NÉEL INSTITUTE Grenoble

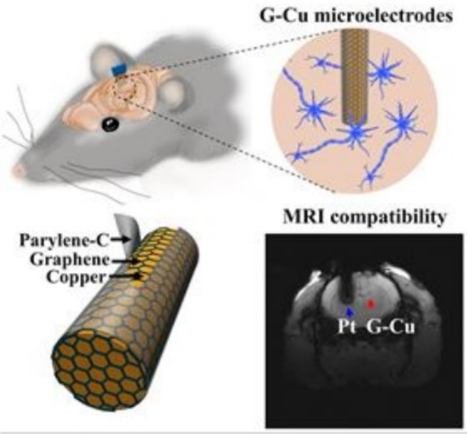
Topic for Master 2 internship – Academic year 2020-2021

Multiscale Brain Interface

The human brain is made up of 100 billion neurons that interact with each other through 100,000 billion connections. While structural maps have reached single cell precision over whole brain, mapping all neuronal signals simultaneously is not achievable today, as those electrical signals are spatially wide spread. In particular, (sub) microscopic mechanisms and their interplays with larger scales remain hidden to the available technology, which impedes to assess all processing abilities of neurons. The aim of the internship is to perform 'pilot' experiment to combine microscale electrical sensing with arrays of graphene field effect transistors (GFETs) and functional Magnetic Resonance Imaging (fMRI) imaging. Signals recorded from neuroimaging data reveals the activity of large assembly of neurons, and are usually complex signals where different frequencies reveals different characteristics of the functioning of the brain. In fMRI, brain connectivity is best evaluated at low frequencies (~0.1Hz). These frequencies are not achievable for standard EEG, but could be obtained with G-FETs. These suitable devices for neural interfaces have demonstrated their ability to detect a wide range of neuronal signals, from slow waves to single spike and ion [1-3]. With the proposed approach, one should therefore be able to simultaneously collect fMRI and electrical low frequency signals, and from there confront them to the mathematical models [4,5].

A first task will focus on the fabrication and characterization of GETs arrays dedicated for long lasting brain recording. Electrical properties of the devices will be followed at the frequencies of interest, and the impact of high magnetic field on the detection performances will be investigated. A second task is to build a dedicated instrumentation of the GFETs array to be compatible with *in-vivo* fMRI measurements, and to characterize the magnetic signature the novel implanted materials. Then, pilots' experiments will be done that combine GFETs recordings and fMRI imaging on anesthetized rodents. Lastly, an important part of the work will be devoted to analyses the recorded signals and confront them to the mathematical models.

The internship is highly interdisciplinary, providing a unique opportunity to combine several expertise (in materials, nano and neuroelectronics, MRI imaging and signal analysis) gathered in three laboratories of Grenoble at Neel Institute, Grenoble Institute of Neurosciences, and Jean Kuntzmann Laboratory. Backgrounds in nanoelectronics or neuro-electrophysiology will be an advantage for the smooth running of the internship.



Schematic of a highly MRI compatible G-Cu neural electrode and the artifact comparison with Pt electrodes of the same size under 7.0 T MRI.

1. Veliev, F. et al. 2D Mater. 5, 045020 (2018).
2. Veliev, F. et al. Front. Neurosci. 11, (2017).
3. Masvidal-Codina, E. et al. Nat. Mater. 18, 280–288 (2019).
4. Achard, S. et al. Phys. Rev. E 77, 036104 (2008).
5. Achard, S. & Gannaz, I. ArXiv181110224 Math Stat (2018).

Right image from Zhao et al., Nano Letters (2016)

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