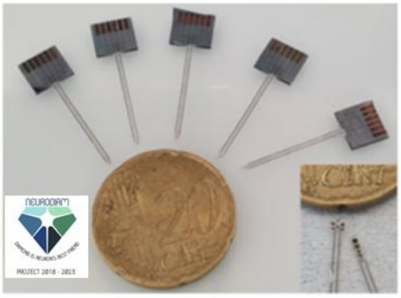
Master Internship Topic **2025/2026**

Modeling and Characterization of the Electrical Impedance of Miniaturized Neural Electrodes



Internship location

ESYCOM Laboratory – Microsensors Team – Devices for humans/living organisms (neurological interface)
https://esycom.cnrs.fr/la-recherche/themes-de-recherche/micro-capteurs/

Supervisors

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Patrick Poulichet, Assistant Professor, ESYCOM
Lionel Rousseau: Clean Room Manager, ESIEE Paris, ESYCOM

Internship context

The development of neural implants for measuring electrophysiological signals is a major challenge in neuroscience and medical research. These devices provide a better understanding of how the brain works, enable the diagnosis of neurological disorders, and open up new avenues for treatment. One of the major challenges in this field is the miniaturization of electrodes in order to improve spatial resolution and reduce tissue inflammatory response. Miniaturization, however, has a significant impact on the electrical properties of the interface between the electrode and the neural tissue, particularly on its **electrical impedance**.

Electrode impedance is a critical parameter that influences the quality and strength of the measured signal. High impedance can result in a poor signal-to-noise ratio, while too low impedance can saturate the readout electronics. Understanding and optimizing this parameter is therefore essential for the design of high-performance implants. This internship, carried out at the ESYCOM laboratory, aims to explore the evolution of the electrical impedance of electrodes as a function of their size, with the goal of moving from the millimeter scale to the micrometer scale. It is part of a European research project, ERC Neurodiam (https://www.neurodiam.eu/).

Objectives

The main objective of the internship is to establish a predictive model of the electrical impedance of neural electrodes as a function of their geometry, in particular their surface area. The specific objectives are as follows:

1. **Experimental characterization:** Measure the electrical impedance of a series of electrodes of different sizes (from millimeters to micrometers), manufactured in a clean room. These measurements will be performed in simulated environments (saline solutions) to mimic in vivo conditions. Impedance data will be collected over a range of frequencies relevant to electrophysiological recording (typically from 1 Hz to 10 kHz).

2. **COMSOL modeling:** Develop a finite element method (FEM) calculation model using COMSOL Multiphysics software. This model will be used to simulate the electrochemical behavior of the electrode-electrolyte interface and predict the impedance of the electrodes based on their geometry.

3. **Correlation and validation:** Correlate experimental results with simulations. Analysis of the discrepancies between measurements and simulations will enable refinement of the model and identification of the physical parameters (such as electrolyte resistance and double layer capacity) that most influence impedance at the micrometric scale.

Internship planning and organisation

The following tasks are expected to be developed :

- **Planning and execution of measurements:** Performing electrochemical impedance spectroscopy (EIS) measurements on the electrodes.
- **Creating numerical models:** Designing and developing FEM models in COMSOL for different electrode geometries.
- **Data analysis:** Processing and analyzing measurement and simulation data, and presenting it in a clear and concise manner.
- **Writing and presentation:** Write a detailed internship report and present the results at an end-of-internship seminar.

Required skills and work environment

The ideal candidate is a Master's student (or equivalent) with a strong interest in interdisciplinarity and the interfaces between electronics, physics, and microfabrication. Previous experience with finite element simulation software (such as COMSOL) is an asset.

The internship will take place at the ESYCOM laboratory in Marne-la-Vallée, in a stimulating research environment equipped with state-of-the-art infrastructure, including a clean room for microfabrication and high-frequency electronics measurement instruments.