Internship/PhD project-ENS Lyon

Brain-inspired ionic computing with nanofluidic memories

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In this Internship, the student will do experimental work on the topic of nanofluidic memory for brain-inspired ionic computing. While current computing architectures rely on electronic components, biology uses solvated ions flowing through nanofluidic channels to process information with extraordinary energy efficiency. Replicating these principles with artificial nanofluidic systems could open a disruptive path toward biomimetic liquid hardware and direct interfacing with living organisms. It holds potential to complement current emerging computing paradigms like neuromorphic and quantum technologies.

The discovery of ionic memory and synapse-like plasticity in nanofluidic devices has launched this emerging field[1–3]. Yet, critical milestones are missing: device performances remain limited, ionic advantages are untapped, and networks of nanofluidic memristors have not been realized.

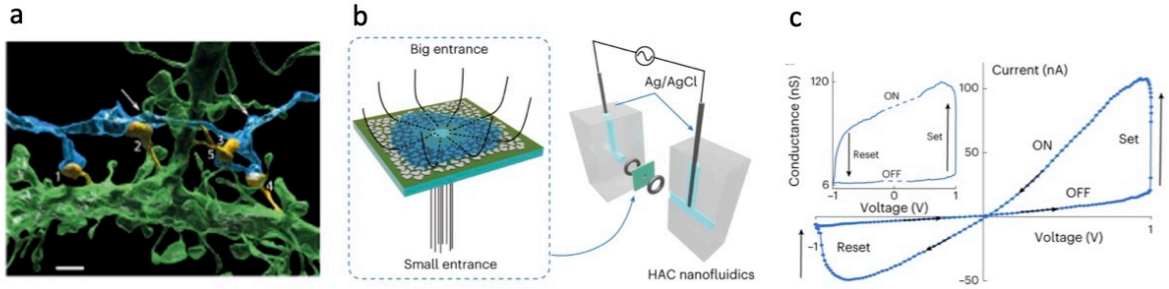

Figure: **Brain-inspired ionic computing with highly asymmetric channels. a,** Image of a biological neural network obtained from a connectomic dataset. Synapses (in yellow) regulate the information transmissions between neurons through nanoscale ionic channels. Adapted from REF 4 **b, left**: Sketch of a highly asymmetric channel behaving as a nanofluidic memristive device. A pierced silicon nitride window (in green) is covered with palladium islands (silver) and capped with a graphite crystal (in blue). **Right:** measurement setup. The device separates two reservoirs filled with electrolytes. An alternative potential is applied between them with redox electrodes, and the resulting current is measured. Adapted from REF **2**. **c,** IV characteristic of the device. It has the shape of loops crossing at the origin, which is the signature of memory. Inset: conductance vs voltage curve. The device shows a bistability between ON and OFF states, similar to biological synapses, that can increase or decrease their level of transmission. Adapted from REF **2.**

The student will work toward realizing these scientific objectives through an interdisciplinary approach at the crossroad of fluid mechanics, interfacial chemistry, and computer science. In particular, (s)he will contribute to the fabrication process of nanofluidic memristors (resistors with a memory), involving the delicate manipulation of 2D materials like graphene. (S)He will then proceed to ion-transport measurements through coupled electrokinetic/optical approaches. The goal is to reach a comprehensive understanding of ionic memory in order to build complex ionic computing circuits.

References

1. Robin*, P., Emmerich*, T., Ismail*, A. *et al.* Long-term memory and synapse-like dynamics in two-dimensional nanofluidic channels. *Science* **379**, 161–167 (2023).
2. Emmerich*, T., Teng*, Y., Ronceray*, N. *et al.* Nanofluidic logic with mechano–ionic memristive switches. *Nat. Electron.* **7**, 271–278 (2024).
3. Emmerich*, T., Ronceray*, N. *et al.* Nanofluidics. *Nat. Rev. Methods Primer* **4**, 1–18 (2024).
4. Kasthuri, N. *et al.* Saturated Reconstruction of a Volume of Neocortex. *Cell* **162**, 648–661 (2015).