Spin electronics sensors for biomagnetic signals detection and medical imaging

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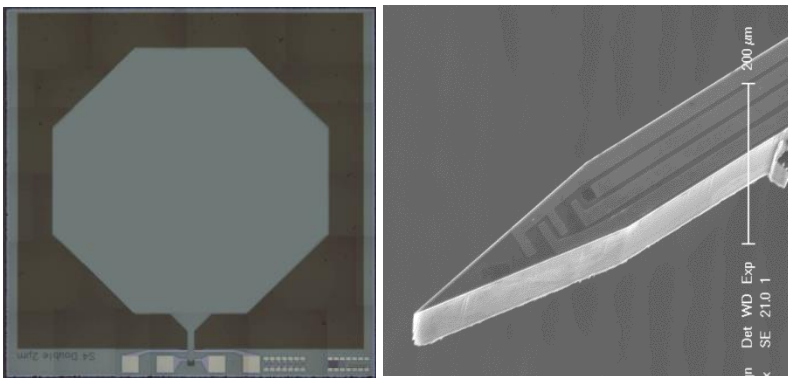
Spin electronics have opened the field of numerous applications in data storage, magnetic field sensing or MRAM. In particular, spin valve devices offer very good sensitivity – below the nanotesla range at room temperature - and since these systems are field sensors and not flux sensors, their sensitivity is weakly dependent with their size, and they can maintain very good performance at extremely small scale, allowing integration of multiple sensors or very small size magnetometer.
Magnetometry addresses many fields, from industrial, as in car industry, to more fundamental problems like in space-magnetometry or biomagnetism.
Biomagnetism, being defined by the very weak signature of magnetic fields generated by living tissues and organisms, either by magnetic particles embedded or attached to cells, or by the electrical activity such as neural currents, requires extremely sensitive sensors to reach the picotesla to femtotesla range of the corresponding signals. Superconducting Quantum Interference Devices (SQUIDS), operating at liquid helium temperature, have been the preferred type of sensors for this purpose.
We have developed new types of magnetometers based on spin electronics [1] to allow measuring the weak fields generated the electrical activity of heart, brain or neuron cells. These sensors exhibit field sensitivities ranging from the nanotelsa (10^{-9}T) down to the femtotesla (10^{-15}T).
The principles of the sensors and their operation for magnetic cardiac mapping [2], low field Magnetic Resonance Imaging (MRI) [3], [4] or local neuronal electromagnetic activity will be shown in this contribution.



Left : Micrograph of a femtotesla-sensitivity magnetometer for Magneto-Cardiography and Low field MRI ; Right : Needle-shape Giant Magneto-Resistance sensor for local electromagnetic neuronal signal detection.

[1] M. Pannetier et al. *Science* 304, 1648 (2004).
[2] M. Pannetier-Lecoeur, et al, *Applied Physics Letters* 98, 153705 (2011).
[3] H. Dyvorne, et al, *Trans. On Appl. Supercond*. (2009).
[4] Q. Herreros et al, *Rev. Sci. Instr.* (2013).

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Fields of Research
Spin electronics, magnetic sensors, biomagnetism, oxides thin films.

Publications

1. *Noise in GMR and TMR sensors,* C. Fermon and M. Pannetier-Lecoeur,In *Giant Magnetoresistance (GMR) sensors, from Basis to State-of-the-Art applications*, Springer (2013), Editors: C. Reig, S. Cardoso de Freitas, S. C; Mukhopa.
2. *Spin electronics based magnetic sensors for biomagnetic measurements*, M. Pannetier-Lecoeur *et al*, In *Magnetoencephalography, From Signals to Dynamic Cortical Networks*, Editors: Selma Supek, Cheryl J. Aine.
3. A. Solignac *et al*, *Physical Review Letters* 109, 027201 (2012).
4. P. P. Freitas *et al, Lab on a Chip* .
5. M. Pannetier *et a*l, *Science*, 304, 1648-1650 (2004).