Lab project M1 PPN & QuanTEEM

PPN PHYSICS • PHOTONICS NANOTECHNOLOGY

04/05/2026 – 19/06/2026

Title of the project: Filament dynamics in memristive artificial neurons

Supervisor(s): Maciej ĆWIERZONA

Laboratory / Department / Team : ICB/Photonics/PRISM

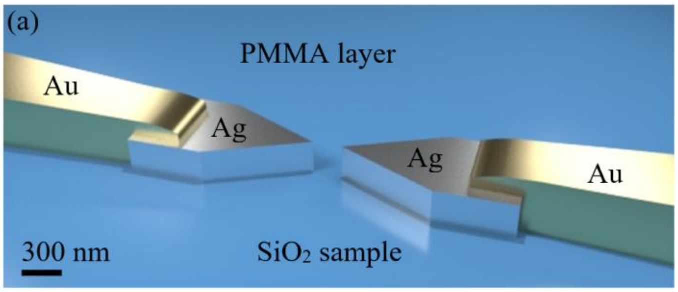
Collaborations:

Summary:

With the ever-growing hunger of Artificial Intelligence (AI) systems for more power and the semiconductor industry's push for the miniaturization of transistors, the ***impassable limits*** of the von Neumann architecture are becoming increasingly apparent. New approaches to information processing are necessary to meet the growing demands of state-of-the-art systems currently under development.

One way to address these issues is to ***draw inspiration from Nature***. One of the approaches, ***Neuromorphic computing***, is inventing new forms of information processing by ***mimicking the human brain***! Indeed, the gray matter that all of us carry around daily is an intricate system with hundreds of billions of ***neurons*** connected by ***synapses***, forming an extremely complex yet efficient information-processing architecture. Models like ***Spiking Neural Networks*** (SNNs) aim to implement biology-inspired information-processing methods to create ultra-low-power ***computing devices***. These technologies are implemented using ***memristive networks*** and could revolutionize information processing by drastically reducing the energy requirements of complex computing systems. Like a synapse, a ***memristor*** is a nanoscale device. In one form, a memristor consists of two metal electrodes separated by a dielectric gap (*Fig. 1a*), and its defining characteristic is the ability to ***switch its resistance state*** in response to applied voltage stimuli[1] (*Fig.1b*). The switch from High Resistive State (***HRS***) to Low Resistive State (***LRS***) is governed by the ***complex dynamics*** of a ***conductive filament*** formed between the device's two electrodes.

The ***<u>objective of this internship</u>*** is to conduct electrical characterizations of in-house-fabricated memristive devices to shed light on the complex nature of ***filament dynamics*** in silver-based memristors. By varying the stimulation parameters, we want to learn how ***voltage amplitude*** and its ***on-off ratio*** affect the device's current response. In neuromorphic systems, electrical pulses act like spikes, triggering synaptic updates. The voltage amplitude and the duty cycle of the active pulse relative to the resting period determine the temporal dynamics of the excitation. The relative duration of the voltage "on" and "off" periods influences how much energy is delivered to the device and how much time the system has to relax between stimuli. This can significantly affect filament growth, partial dissolution, and thermal relaxation processes. In practice, the student will use microprobes, a semiconductor analyzer, a trans-impedance amplifier, an arbitrary function generator, and data-acquisition electronics to send and receive electrical signals to and from memristors. This will be a great opportunity to gain experience in a set of highly valuable skills required in many fields of experimental physics. The student will work in a team with a PhD student and a postdoctoral researcher.



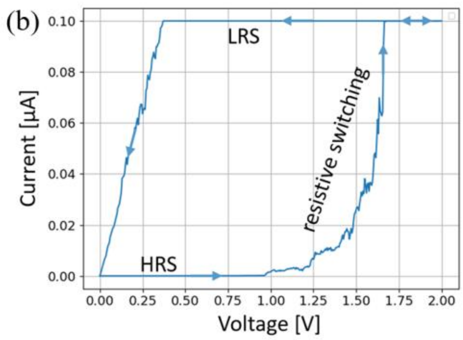


Fig. 1. (a) Visualisation of a nanoscale memristor. (b) Resistive switching during voltage sweep from 0 to 2V.

Type of project (theory / experiment): experiment, with data analysis

Required skills: some electronics background, programming basics, conversational English

[1] K. Malchow, T. Zeelweger, B. Cheng, A. Leray, J. Leuthold, A. Bouhelier, ACS Nano, 18, 35, 24004-24011 (2024)