INSTITUT NÉEL Grenoble

Topic for Master **2** internship – Academic year 2021-2022

Title

Fe Doped tetragonal CuO films as a new ferromagnetic semiconductor

General Scope:

Over the past half a century, a considerable research activity has been dedicated to the development of magnetic semiconductors (MSC) that can work at room temperature [Q. Cao and S Yan, *J. Semicond.* **40** 081501 (2019)]. These materials are of primary importance for spintronics applications. At the beginning investigations focused mainly on II–VI MSC and III–V dilute MSC. More recently the attention turned towards oxides like e.g. ZnO-based MSC.
Here we are interested in CuO, which is an antiferromagnetic semiconductor with a gap of about 1.4 eV. Its structure is monoclinic, at odd with the other 3d transition metal monoxides (FeO, CoO, NiO,…) that have a rock-salt structure. However, single-phase tetragonal CuO films were elaborated by epitaxial growth on $SrTiO_3$(001) substrates [W. Siemons *et al*., *Phys. Rev. B* **79**, 195122 (2009)], up to a thickness of about 3 nm. This transition from monoclinic to tetragonal structure is associated with an increase of the oxygen-mediated superexchange interaction *J* and hence of the Néel temperature. Transition metal doped CuO nanocrystals, and in particular $Cu_{1-x}Fe_xO$ ones, have been elaborated by several methods. The iron substitutes copper in the monoclinic structure resulting in a single phase up to x~0.2. Samples are ferromagnetic, but with quite a small remanence and coercive field at room temperature. During this internship, the scope it to grow Fe-doped tetragonal CuO phase with improved magnetic properties, thanks to the larger superexchange interaction characteristic of the tetragonal phase.

Research topic and facilities available:

During the internship, Fe-doped CuO tetragonal thin films will be grown by MBE deposition on $SrTiO_3$(001). The films will be prepared and studied *in-situ* using two interconnected ultra-high-vacuum chambers, the first one dedicated to MBE growth, the second one to the characterization by low energy electron diffraction (LEED), Auger electron spectroscopy and scanning tunnel microscopy (STM) techniques. LEED allows to establish the crystallographic symmetry of the films, Auger is used to study the composition and the presence of contaminants, STM will be performed here to study the surface roughness and for a first investigation of the electronic properties.
After growth, the transport and magnetic properties will be measured *ex situ*, using the devices available at the Néel institute.

Possible collaboration and networking: SIN team at Néel institute

Required skills: A good background in condensed matter physics, dexterity in experimental work.

Possible extension as a PhD: Possible, but no financed up to now

Starting date: March 2022

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