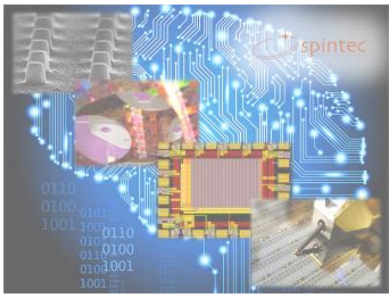


Recruiting a PhD on
Skyrmion-based magnetic field sensor

SPINTEC

Positioned at the crossroad of science and technology, **SPINTEC** (**SPINtronique et TEchnologie des Composants**, https://www.spintec.fr) is one of the leading spintronics research laboratories worldwide. SPINTEC was created in 2002 and rapidly expanded to currently exceed 100 persons, of which 48 permanent staff from CEA, CNRS and Grenoble-Alpes University. The lab aims at bridging the gap between fundamental research and applications in spin electronics. As such, the outcome of the laboratory is not only scientific publications and communications at international conferences, but also a consistent patent portfolio and implementation of relevant functional demonstrators and device nanofabrication. The lab has launched four start-up companies in the past 12 years, and another two are in the pipes. This synergy has placed SPINTEC at the forefront of spintronics research, having actively contributed to the emergence in industry of spintronic memories called MRAM, on which the laboratory holds key patents.

SPINTEC benefits from an idea local environment with a large spectrum of opportunities:

- SPINTEC belongs with the Interdisciplinary Research Institute of Grenoble (IRIG), gathering 10 laboratories with of total of 1000 researchers, technicians, doctoral and post-doctoral students. IRIG covers interdisciplinary skills (physics, chemistry, biology), and provides access to cutting-edge scientific and technological platforms such as PTA cleanroom, and nano-characterization PFNC.
- The Giant Campus Site (also called Scientific Presqu'Île) offers an exceptional scientific environment with partners such as CEA-LETI, Néel Institute and major European facilities (ESRF and ILL on the EPN Campus).
- The entire Campus of Grenoble Alpes University, whose excellence was recently recognized by the national IDEX award, bears a collective dynamics of research challenges in all fields of knowledge.

Grenoble is a cosmopolitan city at the heart of the French Alps. One out of five people living there works in the field of research, innovation or higher education. In addition, Grenoble offers various cultural and sportive opportunities all year round.

CONTEXT

Context. The use of skyrmions to develop a sensor to detect out-of-plane magnetic field is part of the same scientific approach that led to the development of vortex sensors (for in-plane field detection): by exploiting the linear response of vortices over a wide field range, magnetoresistive field sensors could be developed by industry. Here, the development of a skyrmion sensor requires a combination of expertise on ultra-thin magnetic layers hosting skyrmions and know-how on magnetoresistive field sensors. Indeed, skyrmions are most often observed by magneto-optical or atomic force microscopy-based imaging techniques. Nevertheless, it is also possible to detect them electrically by measuring the Hall effect signal in a patterned cross, which gives a relatively small signal, of the order of 1 Ω. Our final goal is thus to include the skyrmion layer in a magnetic tunnel junction in order to take advantage of its high magnetoresistance, which could result in larger signals (of the order of kΩ). These magnetic tunnel junctions (MTJs) promise to achieve this with industry-compatible power and cost parameters, as is the case with fast magnetic memory (MRAM) technologies. However, this requires combining elements that have different constraints in terms of optimum materials.

Context at SPINTEC. Our team at Spintec, in collaboration with Néel Institute, is particularly well placed to meet this technological challenge since it has both the knowledge of skyrmionic layers, the experimental equipment for their characterization and the know-how and equipment for the fabrication of magnetic tunnel junctions for MRAM technology.

During this thesis, one of the challenges to obtain a skyrmion-based magnetic field sensor is to realize an electrical reading of the signal linked to the skyrmion response. To do this, we will explore two directions: firstly, we will use the extraordinary Hall effect to obtain an electrical signal that varies linearly and without hysteresis with the magnetic field applied perpendicular to the plane of the layers. This will allow us, in simple structures, to study the magnetic noise linked to skyrmions and to verify the insensitivity of the sensor to transverse (in-plane) magnetic fields. The advantage of this device is its simplicity of fabrication and the possibility of observing *in-situ* the evolution of the magnetic domains in order to select the optimal materials.

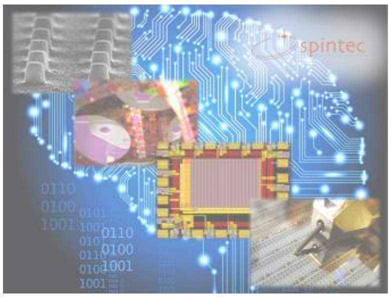
In a second step, in order to increase the sensitivity of the sensor, we will include the skyrmion layers in magnetic tunnel junctions (MTJs) in order to exploit the high efficiency of the tunnel magnetoresistance (TMR) to convert the magnetic signal into an electrical signal. We estimate that, with a TMR of 80%, we will be able to achieve a sensitivity of 1000%/mT, which is several orders of magnitude higher than existing magnetoresistive sensors. One of the challenges of the project will be to stabilize skyrmions in the free layer of an MTJ, while maintaining their high sensitivity to the perpendicular magnetic field and keeping a high TMR.

Finally, we will test the potential of the sensor for the detection of small homogeneous and inhomogeneous magnetic fields, for space and biomedical applications respectively. On the one hand, we will determine the detectivity of the sensors for homogeneous fields. Our group has an active collaboration with the LPC2E in Orléans on a project aiming at integrating ultrasensitive magnetic sensors in space exploration instruments. This will provide expertise on the design of high-performance sensors with associated electronics. On the other hand, to simulate inhomogeneous magnetic fields, we will first use a magnetic magnetic force microscopy tip to approach, in a controlled manner, a micro-magnet of the skyrmion sensor and test the corresponding electrical response. We will then test the response of skyrmion sensors to dispersed magnetic particles. We will develop a collaboration on the subject with the LPCNO in Toulouse, which has expertise in the fabrication and characterization of magnetic micro- and nanoparticles.

POSITION

Skyrmions are circular magnetic domains of (sub-)micron size with increasing interest to the scientific community, considering to use them for information encoding. The aim of this thesis is to exploit the potential of skyrmions in a new way: developing a magnetic field sensor. Indeed, the response of skyrmions to the magnetic field perpendicular to the plane is quasi-linear with a very large slope and no hysteresis. Exploiting these properties in an all-electrical device would provide an integrated magnetometer, highly sensitive to the field oriented perpendicular to the sensor plane. Currently, the only integrated magnetometers sensitive to the perpendicular field are Hall probes whose detectivity is only 1µT/√Hz at low frequency. A skyrmion sensor is expected to achieve better performance, which we estimate to be 3nT/√Hz at 10 Hz, while limiting power consumption. This would make it a sensor of choice for the detection of very small homogeneous magnetic fields for space or geomagnetic applications or inhomogeneous fields for biomedical applications.

The expected profile for the applicant is a Master-2 degree in a field related to physics, nanophysics or condensed-matter with preference for basics in magnetism and/or spintronics.



How to apply:

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- Starting date: October 2023