Magnetrodes: Spin electronics probes for local magnetic recordings of neuronal signals

Myriam Pannetier-Lecoeur*[1]

[1]SPEC-IRAMIS-DRF – CEA, CNRS, Université Paris-Saclay, CEA Saclay 91191 Gif sur Yvette France – France

Résumé

Currents circulating in excitable cells like neurons or nerve fibers may be measured by the radiated magnetic field. At the organ level, these magnetic fields can be detected by non-invasive experiments using highly sensitive magnetometers such as SQUIDS [1], atomic magnetometers [2] or mixed sensors [3], the latter using spin electronics. Thus, Magneto-Encephalography allows measuring neuronal activity at a millisecond resolution and for collective response of population of typically 10 000 neurons and more. To understand the genesis of the signals obtained in brain areas, it is relevant to investigate the fields generated at the level of one or few cells. This requires small and sensitive field sensors, operating at physiological temperatures, which has long been out of reach from existing technologies.

Spin electronics allow now developing small sized and very sensitive magnetometers, reaching the sub-nanotesla field range on micron-size sensors. These devices operate from low temperature to hundreds of ∘C, so they can be used at physiological temperature. Furthermore, spin electronics sensors, based on thin film technology, can be deposited on silicon or glass substrates which can be shaped in needle-type devices to allow penetration in tissues with reduced damages.

We have designed and fabricated magnetic sensors called magnetrodes, as a magnetic equivalent of electrodes, to probe locally the information transmission of excitable cells. These probes contain one or several GMR elements in embodiment compatible to recordings in contact with tissues or within tissues.

I will present results obtained on two experiments performed on living tissues; Action Potential propagation in *in vitro* preparation of muscle cells, which have demonstrated the first local biomagnetic recordings with GMR sensors [4], and *in vivo* recordings of cortical activity [5].

John Clarke and Alex I. Braginski. *The SQUID Handbook: Vol. II Applications of SQUIDs and SQUIDs Systems.* WILEY-VCH, 2006.

*Intervenant

I. K. Kominis, T. W. Kornack, J. C. Allred, and M. V. Romalis. *Nature*, 422 (6932):596–599, 04 2003.

M. Pannetier-Lecoeur, L. Parkkonen, N. Sergeeva-Chollet, H. Polovy, C. Fermon and C. Fowley (2011) *Appl. Phys. Lett.* 98 153705.

Barbieri, F. et al. *Sci. Rep.* 6, 39330; doi: 10.1038/srep39330 (2016).

L. Caruso et al. *Neuron* , Volume 95 , Issue 6 , 1283 - 1291.e4 (2017).