Understanding brain activity requires simultaneous recordings across spatial scales, from single-cell to brain-wide network. Measurements provide insights about the relationship between structures, functions and dynamics in neuronal circuits and assemblies. Electrophysiological techniques carry crucial information about the electrical activity within neurons. Locally probing the magnetic signature of this activity gives direct information about neuronal currents and the vectorial nature of magnetic measurements provides the directionality of neuronal ionic flux without disturbing it. Noticeably, the magnetic signature induced by the neuronal currents is accessible through Magneto EncephaloGraphy (MEG), which provides neuromagnetic field mapping outside the head using Superconducting QUantum Interference Devices (SQUIDs). However, local measurements of neuronal currents at cellular scale requires small and very sensitive devices.

The purpose of the present thesis work is to develop a novel tool for neurophysiology, the magnetic equivalent of electrodes, named "magnetrodes", are able to detect the local neuronal currents through magnetic detection. Recent advances in spin electronics have given rise to Giant MagnetoResistance (GMR) based sensors, which offer the possibility to be miniaturized and sensitive enough to detect very weak magnetic fields like those emitted by neurons at local scale (in the picotesla to nanotesla range). Two kinds of GMR based sensors have been developed throughout this work, one of these are planar probes dedicated to surface measurements (hippocampus slice, muscle or cortex), the other kind are sharp probes, designed in a needle-shape to easily penetrate the tissues and locally record the neuromagnetic fields. Three experiments have been performed, either *in vitro* and *in vivo*. In the first experiment, an Action Potential has been detected magnetically *in vitro* by means of planar GMR sensors, resulting from axial currents within a mouse muscle. The second *in vitro* experiment analyzed the hippocampal mouse brain slices, where both planar and sharp probes were tested giving some preliminary results. Lastly we performed the first magnetic recordings *in vivo* on cat's cerebral cortex, displaying stimulus-induced cortical responses of 10-20nT_{pp}. These results pave the way for local magnetophysiology, a novel approach of brain exploration and interfacing.

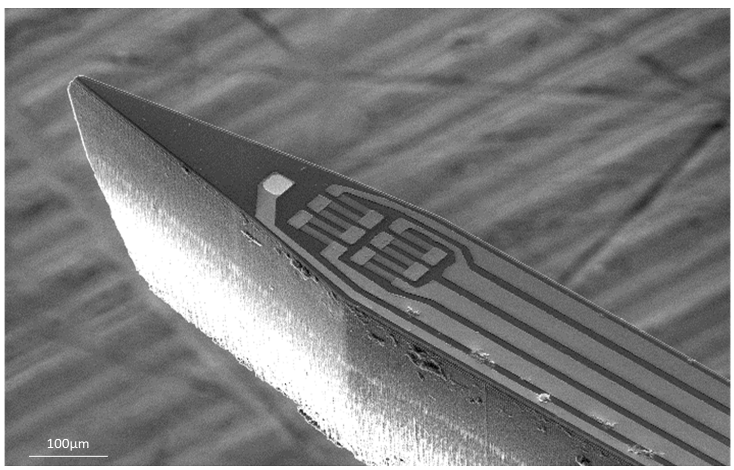

Figure 1: Sharp magnetrode with two GMR elements and an electrode