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DESIGN OF A MULTI-FUNCTIONAL SMART OPTRODE FOR ELECTROPHYSIOLOGY AND OPTOGENETICS

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ABSTRACT

Optogenetics is a neuromodulation method that holds great potential for the realization of advanced neuroprostheses due to its precise spatial-temporal control of neuronal activity [1]. The development of novel optogenetic implants (optrodes) may open new doors to investigate complex brain circuitry and chronic brain disorders, such as epilepsy, migraine, autism, Parkinson's disease, etc [2]. Design challenges for the optrode include interference minimization between the μ LED drivers and the recording electrodes, selection of proper materials, structures and dimensions to minimize tissue damage, biocompatibility, and batch production.

In this work, we propose the construction of a multi-functional optrode to be used for physiological studies in group-housed, freely-moving rodents. It comprises commercial blue-light μ LEDs for optical stimulation, an active electrode array for recording the local field potentials at different depths in the brain, and a time-domain temperature sensor.

To accomplish this, silicon bulk micromachining is the essential technique used for the device manufacturing. Process steps include epitaxial growth, layers deposition, geometrical etching, ionic implantation, oxidation and diffusion.

For the interconnection of the μ LEDs, flip-chip bonding is used. Light intensity and frequency can be controlled via a microcontroller interface assembled on a flexible PCB mounted on the rodent head-stage. The active microelectrode array (MEA) is constructed from a Ti/TiN layer to both meet the biocompatibility requirements and to reduce the electrode-tissue interface impedance, and by this the associated thermal noise. Using a custom, simple, robust and cost-effective BiFET in-house IC technology, the recording amplifiers are monolithically integrated into the MEA to achieve a high signal-to-noise ratio (SNR) and to minimize potential crosstalk coming from the μ LED drivers.

Using the same BiFET IC technology, a time-domain temperature sensor is monolithically integrated into the optrode to anticipate possible brain tissue temperature changes of more than 1°C that may come from heat dissipation in the μ LEDs or circuit power dissipation.

Finally, the optrode is coated with a PDMS film to electrically protect the μ LEDs from the tissue and avoid uncontrollable electrical stimulation of the brain tissue.

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