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Available Master thesis/Projects at the PLASTICITY NEUROELECTRONICS (PLASTRONICS) LAB

Project 1:

Smart surface Biofunctionalization for enhancing extracellular neuronal signals to feature intracellular-repertoire on a large-scale CMOS-chip

The project explores the application of smart biofunctionalization[1] to provide a novel bio-electronic interface between the high-density CMOS-MEA[2] surface and cell membrane of neuronal networks. The aim is to engineer a large-scale method allowing simultaneous non-invasive, long-term, high spatiotemporal resolution bioelectrical signal detection from several thousand of intracellular-like[3,4] spiking activity of human-derived neurons. This work has a high impact on assessing neuronal network dynamics and connections with a higher throughput capacity than standard electrophysiological methods (i.e., patch-clamp). The goal of a 6-8 month student project is to learn the application of the biofunctionalization method for growing human-derived neurons on CMOS-chip devices. Also, recording neuronal intracellular-like signals using planner CMOS microelectrodes, and simulate a model for a neuron-electrode passive electrical coupling circuit.

Project field:

Neuroscience, bioengineering, microtechnology, surface chemistry, and electrophysiology

Project requirements:

knowledge in neurobiology, extracellular electrophysiology, coding, and simulation.

References

1. Amin, H., Dipalo, M., De Angelis, F. & Berdondini, L. Biofunctionalized 3D nanopillar arrays fostering cell-guidance and promoting synapse stability and neuronal activity in networks. *ACS Appl. Mater. Interfaces* 1–9 (2018) doi:10.1021/acsami.8b00387.

2. Amin, H., Nieus, T., Lonardoni, D., Maccione, A. & Berdondini, L. High-resolution bioelectrical imaging of Aβ-induced network dysfunction on CMOS-MEAs for neurotoxicity and rescue studies. *Sci. Rep.* **7**, 2460 (2017).

3. Spira, M. E. & Hai, A. Multi-electrode array technologies for neuroscience and cardiology. *Nat. Nanotechnol.* **8**, 83–94 (2013).

4. Spira, M. Parallel probing of intracellular neuron potentials. *Nat. Biomed. Eng.* **4**, 146–147 (2020).

DZNE
Deutsches Zentrum für
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Project 2:

Performance of graph-theoretical analysis on large neuronal ensembles for revealing emergent network dynamics

The project exploits the combination of high-resolution network electrophysiological readouts[1] and graph-theoretical analysis[2] to construct unique cellular microscale neuronal network features. These graphical features will provide non-invasive microscale composite parameters to understand the biological underpinnings of global and local characteristics of neuronal networks in health and disease. The project will also include data recorded from healthy, and a disease model where the extracted graphical features will be provided to a classifier to provide diagnostic parameters for each condition. The goal of a 6-8 month student project is to learn the recording of large-scale neuronal firing activity using CMOS-MEAs. Then, employing graph-theoretical metrics to automatically extract network functional features as parameters of healthy network performance and disease severity. Finally, implementing a machine learning approach[3] to make competing predictions about how healthy and drug-recovered networks should impact the disease-associated connectional architecture.

Project field:

Neurocomputation, bioengineering, microtechnology, electrophysiology

Project requirements:

Good skills in coding and modeling in Python, basic knowledge in Neurobiology, and neurophysiology/electrophysiology

References

1. Amin, H., Nieus, T., Lonardoni, D., Maccione, A. & Berdondini, L. High-resolution bioelectrical imaging of Aβ-induced network dysfunction on CMOS-MEAs for neurotoxicity and rescue studies. *Sci. Rep.* **7**, 2460 (2017).

2. Bullmore, E. & Sporns, O. Complex brain networks: graph theoretical analysis of structural and functional systems. *Nat Rev Neurosci* **10**, 186–198 (2009).

3. Richards, B. A. *et al.* A deep learning framework for neuroscience. *Nat. Neurosci.* **22**, 1761–1770 (2019).