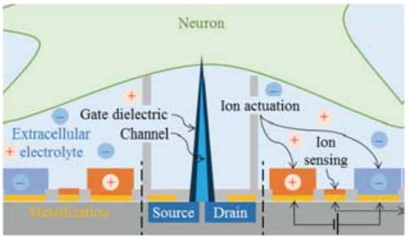
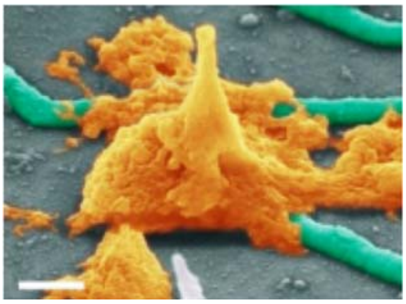
PhD Project





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Italian Co-tutor(s): Prof. Pierpaolo Palestri, Ing. Denis Brandalise

Title:
Iontronic actuators and nanowire devices for neuron activity stimulation and sensing

Introduction:
Understanding neuron physiology in realistic environments with cheap and massively parallel devices is a challenging long term research objective. Currently, Micro Electrode Array platforms are used for both electrical neurostimulation and neuron signal recording. In realistic electrolyte environments, however, the neuron interacts with its neighbors via ion exchange through the membrane as well. Nanoelectronics can provide disruptive contributions to mimic more realistic neuron conditions for neuroscience studies. In particular, vertical nanowires that detect intracellular electrophysiological events with high sensitivity and spatial resolution can be coupled to ion-tronic patches inspired by polymer-based batteries that act as electrochemical actuators in a combined electronic and iontronic stimulus-sensing platform.

Proposed research activity and thesis objectives:
The objective of the PhD thesis is to develop mixed electronic-iontronic platforms for meuroscience. IN particular, to investigate the operation of vertical nanowire needles, vertical nanowire field effect transistors and iontronic patches inspired by polymer-based batteries as sensor probes and electrochemical actuators of neuron activity. Starting from the pioneering work by Lieber et al. on nanowire sensors [1] and by PEDOT:PSS doped polymer technology for low-cost low-weight batteries [2], and following an extensive literature search, *ad-hoc* and TCAD models for realistic nano-needle, nano-FET and patch architectures will be identified. Methods and models to simulate ion emitters' efficiency and ion diffusion will be developed and extensively used to investigate a wide design space. Three-dimensional numerical simulations and compact models of ion and electron transport in the semiconductor and in the electrolyte will provide guidelines to identify the most promising device architectures, nanowire dimensions, fluid gate insulator materials, etc. Characterizations and model calibrations on data provided by partners will be part of the endeavour. In-house developed and commercial simulation tools will flank experiments by partners aimed at achieving enhanced electrical signal to noise readout.

Vision goals of the activity: An optimized vertical nanowire sensing platform combined with actuation and conventional microelectrode array readout electronics will be designed to eventually deliver a complete actuation/sensing platform. The platform could then be used for closed-loop studies of neuron physiology, aimed at shedding new light on control of neurophysiological diseases such as for instance epilepsy, which is estimated to affect as many as 50 million people worldwide.

Supporting research projects (and Department)
The activity will be carried out at the DIEF, Università degli Studi di Modena e Reggio Emilia and it is connected to the H2020 IN-FET project "Ionic Neuromodulation For Epilepsy Treatment" (www.in-fet.eu).

Possible connections with research groups, companies, universities involved in IN-FET.
IBM Research Zurich (CH - nanowire fabrication)
University of Sheffield (UK – iontronic device fabrication)
University of Geneva (H - electrophysiological networks and signals)
IUNET Research Consortium (IT - www.iunet.info)

Essential bibliography:
[1] Lieber et al., IEEE Trans. on Nanotechnology, vol.9, n.3, 2010, doi: 10.1109/TNANO.2009.2031807
[2] T.A. Sjöström et al., Advanced Material Technologies, DOI: 10.1002/admt.201700360
[2] A.Bandiziol et al., IEEE Trans. on Electron Dev., vol.62, n.10, 2015, doi: 10.1109/TED.2015.2464251
[3] ENBIOS-2D LAB, www.nanohub.org , doi:10.4231/D3V11VM7D