EMRP Call 2011 - Health, SI Broader Scope & New Technologies

Selected Research Topic number: **SRT-n08**
Version: 1.0

Title: Metrology for spintronic circuits and devices

Abstract

In the fast evolving field of nanoscale magnetism, the development and validation of novel metrology tools for the measurement of spin currents and spin waves are instrumental to tackling the challenges in the development of novel spin-based circuitry. The generation, detection and processing of spin waves is still in its early stages, but devices have been developed which are suitable to develop into accurate metrology tools. Such a new metrology framework will support the validation of spin-based experimental techniques and provide references for the measurement of spin related phenomena, allowing the European metrology infrastructure and industry to take a leading role in the development of state of the art applications.

Conformity with the Work Programme

This Call for JRPs conforms to the EMRP Outline 2008, section on “Grand Challenges” related to Health, New Technologies & Fundamental Metrology on pages 9 and 25.

Keywords

Magnetic nanostructures, Spintronics, Spin waves, Domain walls, Magnetic thin films, magnons, Patterned magnetic materials, Micromagnetic modelling, logic circuitry.

Background to the Metrological Challenges

In the last three decades a new science has been emerging from the activities at the convergence of electronics and magnetism and connected to the understanding of effects associated to the spin degree of freedom of the charge-carrying electrons. This has developed into a new science area based on the generation and use of purely spin-related electrical signals, which is expected to have a major impact on computer processing, sensors and new materials. Despite the widespread development of spintronics devices and circuitry, no specific effort has been devoted to the establishment of traceable characterisation techniques for this field. Active research areas in need of this support include magnetism at the nanometre scale, spintronic effects in nanosized metallic and semiconductor materials and thermo magnetic effects in magnetic nanostructures.

An increasing number of circuits under development rely on spin polarisation to store, transfer and process information. Memory applications based on the electron spin such as the magnetoresistive random access memory M-RAM and spin transfer torque random access memory STT-RAM, have been successfully developed in the last decade, and are now in different stages of commercial exploitation.

Currently, research and development in this field is focused on the analysis of spin polarized currents and spin-transfer torque effects, which allow the switching of the magnetisation in memory elements at the nanosecond timescale and can also be exploited for information processing as spin waves allow a very efficient transfer and storage of information devoid of electron transport, with a large increase in processing speed and potentially saving energy.

At the moment no traceable experimental technique is available to quantify spin polarisation. Very recent scientific developments permit the development of traceable measurement techniques [1-7]. These measurement techniques allow reliability and repeatability and do not require an extensive use of extreme nanotechnology tools for the preparation of properly structured samples.

The experimental techniques have been supported by recent advances in theoretical and computational models able to provide a physical insight into magnetization dynamics at the nanoscale level. This increasing

interest in spintronics devices has boosted the development of theoretical models describing the interplay between spin-polarized currents and domain walls in magnetic nanostructures [8-10].

Scientific and Technological Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the JRP-Protocol.

This JRP shall focus on the development of measurement methods to support the realisation and modelling of reference structures for the generation, measurement (including imaging) and processing of spintronic signals for metrological applications.

The aim is to provide a scientific and metrological framework to support the design, production, testing and calibration of devices and circuits allowing the generation, detection and processing of spin-based signals.

The specific objectives are

1. metrology tools for the traceable characterisation of spin polarisation, spin orbit coupling, phonon-magnon interactions and thermally induced spin;
2. tools for the traceable characterisation of the static and dynamic properties of magnetic domain walls driven by spin-polarised currents and magnetic fields in nanostructured geometries;
3. metrology for advanced logic circuitry;
4. advanced numerical models as a support to the design and analysis of nanometre-size magnetic systems and their applications;
5. the development of standard devices and reference structures to support the tools outlined above.

Proposals must clearly state the stakeholder need for the proposed measurement capabilities and their applications.

These objectives will require large-scale approaches that are beyond the capabilities of single National Metrology Institutes and Designated Institutes. To enhance the impact of the research, the involvement of the appropriate user community such as industry, and standardisation and regulatory bodies, is strongly recommended.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. The proposed JRP must clearly demonstrate its differences to the techniques developed in the iMERA-Plus JRP 'T4.J02 NanoSpin' and the A169 JRP IND08.'MetMags' expected to begin on 1 July 2011.

The total eligible cost of any proposal received for this SRT is expected to be around the 2.7 M€ guideline for proposals in this call.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the "end user" community (eg letters of support) is encouraged.

You should detail other impacts of your proposed JRP as detailed in the document "Guide 4: Writing a Joint Research Project"

You should detail how your JRP results are going to:

- feed into the development of urgent documentary standards through appropriate standards bodies
- transfer knowledge to the computing and telecommunications sectors.
- transfer knowledge to the sensor and instrumentation sector.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards

- the metrology capacity of Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.

Additional information

The references were provided by PRT submitters; proposers should therefore establish the relevance of any references.

[1] K. Uchida et al. Observation of the spin Seebeck effect, Nature 455, 778-781 (2008).

[2] C. M. Jaworski et al. Observation of the spin-Seebeck effect in a ferromagnetic semicond., Nature Materials 9,898–903 (2010).

[3] K. Uchida et al. Spin Seebeck insulator, Nature Materials 9, 894–897, (2010).

[4] A. Slachter, F. L. Bakker, J-P. Adam, and B. J. van Wees, Thermally driven spin injection from a ferromagnet into a non-magnetic metal, Nature Physics 6, 879–882, (2010).

[5] J. Wunderlich, B. Kaestner, J. Sinova, et al. Experimental observation of the spin-Hall effect in a two-dimensional spin-orbit coupled semiconductor system, Phys. Rev. Lett. 94, 047204 (2005).

[6] J.Wunderlich, A. C. Irvine, Jairo Sinova, B. G. Park, L. P. Zârbo, X. L. Xu, B. Kaestner, V. Novák and T. Jungwirth, Spin-injection Hall effect in a planar photovoltaic cell, Nature Physics 5, 675 (2009).

[7] J. Wunderlich, B.G. Park, A.C. Irvine, et al. Spin Hall Effect Transistor, Science 330, 1801-1804 (2010).

[8] J. Fidler and T. Schrefl, “Micromagnetic modelling—The current state of the art,” J.Phys.D, 33, pp. R135–R156, 2000.

[9] J.C. Slonczewski, "Current-driven excitation of magnetic multilayers", JMMM, vol. 159, L1-L7, 1996.

[10] D.V.Berkov, J.Miltat, "Spin-torque driven magnetization dynamics: micromagnetic mod.", JMMM, v. 320, pp. 1238, 2008.