M. Denoual¹, M. Harnois², S. Saez¹, C. Dolabdjian¹ and V. Senez²
¹University of Caen Basse-Normandie GREYC-ENSICAEN, Caen, France
²University of Lille Nord de France, IEMN, Lille, France

# Microfluidic Microsystem for Magnetic Sensing of Nanoparticles with Giant Magneto-Impedance Technology

Magnetic nanoparticles

What is a magnetic nanoparticle?

Magnetic nanoparticles are small particles made of magnetic material such as magnetite Fe₃O₄, MnFe₂O₄ or (XO)(MF₂O₄). X for Co, Li, Zn, Ni.

Their small size with diameter below 30 nm makes them superparamagnetic. Only one magnetic domain exist in such small particles (magnetic monodomain), and the consequence is a magnetization cycle without hysteresis.

In practice, nanoparticles are used under two forms:
- dissolved in a liquid (ferrofluid),
- encapsulated in or around a non-magnetic matrix to form beads. In the case of biomedical applications, the beads are coated with biochemical cross-linkers to allow specific binding.

Main applications of magnetic nanoparticles

- Non-Destructive Testing (NDT) of non-conductive materials (aeroplane, automotive industries)
- Magnetic marking: anti-theft, money marking (magnetic ink)
- Biomedical applications
  - Manipulation and sorting
    - Treatment (local treatment, hyperthermia)
    - Detection/Imaging
      - detection of magnetic particles, Bead Array Counter, contrast enhancement Magnetic Resonance Imaging (MRI), Magnetic Particle Imaging (MPI), AC-susceptibility, magnetorelaxometry
  - Clinical applications: local treatment, hyperthermia

Detection of magnetic nanoparticles

Principle

The detection principle is the following: the superparamagnetic nanoparticles in the liquid medium are magnetized with an external magnetic field. Then their magnetic moments are detected with a magnetic sensor. Under the magnetization field, the magnetization of the nanoparticles in the liquid is given by

\[ M = 2H_{mag} \chi_m A m^{-1} \]

where \( \chi_m \) is the susceptibility of the magnetic nanoparticles in the liquid. The magnetization of the liquid sample induces a magnetic induction at a point \( P \) of the space which maximum can be expressed by

\[ B_{mag}(P) = \frac{2H_{mag} \chi_m V}{4\pi} \]

where \( V \) is the volume of the magnetic liquid and \( d \) is the distance between the point \( P \) and the magnetic liquid.

In order to sense the magnetic field produced by the magnetic liquid, the magnetic sensor is placed perpendicularly to the magnetization field. This enables a higher measurement dynamic and prevents the saturation of the magnetic sensor. As few mT of measured, sensitive magnetic sensor should be used.

For integration and sensitivity reasons, GMI microwire sensors were chosen.

Future work and expected limits

Potential modifications in order to work with GMI nominal performance (10 kV/T and few pT/Hz) to 1 kHz compared to 6 Hz will lead to theoretical sensitivity improved by a factor one thousand at least. This means a reduction of the detection volume down to below 100 nl, i.e. a (50 µm)^3.

This project is funded by the Nanotrans program of the CNANO NO.