ABSTRACT

A FLEXIBLE ORIGAMI OPTO-ELECTRO ARRAY FOR IN VIVO OPTOGENETIC STIMULATION AND ELECTROPHYSIOLOGY AND STABILITY PERFORMANCE ANALYSIS FOR CHRONIC NEURAL IMPLANTS

By: Yan Gong
Advisor: Wen Li

To date, a wide variety of neural tissue implants have been developed for neurophysiology recording from living tissues, and neural interfaces provide a direct communication pathway between nervous systems and machines. This direct communication pathway offers a new potential method to research neuron working mechanism, and to manipulate neuron activity. Simultaneously, many challenges, that raised up with rapid development of biomedical implants, need to be overcome. First, an ideal neural implant should ensure its own safety, which means minimizing the damage to the tissue and performing reliably and accurately for long periods of time. On the basis of safe implantation, better recording capabilities, flexible and configurable are required by future tools. For decades, many artificial neural interfaces evoke sensation in central and peripheral nervous systems (CNS and PNS respectively) by electrical signals. However, electrical stimulation has many limitations and difficulties, hardly considered the best solution for many cases, neural stimulation needs
improved technology. Optogenetic, a rising role in field of neural interfaces, has proven its capabilities by direct optical stimulation of genetically modified target neuron population and achieving dramatical advantages comparing with traditional methods in spatial and temporal resolution.

This written report provides a development process towards an origami implantable recording array integrated with multiple micro-LEDs, and conduct systematic research on the challenges mentioned above, including but no limited to packaging technique, packaging material, and evaluation of encapsulation in reactive environments.

In order to systematically study package material and package technique, different materials properties are discussed for the chronic implantation of devices in the complex environment of the body, including biocompatibility, and moisture and gas hermeticity. This report summarizes common solid and soft packaging used in a variety of neural interface designs, as well as their packaging performances in term of electrical properties, mechanical properties, stability, biodegradability, biocompatibility, and optical properties.

For study reliable packaging for implantable neural prosthetic devices in body fluids. This report studied the stability of Parylene C (PA), SiO2, and Si3N4 packages and coating strategies on tungsten wires using accelerated, reactive aging tests in three solutions: pH 7.4 phosphate-buffered saline (PBS), PBS + 30 mM H2O2, and PBS + 150 mM H2O2 to simulate different inflammation situations. Different combinations of coating thicknesses and deposition methods to meet different design requirements were studied at various testing temperatures to accelerate the aging process.
Finally, these package techniques and material knowledge were used to fabricate origami neural implants. A 2D to 3D convertible, thin-film, opto-electro array with 4 addressable microscale light-emitting diodes (LEDs) for surface illumination and 9 penetrating electrodes for simultaneous recordings has been developed. The fabrication methods have been discussed with the electrical, optical, and thermal characteristics of the opto-electro array being quantified.