Stage N° : 6

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Title

Ultra-sensitive magnetic field sensor for space applications

Keywords
magnetic field, sensor, high sensitivity

Summary
Magnetic sensors for space flight are highly sensitive inductive sensors but they are cumbersome and heavy (150g/axis) which impacts the launching cost. Since many years, research has been performed in order to reduce the sensor size and mass. However, no further progress is expected on this line without a definite change of paradigm. The solution could be spintronic devices provided they could present the proper sensitivity. We are therefore developing a magnetic sensor which combines an innovative architecture with a low-noise magnetoresistive element. Our objective is to improve the sensor performances by including an innovative magnetic tunnel junction that we intend to protect with a patent. The experimental work will be: i) the microfabrication of the device; ii) measurement of the electrical noise; iii) optimization of the junction composition and geometry by numerical simulations.

Details
The aim of this project is to manufacture a magnetic sensor that could be a serious competitor, in term of sensitivity, to those currently shipped onboard the space missions, with a weight reduction of at least two orders of magnitude. Up to now, magnetic field sensor used for space missions are inductive magnetic sensors that have a very high sensitivity, up to few tenths of fT. Nevertheless, this very good sensitivity is achieved at the cost of large size and mass (150g per axis), markedly increasing the launching cost. Solutions to reduce the sensor mass has been systematically tested for years but no further improvement can now be obtained without a change of paradigm. Using nano-devices from spin electronics integrated on silicon would allow a significant progress in the size and mass reduction of vectorial magnetic sensors provided they could have the required sensitivity.
We are therefore developing an ultra-sensitive magnetic sensor that combines an innovative architecture and a low noise magnetoresistive element. It includes a magnetic circuit, a biasing coil and a tunnel junction, made with thin film technology, an electronic circuit in ASIC technology and a feed-back coil made with a micro winding process, the latter responsible for the sensor high performance in terms of linearity and stability. The sensor high sensitivity is obtained by a strong amplification (>300) of the measured magnetic field thanks to the magnetic circuit acting as a flux concentrator, and by using magnetic tunnel junctions with high magnetoresistive ratio.
The originality of the proposed sensor lies in a differential and heterodyne detection combined with a feed-back: the magnetic field to be measured is modulated by an ac biasing field, so that the measurement is translated in the vicinity of the biasing frequency where the noise is low.

Our objective is now to improve the quality of the flux concentrator by the choice of materials (laminated NiFe layer, multilayer with antiferromagnetic coupling or amorphous alloys) and to replace the current tunnel junction by an innovative junction (patent in progress). Optimizing the new junction will require numerical simulations and experimental tests.

The innovative and ambitious features of the proposed solution should allow to develop a sensor able to detect magnetic fields as low as 100fT/Hz1/2 in the frequency range below 10kHz, which corresponds to a sensitivity three orders of magnitude larger than the best magnetoresistive sensors currently available. Furthermore, a large reduction in size increases the sensor spatial resolution which extends the scope of applications towards the medical sector, biotechnologies or non-destructive control for example.

Requested skills
Solid state physics

Possibility to follow with a PhD Yes/No
Yes

Figure