Nanomagnetism & Spintronics

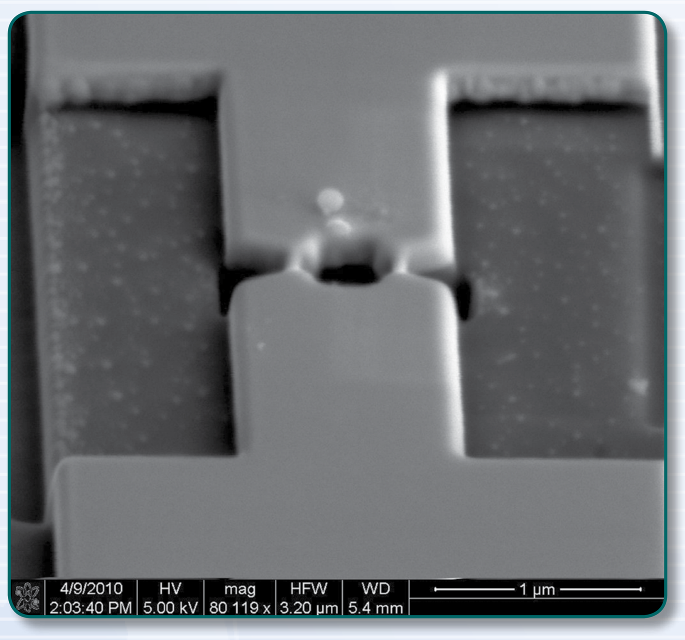
EURAMET
European Association of National Metrology Institutes

The need for the project

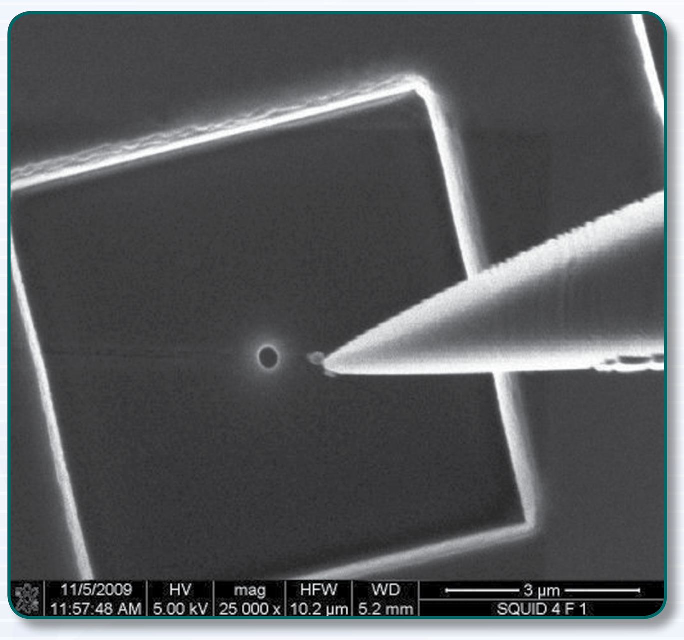
Developments in the fields of nanomagnetism and spintronics include a wide range of applications such as ultra strong magnets, spin polarized materials, ultra high density recording media (hard disks, flash memories/MRAM), spin transistors and DNA- and bio-sensors.

All of these developments urgently require measurement tools to reliably and traceably characterise magnetic nanomaterials.

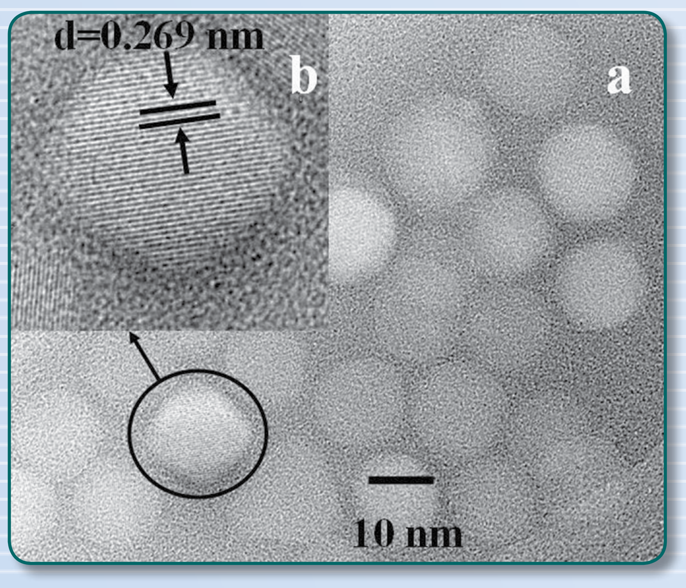
The aim of this project was to establish a metrological basis for the field of nanomagnetism and to provide reference samples and measurement methods to industrial and academic end-users.



