Date & Time : Tuesday, May 27th, 2025 2:00pm-3:00pm

Place : Seminar Room 5 (A615), 6th Floor, ISSP

Lecturer : Dr. Aurelien Lagarrigue

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Analog Control of Ferromagnetic Magnetization Through Spin-Orbit Torque for Neuromorphic Computing

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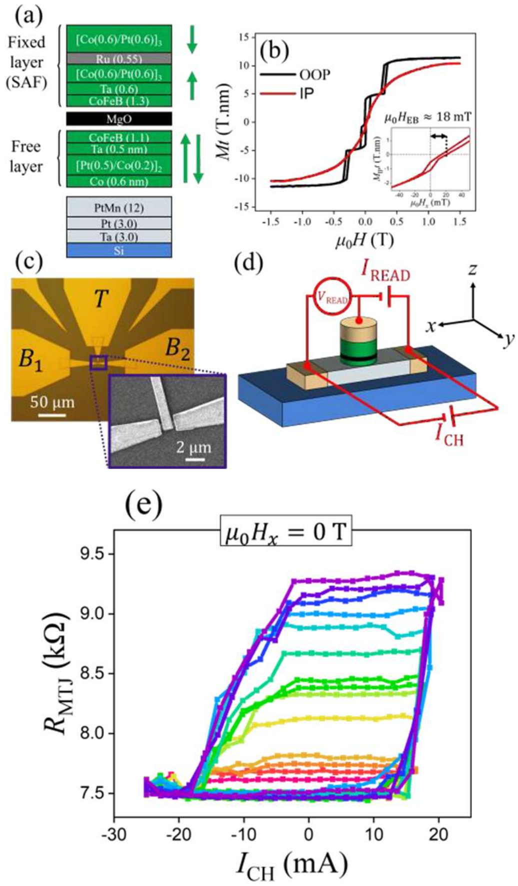

As conventional computing struggles to address several tasks with high energy efficiency, significant efforts have been devoted to neuromorphic computing. This promising alternative aims to mimic the physiological behavior of biological neurons and synapses using solid-state components. Analog-like behavior was observed in spin-orbit torque (SOT) based devices with antiferromagnet/ferromagnet heterostructures [1,2]. However, the small anomalous Hall resistance variations and the 4-terminal Hall bar geometry are not optimal for practical applications, motivating the present studies.

In the first part, I will present a study of 3-terminal perpendicular magnetic tunnel junctions (MTJs) with diameter D_{MTJ} ranging from 200 nm to 10 µm, patterned on top of an antiferromagnetic PtMn channel. The write operation is performed by applying a current pulse I_{CH} through the channel, while the read operation is conducted through tunnelling magnetoresistance (TMR) measurements. The MTJ's stack structure is shown in **Fig. (a)**, alongside the hysteresis magnetic loops, microscope pictures and measuring set-up. We demonstrate analog and field-free SOT switching of the MTJ's resistance. **Figure (e)** shows R_{MTJ} (I_{CH}) with several intermediate non-volatile resistive states and a resistance variation of > 1 kΩ. In-depth measurements with magnetic field reveal the potential to achieve even higher resistance change with TMR > 100%.

In the second part, I will focus on a secondary project involving nanocomposite ferromagnetic heterostructures (CoPtCrB), characterized by significantly smaller magnetic domains. This feature enables further miniaturization of the devices. Hall effect measurements revealed field- and current-induced switching in nanodots, with diameters reduced to as little as 50 nm. The intermediate states observed are clearly distinguishable and can be reliably controlled—an essential characteristic for synaptic devices.

These results pave the way for energy-efficient artificial synapses for neuromorphic applications.

[1] S. Fukami et al., Nat. Mater. 15, 535 (2016).

[2] A. Kurenkov et al., Appl. Phys. Lett. 110, (2017).

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