Title: Metrology for magnetoresistive sensor applications

Abstract

Magnetoresistive (MR) sensors are widely used in automotive applications, consumer products, and ICT. In these fields the fast product development creates the need for MR sensors with significantly improved specifications and lower cost. Some of the main industrially-identified challenges are 1) to improve precision control of the stray field of magnetic scales for position and angular encoding, 2) to increase the MR sensing bandwidth for faster operation, and 3) to improve reliability and optimization of novel MR sensor concepts based on magnetic domain wall motion.

Keywords

Magnetoresistance, position sensors, angular sensors, magnetic sensors, magnetic thin films, magnetic microstructure, domain walls

Background to the Metrological Challenges

Magnetic sensors can be found in a broad range of products in various fields of industry such as consumer electronics, information and communication technology (ICT) biotechnologies and automotive. More than 5 billion magnetic sensors and switches were sold last year. Products must move from competing purely on price to non-price factors, especially as customers look for unique solutions with tangible benefits. Manufacturers are investing in technological advancements and the widening of magnetic sensor application areas. The goal of the proposed research is to foster the development and testing capabilities of advanced MR sensors by the European sensor industry and to advance their application for accurate and reliable measurement and control in present and emerging applications.

One industrial challenge of MR sensor development is the precision control of the stray field of magnetic scales for position and angular encoding. Today’s magnetic scales possess magnetic bit widths down to 200 µm. However, the local stray field distribution may vary and is not precisely known limiting the validity of the interpolation and hence the position control. The development and testing of next generation magnetic scales, with significantly smaller bit widths down to 10 µm, requires metrology to reliably measure and validate the local magnetization and stray field distribution and such metrology is presently not available.

Another industrial challenge is to increase the MR sensing bandwidth for faster operation. The ultimate physical limit of MR sensor band width is given by the precession frequency of the MR thin film with frequencies up to several GHz. However, real MR sensor devices have significantly lower bandwidth and there is a metrology need to evaluate the different effective bandwidth limits.

The final challenge is to improve the reliability and optimise novel MR sensor concepts. Presently most MR sensors rely on the coherent reorientation of the magnetization in a magnetic thin film. Recently a new class of MR sensors, which promise low power magnetic logic and ultra high density data storage, has emerged. These sensors are based on the controlled motion of a single magnetic domain wall (DW) in a magnetic nanowire and a thorough metrological characterisation is needed to underpin the industrial development.

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 proposal.

The JRP shall focus on the development of metrological capacity for advanced magnetoresistive (MR) thin film sensor devices.

The specific objectives are

1. To develop tools and methods for traceable characterisations of the stray field distribution of magnetic scales and pole rings with resolution down to 3 µm (to increase the accuracy of position and angle encoders and to enable scaling of the magnetic bit width of the encoders down to 10 µm)
2. To develop test-beds and methods to characterize the high frequency response of magnetoresistive sensors in the frequency range from 1 MHz to 5 GHz and to determine the factors limiting the bandwidth (e.g., RLC time-constant, dielectric losses, magnetization dynamics)
3. To develop metrology tools to characterize magnetoresistive sensors relying on the manipulation of magnetic domain walls. Namely: to simulate and to predict the response of domain-wall based sensors; to image the domain-wall properties with resolution below 100 nm, over an extended temperature range from -25 °C to 100 °C, and in applied fields up to 100 mT; to evaluate the magneto transport properties and reliability of domain-wall based sensors (i.e. 100 - 1000 cycles) over the above extended temperature and field range.
4. To engage with industries (such as consumer electronics, information and communication technology (ICT), biotechnologies and automotive) that manufacture and exploits magnetic sensors to facilitate the take up of the technology and measurement infrastructure developed by the project, to support the development of new, innovative products, thereby enhancing the competitiveness of EU 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 project IND08 MetMags and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs to be 1.5 M€, and has defined an upper limit of 1.8 M€ for any 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 deviation from this must be justified.

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,
- Drive innovation in industrial production and facilitate new or significantly improved products through exploiting top-level metrological technology,
- Improve the competitiveness of EU industry,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the industrial sectors such as consumer electronics, information and communication technology (ICT), biotechnologies and automotive

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

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.