Interfacing neurons network with polycrystalline graphene field effect transistors

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Graphene offers an ideal platform for recording and culturing neural networks. It is partially due to its exceptional neuronal affinity and the presence of readily accessible surface charges which give the unprecedented possibility to realize a direct coupling with cells.
Here, we report the cytocompatibility study of pristine monolayer graphene, and its significant advantage for neuromedicine and fundamental research compared with other electrodes materials. We show that bare (CVD-grown) graphene monolayers [1] actively promotes neurites outgrowth without any surface functionalization with cell-adhesive coating (for instance poly-L-lysine). Our investigation with Raman spectroscopy show the impact of graphene crystallinity on the neurons adhesion and further growth, the monolayer becoming cell-repulsive with increasing amount of defect [2]. The ability to control the neuronal affinity of the graphene-coated substrate opens the way to a variety of applications for patterning long-lasting (in-vitro) neural networks (Fig.1) and for in-vivo implants with reduced inflammatory response and glial scars [3].
Moreover, the nano-structuration of those large (mm²) graphene monolayers allows the fabrication of dense arrays of highly sensitive field effect transistors. Indeed, all the graphene liquid-gated transistors (G-FETs, fig.1b) showed reproducible electrical properties (mobility and sensitivity being around 6000 cm².V-1.s-1 and 3-4 mS/V) and allowed a rapid detection of very small (75 µV) potential spikes comparable with neuronal signaling. As graphene could be transferred on a wide range of substrate, we realized graphene FETs arrays on Si/SiO2, glass and polyimide substrates and interfaced them with primary neurons (during about 21 days) to record their spontaneous electrical activity (Fig.1c). We investigate how structural 1D defect can interact with neurons and improve the GFET sensitivity.

References

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Figures

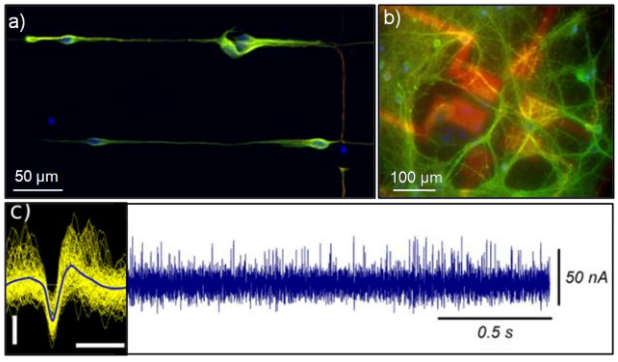

Figure 1: (a) Enhanced growth and confinement of primary hippocampal neurons (DIV2) with graphene based micro-patterns. Immuno-fluorescente staining labels the soma (bleu), the neurites (green) and the axon (red). (b) 21 days old neurons cultured on graphene field effect transistors and (c) time-traces of the GFETs drain-source current in response to neuron spikes (right). Surimposed extracellular spikes estimated from the GFET response. Scale bar 2ms and 200µV.