Title: Metrology for the dynamics of industrial magnetic sensors and sensor materials

Abstract

Magnetic sensors are an enabling technology for future applications in industrial automation and process control. For many applications the dynamic response of magnetic materials and sensors is the decisive performance parameter, as it governs the bandwidth of sensor based devices and the clock speed in spin-based electronics. However, in order to develop and advance such sensors better metrological tools are required over the entire application-relevant range of frequencies from direct current (DC) to beyond 100 Gigahertz (GHz).

Keywords

Magnetic sensors, sensor bandwidth, ultrafast magnetisation dynamics, domain wall propagation dynamics, ferromagnetic resonance.

Background to the Metrological Challenges

Magnetic sensors are widely used in industry and they are one of the key technologies in automation techniques. However, new metrological approaches and traceable methods are required in order to improve the reliability of magnetic sensors and sensor based products and to establish ISO compliant production chains. The development of industry compatible characterisation tools for magnetic sensors and sensor materials would also foster advanced material development, quality control and supply.

The efficient bandwidth in magnetoresistive sensors is limited by the sensor materials dynamics. Therefore, bandwidth metrology is a need to characterise sensor materials as well as to measure and evaluate the effect of different sensor designs and components on the sensor dynamic properties, in order to unlock future high frequency magnetoresistive sensor applications.

Ferromagnetic resonance (FMR) is a well-established tool for probing precessional dynamics, and due to its sensitivity to effective field contributions it can be employed for magnetic anisotropy analysis. However, the industrial application of FMR for anisotropy analysis requires standardised measurement and analysis procedures to be produced.

The study of dynamic properties of the magnetic domain walls (DWs) in ferromagnetic nanostructures has recently increased due to further relevant technological applications based on DWs, such as magnetic nanosensors, and their dynamics. The speed and the controllability of the DW displacement on a nanosecond timescale are a key parameter for the usability of such DW devices, but new reliable measurement tools are required to understand DW propagation mechanisms and to underpin future research and development.

The ultimate operational speed of magnetic sensing devices relies on the precession frequency of the magnetisation vector, leading to nanosecond switching times in standard materials. Currently, researchers are searching for novel materials that can overcome those limits when advancing to higher clock speeds. However suitable metrology precessional dynamics beyond 100 GHz are not yet available. Therefore there is a need to develop new metrological tools which can characterise the dynamic response of magnetic sensors and materials over the entire application-relevant range of frequencies from DC to beyond 100 GHz. This output could support the next generation of ultrafast storage devices and novel sensor materials with ultrafast response times.

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 protocol.

The JRP shall focus on the traceable measurement and characterisation of the dynamics of industrial magnetic sensors and sensor materials.

The specific objectives are:

1. To develop a validated and traceable method for the characterisation of the dynamic response of magnetic sensor materials and real sensors. This should include bandwidth, noise figure and complex susceptibility in the direct current (DC) to the megahertz regime and the influence of sensor design on dynamic properties.
2. To develop traceable broadband ferromagnetic resonance (FMR) methods for use as non-invasive tools for precessional dynamic based measurements of magnetic anisotropy components in the gigahertz regime. This should include the analysis of single patterned magnetic nanostructures and the development of traceable methods for time efficient evaluation with an uncertainty budget.
3. To develop validated and traceable methods for domain wall (DW) propagation dynamics in the nanosecond timescale, induced by fields or spin transfer torques. This should include validated magnetoresistive and imaging based methods and the implementation of time-resolved domain wall position monitoring with a target spatial resolution below 10 nm.
4. To develop validated optical sampling methods for ultrafast magnetisation dynamics beyond 100 GHz.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain (magnetic sensor suppliers), standards developing organisations (ISO) and end users (e.g. power electronics, machinery tools and the automotive industry).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMRP JRP IND08 ‘Metrology for advanced industrial magnetics’ (MetMags) and EMRP JRP EXL04 ‘Spintronics and spin-caloritronics in magnetic nanosystems’ (SpinCal) and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the sensors and instrumentation sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. 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 EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.