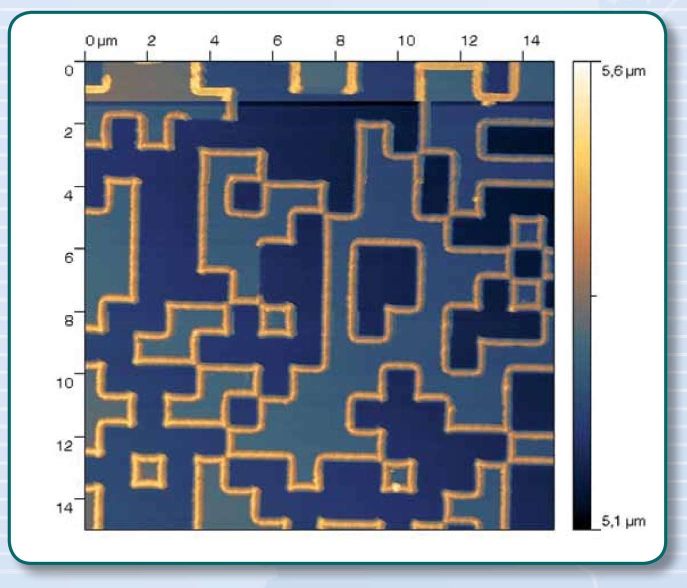
Single particle detection with nano-SQUID: 120 nm SiO_2/Fe_3O_4 nanoparticles (104 mB) on nano-SQUID with the loop sixe ~300 nm.



Single particle detection with nano-Hall sensor: Manipulation of a 120 nm FePt nanobead.



(a) High resolution TEM image of iron oxide nanoparticles (b) 12 nm maghemite (γ-Fe_2O_3) particle with visible atomic planes.



Magnetic Force Microscopy calibration sample.

Technical achievements

Reference Nanomaterials:
The project produced thin films of Permalloy integrated in coplanar waveguides for time and frequency domain dynamics measurements, Gallium Manganese Arsenide (GaMnAs) diluted magnetic semiconductor samples for precessional dynamics, size monodispersed nanoparticles for high resolution scanning probe microscopy and ultra sensitive magnetic moment detection and samples of hard magnetic materials with perpendicular anisotropy for high resolution scanning probe microscopy.

Time and frequency domain dynamics:
The project developed the inductive metrology of ferromagnetic resonance frequency (fFMR) and the Gilbert damping (α) of soft magnetic thin film have been established and validated and a set of calibrated soft magnetic reference samples is available for external inductive measurements of fFMR and α. Metrology for the Spin Torque precession of individual nanodevices in time and frequency domains has also been established.

High Resolution Scanning Probe Microscopy:
Quantitative Magnetic Force Microscopy with a resolution of less than 50 nm has been demonstrated using magnetic nanoparticles.

Ultra sensitive magnetic moment detection:
A prototype magnetic detector based on nano-SQUID magnetic moment sensitivity and a nanosized (<500 nm) metallic and semiconductor (i.e. two dimensional electron gas heterostructures) Hall sensors were developed.

New techniques and samples

New reference samples and techniques were developed and transferred to industrial and academic end-users, such as:

- time resolved damping techniques - used by Singulus Technologies AG and University of Bielefeld, Germany
- damping reference samples – used by Tohoku University, Japan
- nano-SQUID detection technique of a single nanoparticles – used by University of Tubingen, Germany
- Hall sensor detection techniques for single nanoparticles/ nanowires – used by University of Duisburg, Germany and CSIC, Spain

Dissemination through end-users

A 'Nanomagnetism' group, involved in a wide range of scientific activities and their dissemination, was created with project collaborators, e.g:

reference nanomaterials: University of Duisburg, Trinity College Dublin, University College Cork, University of Vienna

sensor fabrication and nanomanipulation: Imperial College London, Cambridge University, Surrey University

preparation of hard magnetic thin films for hard magnetic reference samples: TU Chemnitz, Hitachi and IMEM Parma

ferromagnetic resonance and damping for microwave applications: Tohoku University, NIST Boulder, University of Colorado, Northeastern University Boston

tunneling Magnetic Junctions dynamics and point contacts for memory/sensor applications: Singulus AG, University of Bielefeld, NIST Boulder

high resolution magnetic microscopy/MFM calibration: TU Chemnitz, Hitachi GST, University of Parma, University of Göttingen, IFW Dresden, TU Braunschweig, Magnicon GmbH

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