



Internship Proposal 2026-2027 – Master 2

Integration of Enzymatic Electrochemical Sensors for Flow-Based Measurements in Microfluidic Chips

A) FACT SHEET

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Field: Electrochemistry ; Analytical Chemistry ; Microfluidics

Level: M2

Background and Objectives

The integration of electrochemical detection into microdevices is highly attractive because of its advantages over techniques such as optical methods. Electrochemical measurements are rapid, directly related to analyte concentration, and require very small sample volumes. However, as device dimensions decrease, confinement effects make the local control of physicochemical processes more challenging, potentially affecting electrochemical performance.

This is particularly relevant for amperometric sensors integrated into microchannels, whose response depends strongly on local flow rate and hydrodynamic conditions [1]. The issue becomes critical when flow conditions cannot be precisely controlled or are inherently variable, as in the continuous analysis of biological fluids using wearable microfluidic systems. Examples include patch-based devices for sweat collection [2] and contact-lens-based systems for tear collection, where fluid transport is driven by physiological processes such as sweating or tear secretion.

Reliable amperometric detection under these conditions therefore requires addressing the fundamental dependence of electrochemical measurements on flow conditions, beyond simply overcoming a technological challenge. Demonstrating reliable sensing under controlled and variable flow could extend the application of amperometric sensors, which have so far been primarily used for analyzing fluids under static or stagnant conditions.

B) PROJECT DESCRIPTION

1. Presentation and description of the project

During this internship, we will investigate amperometric measurements using enzymatic sensors under flow conditions. Given the growing interest in wearable patch-type microsystems for monitoring physiological status, the approach will focus on the detection of physiologically relevant analytes such as glucose and lactate [3]. The study will be carried out in the laboratory using microfluidic devices designed to closely mimic the geometry and operating conditions of flexible wearable systems. Controlled flow conditions will be established to systematically investigate the influence of flow rate on sensor performance.

The first stage of the project will involve the fabrication and functionalization of the sensors. Platinum or gold microelectrodes will be modified with an enzymatic layer using different approaches. These will include the deposition and drying of enzyme-containing droplets on the electrode surface, as well as the electrodeposition of enzyme-containing layers through enzyme encapsulation. The fabrication and functionalization conditions will be optimized to ensure reliable sensor operation within micrometer-scale channels.

The second stage will focus on evaluating sensor performance under flow conditions using the optimal fabrication parameters identified in the first stage. In particular, the sensor response will be characterized as a function of flow rate in synthetic solutions and subsequently in sweat samples.

Depending on the results obtained, a final stage could involve the development of a fully integrated microdevice incorporating a module for the in-situ monitoring of flow rates, in addition to the enzymatic sensors.

2. Techniques / methods used

- Cleanroom microfabrication techniques: photolithography, sputter deposition, and plasma bonding.
- Microfluidic techniques: flow-rate control using a syringe pump or pressure controller.
- Electrochemical techniques: chronoamperometry and voltammetry.
- Characterization techniques: profilometry and scanning electron microscopy (SEM).

3. Expected results

The internship is expected to establish and optimize a microfluidic platform enabling accurate electrochemical enzymatic detections under flow conditions. The project will specifically:

- evaluate the influence of hydrodynamic conditions on the detection performance;
- optimize the operating conditions according to the enzymatic sensor used;
- establish calibration curves as a function of the flow rate.

Overall, this project will provide a multimodal microfluidic/electrochemical methodology for integrating enzymatic sensors in combination with flow rate determination, for the development of wearable patch-type microsystems for the monitoring of physiological status.

4. References

- [1] C. Amatore, N. Da Mota, C. Sella, L. Thouin, *Analytical Chemistry* 79 (2007) 8502, (<https://doi.org/10.1021/ac070971y>).
- [2] A. Martin, J. Kim, J. F. Kurniawan, J. R. Sempionatto, J. R. Moreto, G. Tang, A. S. Campbell, A. Shin, M. Y. Lee, X. Liu, J. Wang; *ACS Sens* 2 (2017) 1860, (<https://doi.org/10.1021/acssensors.7b00729>).
- [3] H. Yamaguchi, M. Miyazaki, *Trac-Trends in Analytical Chemistry* 159 (2023) (<https://doi.org/10.1016/j.trac.2022.116908>)