Ferromagnetic oxide nanosheets for spintronic applications

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This PhD is at the interface between material science and spin-electronics. This joint-project will take place in IPR (Institut de Physique de Rennes) and ISCR (Institut des Sciences Chimiques de Rennes) in the framework of the ONSET ANR project which started in January 2023. ONSET is an exploratory project aiming at investigating the potential of so far uncharted 2D oxide nanosheet (ONS) materials as building blocks for spin electronics. Those new ONS families are expected to offer model properties ranging from high-k dielectrics to 2D ferroelectrics or 2D ferromagnets [1] while being intrinsically air stable, an overall key asset for 2D spin electronics. The project will target to demonstrate this potential by developing an outstanding material such as an air stable 2D ferromagnet operating at room temperature. For this, it will focus on versatile model systems such as the recently unveiled $Ti_{1-x-y}Fe_xCo_yO_2$ ONS, a ferromagnetic insulator [1-3] that can be used as a spin-filter. This ONS family will be developed ranging from synthesis of bulk layered oxide crystals (by solid state chemistry methods) to integration and investigation into magnetic tunnel junctions. Preparation of magneto-resistive devices based on this 2D oxide family will be a major outcome of ONSET in the context of actual rapid development of 2D spintronics.

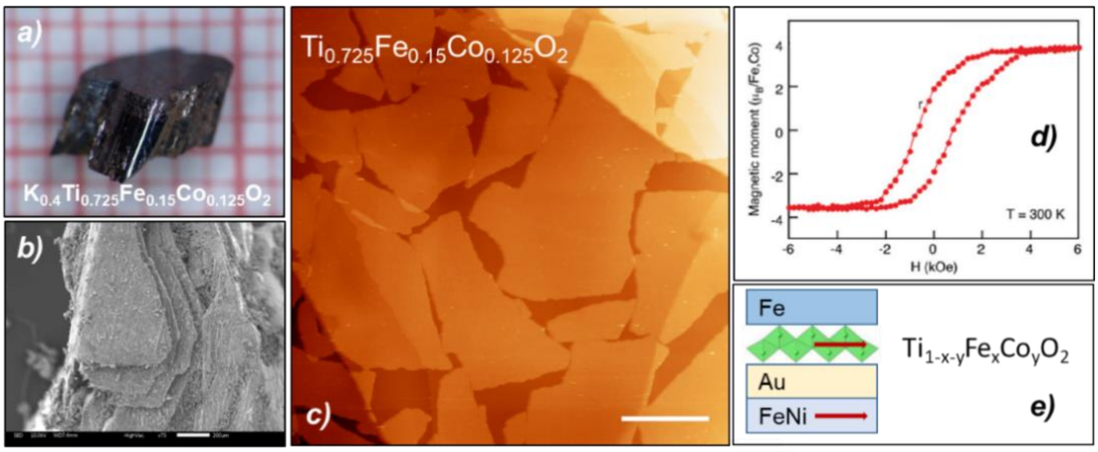

Figure 1 : millimetric crystal of the parent layered phase $K_{0.4}Ti_{1-x-y}Fe_xCo_yO_2$: a) photograph and b) SEM micrograph (scale bar 200µm) ; c) STM image of $Ti_{1-x-y}Fe_xCo_yO_2$ nanosheets transfered on graphite surface (scale bar 200nm) ; d) room-temperature hysteresis loop of $Ti_{1-x-y}Fe_xCo_yO_2$ (from [3]) ; example of a prototypical magnetic tunnel junction integrating a $Ti_{1-x-y}Fe_xCo_yO_2$ nanosheet.

The PhD candidate will first optimise the doping level in magnetic elements in the $Ti_{1--x--y}Fe_xCo_yO_2$ ONS to achieve optimal magnetic properties (high Curie point, high saturation magnetization and low coercive field) [3]. A specific effort will be dedicated to the fine tuning of growth parameters to achieve large size single crystals of the parent layered phase. The bulk magnetic properties will be studied by SQUID and magneto-optical Kerr effect will be used to study the 2D ONS. Two different exfoliation strategies will be used to obtain single $Ti_{1--x-y}Fe_xCo_yO_2$ nanosheets. Chemical exfoliation, already mastered in the ONSET consortium, will be routinely allow to prepare ONS colloidal solutions (lateral size between 1 and 10µm) that can be used to transfer ONS films by drop-casting on virtually any substrate. Large size bulk layered single crystals will be alternatively mechanically exfolliated to obtain extended flakes (lateral size exceeding 100 µm). The obtained nanosheets will be characterized after exfoliation and transfer by SEM, AFM, STM and Raman spectroscopy. The electronic properties of ferromagnetic ONS will be intensively studied by electronic spectroscopies in house and in SOLEIL synchrotron (angle and spin-resolved photoemission, X-ray magnetic circular dichroism). Finally, the PhD candidate will integrate the $Ti_{1--xy}Fe_xCo_yO_2$ ONS in reference magnetic tunnel junctions associating the 2D spin-filter with ferromagnetic transition metals (Fe, Co). The transport and magneto-transport properties of the patterned magnetic tunnel junctions will be studied and correlated to the electronic properties at the junction interfaces.

[1] M. Osada, T. Sasaki, Adv. Mater. **24**, 210 (2012).
[2] B.W. Li et al., J. Am. Chem. Soc. **139**, 10868 (2017).
[3] M. Osada et al., Nanoscale **6**, 14227 (2014).

Candidate profile : We are looking for a highly motivated student graduated with a Master in Nanoscience or Material Science and with excellent academic record. He/she should have a pronounced taste for experimental physics (elaboration, characterization). Advanced knowledges in solid state physics (electronic properties, magnetism, transport and magneto-transport) will be an asset.

Candidates are invited to submit a CV, motivation letter, complete academic records with marks and recommendation letters.

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