Miniature and ultra-sensitive magnetic sensor for space applications

Contact: Claire BARADUC DRF//INAC/SPINTEC claire.baraduc@cea.fr 0438784235

PhD may follow: Yes

Summary :

The aim is to develop a miniature and ultra-sensitive magnetometer (100 fT / âˆšHz), using magnetic tunnel junctions and microfabrication techniques from microelectronics. This magnetometer could replace the magnetometers currently used on space missions with a mass reduction by a factor of 100. This extreme lightness (~ 1 g without electronics) would represent a competitive advantage over inductive sensors currently used in space missions (mass > 1 kg).

The proposed magnetometer combines a magnetic tunnel junction as sensing element of the sensor, a flux concentrator to amplify the field to be measured, and a magnetic field modulation system to reduce the noise of the measurement. Preliminary studies have shown the feasibility of the basic bricks of this sensor. It is now necessary to optimize the flux concentrator and the magnetic tunnel junction, in particular by developing an innovative junction that is currently the subject of a patent application. A detailed understanding of the underlying physics is necessary to optimize the sensitivity of the tunnel junction: the choice of materials and geometry (size, shape, thickness) will results from a tradeoff between increasing the sensitivity and keeping a uniformly magnetized state within the junction.

The internship work will mainly be experimental (microfabrication, electrical and magnetic characterization, noise measurements, magnetic imaging) but will also include analysis and simulations.

Full description :

The objective is to develop a miniature and ultra-sensitive magnetometer using magnetic tunnel junctions and microfabrication techniques derived from microelectronics. This magnetometer, if it achieves the expected performances (100 fT/âˆšHz detectivity), could replace the magnetometers currently used on space missions with a mass reduction by a factor 100. The device (without electronics) is fabricated on a silicon substrate of 10x4mm2 and weighs about 1 gram. By contrast, magnetic sensors currently used in space missions are inductive sensors, and their very high sensitivity is achieved at the cost of considerable footprint and mass (1 to 2.5 kg).

The proposed magnetometer is the result of work carried out within a long-standing partnership between SPINTEC laboratory and LPC2E space laboratory (CNRS-UniversitÃ© d'OrlÃ©ans). The sensor combines a magnetic tunnel junction as a sensitive element, a flux concentrator for amplifying the field to be measured and a magnetic field modulation system for reducing the noise of the measurement. The projections based on results already obtained suggest that a detectivity of 1pT/âˆšHz to 100 fT/âˆšHz could be obtained in the DC-10 kHz band, if the magnetic tunnel junction and the flux concentrator are optimized. Significant progress could be achieved through research on materials and a thorough study of magnetic properties.

Our goal is to develop a magnetic tunnel junction with high sensitivity and low noise. For this, we will test an innovative junction concept, which is currently the subject of a common patent application of LPC2E and Spintec.

First, we will try to optimize the materials and shape of the junction in order to obtain a coherent rotation of the magnetization at low-field: this involves combining analytical modeling, numerical simulations and experimental tests in order to determine the best parameters. These tests will require the deposition of multilayers, microfabrication in clean room and electrical characterization measurements. To analyze the magnetic behavior of the sample at a local scale, we will image the sample using magnetic force microscopy (MFM) or Kerr effect microscopy. In a second step, we will reduce the noise of the junctions obtained, by increasing the magnetic volume. This can be achieved either by increasing the junction size (provided that the magnetic uniformity is not degraded), or by connecting the junctions in a serial / parallel circuit. However, the space constraint due to the air gap of the flux concentrator will prevent to use a large number of junctions. The best form of junction and the best compromise between the number of junctions and the size of the air gap will be sought by modeling, the air-gap being approximately inversely proportional to the gain of the concentrator.

The proposed research will be carried out mainly at SPINTEC laboratory and in the PTA (clean-room in the same building) and will involve magnetic thin-film deposition, micro-fabrication, electrical and magnetic measurements and numerical simulations. Besides the junction optimization, a specific effort will be devoted to improve the reliability of a few critical technological steps of the complex microfabrication process (8 mask levels and about 50 process steps).

Requested skills :
solid state physics