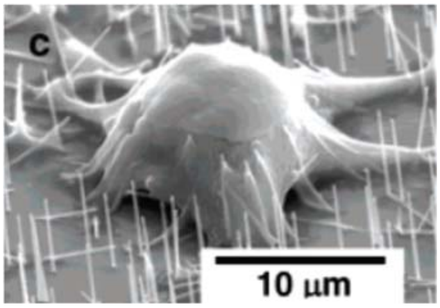
Master thesis Project



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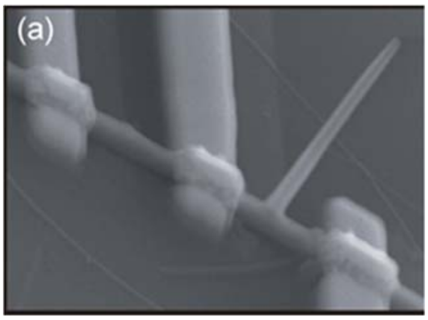
Title:
Vertical nanowire devices for neuron activity sensing and stimulation

Introduction:
Understanding neuron physiology in realistic environments with cheap and massively parallel devices is a challenging long term research objective. Nanoelectronics technology can provide disruptive contributions to this end. In particular, semiconductor nanowire (NW) devices that can address intracellular electrophysiological events with high sensitivity and spatial resolution are emerging as key tools in nanobioelectronics.
The figures represent neuron cells cultivated on rendomly distributed vertical nanowires (top) and an individual nanowire FET device with a needle to contact the neuron protruding from the channel region between the Source and Drain contacts (bottom).



Proposed research activity and Master thesis objectives:
The objective of the Master thesis is to investigate the operation of vertical nanowire needles and vertical nanowire field effect transistors as electrochemical sensors and probes of neuron activity. Starting from the pioneering work by Lieber et al. [1], and following an extensive literature search, TCAD models for realistic nano-needle and nano-FET architectures will be identified. The starting point will be a device where the nanowire protrudes vertically from the channel region. Three-dimensional TCAD simulations of the device electrical behaviour in electrolyte environment will be carried out to identify the most promising device architecture, nanowire dimensions and position in the channel, gate insulator material. The goal of this optimization will be to enhance the electrical signal readout from the sensor element. Simulations will be carried out with the Synopsys Sentaurus tools, where electrolytes will be treated as proposed in [2]. Simulations will be benchmarked with those derived from the ElectronicNanoBIOsensorSimolator (ENBIOS) developed in-house by the research group [3]. Activities are carried out in collaboration with research groups of the IUNET consortium, and major European Universities involved in the H2020 IN-FET project.

Vision goals of the activity: An optimized vertical nanowire sensing platform fabricated along the guidelines developed in this thesis could be combined with actuation and conventional microelectrode array readout electronics 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 a number 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"

Possible connections with research groups, companies, universities involved in IN-FET.
IBM Research Zurich (nanowire fabrication)
University of Geneva (electrophysiological networks and signals)
SISSA Trieste (neurophysiological experiments)
IUNET Research Consortium (www.iunet.info)

Possible connections with research groups, companies, universities involved in IN-FET.
Essential bibliography:
[1] Lieber et al., IEEE Trans. on Nanotechnology, vol.9, n.3, 2010, doi: 10.1109/TNANO.2009.2031807
[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