phD thesis 2019 – Funded project

Submillimeter magnets for portable magnetic devices

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Portable and flexible electronics are spread in countless devices of our daily life thanks to the tremendous efforts of the semiconductor industry to keep on integrating smaller but more efficient transistors. Surprisingly, micromachined devices requiring magnetic actuation, such as actuators, relays, sensors, isolators, did not benefit from the same development and presently require external macroscopic permanent magnets (PM) to ensure their proper use, thus, limiting their compactness and portability. **Despite tremendous efforts, the integration of performant magnetic materials within miniaturized circuits remains both a scientific and a technological challenge**.
Consequently, the actuation of the current devices is ensured by permanent macroscopic permanent magnets, thus limiting their compactness and their portability.

Among the various devices requiring the integration of powerful sub-millimter magnets, micro-sources of energy are highly sought. Indeed, these micro-sources of energy are the keystone for the development of portable devices such as smart devices inter-connected by the Internet of Things (IoT).[1] Mechanical vibrations in the environment, characterized by low frequency excitations (f <100 Hz), could be considered as renewable energy sources if efficient energy conversion is achieved.[2] However, the problem of integrating magnets (Figure 1), necessary for efficient electromagnetic transduction, prevents the large-scale use of this technology.

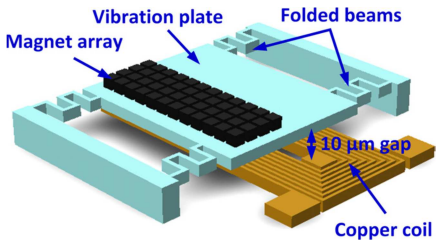

Figure 1. *Schematic view of an electromagnetic energy harvester [1]*

We have developed at the LPCNO a new magnetophoresis approach for the fabrication of integrated submillimeter magnets. This bottom-up approach is based on a unique know-how on the synthesis of Co nanorods (NRs) with optimized magnetic properties.[3] By playing on the local structuration of the substrate and the direction of the magnetic field, we have shown that it is possible to align and assemble NRs in order to obtain submillimetric magnets with planar or perpendicular magnetization (Figure 2).[4] Part of the work of the thesis will be to study the magnetic and capillary forces involved in the self-assembly and drying of these structures and combine them to optimize the intrinsic properties of the magnets (alignment and density). The scientific knowledge and complementary know-how of LPCNO and IMFT on colloidal suspensions and capillary effects will be an important asset for the completion of the project.

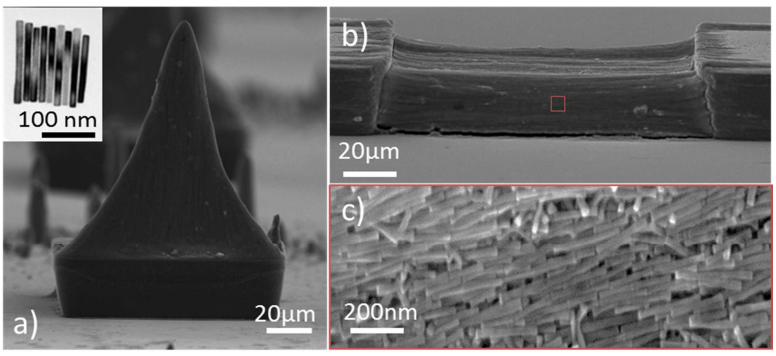

Figure 2. *Electron microscopy images of permanent magnets with a) perpendicular and b) planar magnetization. These magnets were prepared by controlled evaporation of a suspension of Co NRs (insert figure a). c) Magnified view of the magnet revealing the alignment of the NRs.*

The work program focuses on the major challenges presented by this project:

(i) The synthesis and the modification of the surface chemistry of Co NRs.
(ii) The study of the localised assembly of NRs under the combined effect of magnetic and capillary forces to control the final shape of the magnet and further increase its density.
(iii) The characterization of the induced magnetic field created by these nanostractured magnets.
(iv) The fabrication of an array of micro-magnets to be integrated onto an electromagnetc energy harvester developped in close collaboration with Thierry Leïchlé at LAAS.

The proposed multi-disciplinary subject will give the phD student the opportunity to acquire know-how in a multiple of domains ranging from liquid-phase chemistry, fluid physics, nanotechnology and nanomagnetism that can lead to a functional device. This phD offer is both for chemists interested in nanotechnology and physicists interested in the synthesis of nanoparticles by soft chemistry.

Thanks to strong and fruitful national and international collaborations established by the LPCNO and the IMFT, the phD candidate will have access to advanced characterization techniques (Microscopy in Zaragoza, Spain or in Sydney, Australia).

The phD student can easily promote such a subject in several industrial sectors (sensors, microelectronics, micro-nanofluidics ...) and academics.

References

[1] Han, M. et al. ***Sens. Actuators Phys.*** 2014, *219*, 38
[2] Roy, S.; Mallick, D.; Kankana, P. ***IEEE Trans. On Magnet***. 2019, DOI : 10.1109/TMAG.2019.2896105
[3] Anagnostopoulou, E. et al. ***Nanoscale*** 2016, *8*, 4020.
[4] Moritz, P., Lacroix, LM. ; Viau, G. ; Leïchlé, T. Patent « Procédé de fabrication d'un aimant permanent » (FR1872920)