Proposal N° :**8**

Contact
BOULLE Olivier, olivier.boulle@cea.fr Tel : +33(0)4 38 78 21 56

Title
Magnetic skyrmion in ultrathin nanostructures

Keywords
Spintronics, nanomagnetism, magnetic memories

Summary
The recent discovery of nanometer-size whirling magnetic structures named magnetic skyrmions has opened a new path to manipulate magnetization at the nanoscale [1,2]. Magnetic skyrmions are characterized by a chiral and topologically non-trivial spin structure, i.e their magnetization texture cannot be continuously transformed into the uniform magnetic state without causing a singularity (see Fig.1). Skyrmions can also be manipulated by in-plane current, which has led to novel concepts of non-volatile magnetic memories and logic devices where skyrmions in nanotracks are the information carriers. The nanometer size of the skyrmions combined with the low current density needed to induce their motion would lead to devices with an unprecedented combination of high storage density, fast operation and low power consumption. Although predicted at the end of the 1980's, magnetic skyrmions were first observed in 2009 in B20 chiral magnets thin films and later in ultrathin epitaxial films at low temperature. Recently, magnetic skyrmions were reported at room temperature in ultrathin sputtered thin films which is a first step toward the practical realization of skyrmion logic and memory based devices. In particular, Spintec recently demonstrated room temperature magnetic skyrmion in ultrathin Pt/Co/MgO nanostructure at zero external magnetic field [3] (Fig.1 (b-c)) as well as their fast current induced motion. The objective of the intnership will be to push forward fundamental knowledge in view of technological applications for memory and logics. The aims will be to develop novel and unexplored material systems to achieve nm scale skyrmions stable at room temperature and allow their fast and reliable current induced skyrmion manipulation.

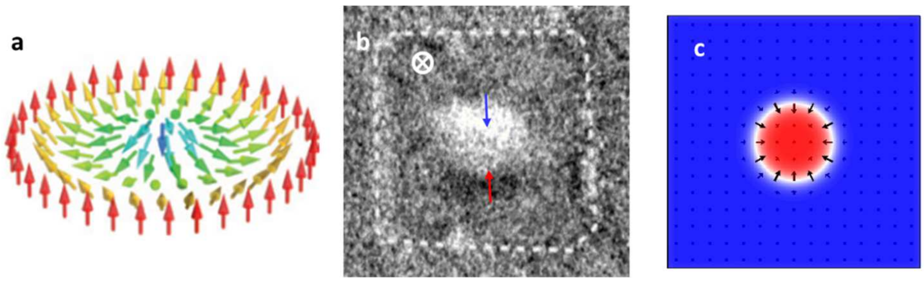

Fig. 1. a - Schematic representation of a magnetic skyrmion [1]. b XMCD-PEEM image of magnetic skyrmion (130 nm diameter) at room temperature and zero magnetic film in an ultrathin Pt/Co/MgO nanostructures [3]*. c. Spin structure from micromagnetic simulations.*

Full description of the subject
The recent discovery of nanometer-size whirling magnetic structures named magnetic skyrmions has opened a new path to manipulate magnetization at the nanoscale [1,2]. Magnetic skyrmions are characterized by a chiral and topologically non-trivial spin structure, i.e their magnetization texture cannot be continuously transformed into the

uniform magnetic state without causing a singularity (see Fig.1). Skyrmions can also be manipulated by in-plane current, which has led to novel concepts of non-volatile magnetic memories and logic devices where skyrmions in nanotracks are the information carriers. The nanometer size of the skyrmions combined with the low current density needed to induce their motion would lead to devices with an unprecedented combination of high storage density, fast operation and low power consumption. Although predicted at the end of the 1980's, magnetic skyrmions were first observed in 2009 in B20 chiral magnets thin films and later in ultrathin epitaxial films at low temperature. Recently, magnetic skyrmions were reported at room temperature in ultrathin sputtered thin films which is a first step toward the practical realization of skyrmion logic and memory based devices. In particular, Spintec recently demonstrated room temperature magnetic skyrmion in ultrathin Pt/Co/MgO nanostructure at zero external magnetic field [3] (Fig.1 (b-c)) as well as their fast current induced motion. The objective of the intnership will be to push forward fundamental knowledge in view of technological applications for memory and logics. The aims will be to develop novel and unexplored material systems to achieve nm scale skyrmions stable at room temperature and allow their fast and reliable current induced skyrmion manipulation.

The internship will be based on all the experimental methods and techniques used for the development and characterization of spintronics devices: sputter deposition of ultra-thin multilayer materials and characterization of their magnetic properties by magnetometry methods, followed by nanofabrication of nanostructures cut in these layers by electron lithography and ion etching. Nanofabrication will be performed at the PTA nanofabrication platform located in the same building as the Spintec laboratory. The nanostructures will then be characterized by magneto-transport and magnetic microscopy (MFM) methods to highlight the nucleation of isolated skyrmions and their magnetic structure. Magnetic microscopy experiments based on X-rays, STXM or XMCD-PEEM will be planned in different European synchrotrons.

[1] A. Fert, V. Cros, and J. Sampaio, Nat. Nanotechnol. 8, 152 (2013)
[2] N. Nagaosa and Y. Tokura, Nat. Nanotechnol. 8, 899 (2013)
[3] O. Boulle et al., Nat. Nanotechnol. 11, 449 (2016).

Requested skills
Master 2 in nanophysics/solid state physics

Possibility to follow with a PhD Yes