instrumentation for signal acquisition and data reduction
• Autonomous, self-calibrating wireless transceiver architecture for receiving power and transmitting data
• Hermetically-sealed micropackage suitable for chronic use
• Surgical tool to facilitate manual and robot-assisted insertion

MOTIVATION
Brain Machine Interfaces (BMIs) have a genuine opportunity to impact through clinical translation, for example, restoring movement and communication in patient populations with tetraplegia, amyotrophic lateral sclerosis, locked-in syndrome, and speech disturbances.

GRAND CHALLENGES
• Improving the overall decoding capacity of chronic neural interfaces
• Achieving complete wireless power delivery and data telemetry
• Scaling the number of electrodes and record from larger areas of the brain
• Ensuring chronic stability and long-term reliability of the implanted devices

LFPs: RECORDING, PROCESSING, AND DECODING
• Each probe uses 8 microelectrodes to observe local field potentials (LFPs) along the cortical column
• LFPs have been shown to be more chemically stable than extracellular action potentials (EAPs)
• Niobium features a small diffusion current density, chemical stability, and biological inertness, which is suitable as an electrode material for recording LFPs
• Microscopic electrode length varies from 1.5 to 5.0 mm (correspond to approximately cortical layers 9 to 34)
• Each probe employs adaptive filtering to generate a set of multi-channel LFP signals
• The locally referenced (differential) recordings aim to increase the spatial ‘focal’ of the LFPs
• An unprocessed, ultra-low power, adaptive selection is performed locally to select relevant/informative signals & reduce the amount of data sent to the external processor
• The external processor extracts informative features and infers/delivers the underlying spike dynamics/behavior
• Informative features can be extracted from the time domain (e.g. local motor potential, LMP) and/or frequency domain (e.g. power in the delta or high gamma bands)
• Due to large scales, nonlinear, and nonstationary neural activity observed from many distributed probes, we employ a deep-learning based decoder, which will be optimized and deployed in a small, portable, and relatively low-power platform (FPGA/RISC) for real-time application

WIRELESS AND SENSING ELECTRONIC SYSTEM
• This integrated system presents a distributed architecture that may be able to incorporate 100s of sub-implant units together
• Each probe performs wireless telemetry as well as autonomous power management using a gold-plated Ni-coll BF-coil

PROBE CONSTRUCTION AND IMPLANTATION
• Use of bio-compatible material and standard microfabrication technologies for minimization, bio- and CMOS compatibility
• Structure consists of two modules: CMOS housing hermetically packaged microelectronic module and polymer-encapsulated microcircuit array
• Hemerticity and system robustness are achieved thanks to externally bonded joints and low-permeability outer polymer jacket encapsulation
• Feedthroughs are formed by tunneling connections under the seal ring and electrically connecting them to the other module by bump/bucktestrom bonding
• Implantation will be performed using a custom-insertion device comprising a sliding anti-backing guide and accompanying syringe applicator
• Implantation method allows for better electrode orthogonality to the cortex and maintaining low insertion forces