Graphene Transistors for Detection of Neuronal Activity

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Abstract: Due to its outstanding properties graphene offers an ideal platform for sensing and culturing neural networks. Its biocompatible, soft, and chemically inert nature associated to the lack of dangling bonds offers novel perspectives for direct integration in bioelectric probes. The presence of readily accessible surface charges gives the unprecedented possibility to realize a strong electrical coupling with cells. Moreover, the possibility to transfer it on transparent and flexible substrates opens the way to a variety of applications for in-vitro studies and in-vivo implants with reduced inflammatory response [1].

Here we present a study of our CVD grown SL graphene [2] with regard to its biocompatibility and bioelectrical interfacing. We found, that while on any other substrate an adhesive coating *(such as poly-L-lysine)* is needed to assure neuronal growth in culture, graphene actively promotes the growth even without a coating. Moreover, in comparison to other frequently used substrates the neuron density and the neurite length are significantly higher for neurons cultured on uncoated graphene as shown in Fig. 1.

Further, in order to prove the ability of graphene based devices to detect neuronal signals, we realized graphene FET arrays on Si/SiO_2, glass and polyimide substrates and performed characterization measurements in cell culture medium with a Pt gate electrode. To mimic the neuronal spiking we superimposed 1ms long Gaussian pulses on the DC offset of the Pt-electrode. All graphene FETs showed reproducible electrical properties with a mobility around *6000* $cm^2V^{-1}s^{-1}$ and a sensitivity to potential changes up to *2 mS/V* allowing a rapid detection of very small *(around 200µV)* potential spikes comparable with neuronal signaling [3]. Also, neurons were shown to survive on graphene FETs for periods up to 19-21 days achieving the regular maturation stage.

In conclusion, our studies show the enormous potential of graphene based devices as neuronal growth support and bioelectrical sensors.

References:

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Figures:

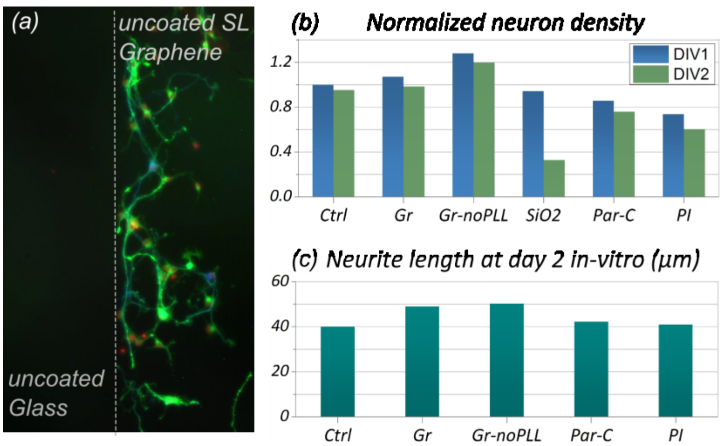

Fig. 1: Coating-free graphene promotes neuronal growth. a) Coating-free glass and graphene with neurons after 4 days in culture. The neurons survive only on graphene. b) Neuron density on day 1 and day 2 of and c) the average neurite length on day 2 of culture on different substrates: Ctrl - glass control sample, Gr - graphene, Gr-noPLL – coating-free graphene, Par-C – parylene-C and PI – polyimide.

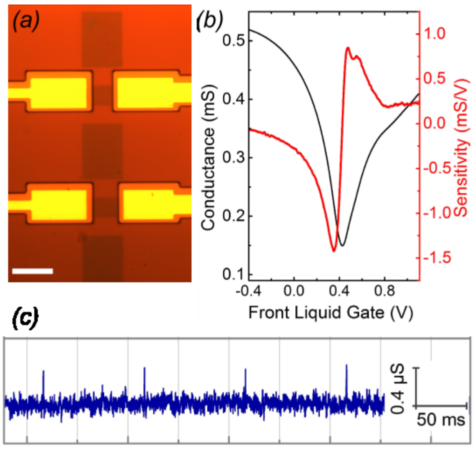

Fig. 2: Graphene FET characteristics. a) Optical micrograph of a typical device.
b) Conductance variation (black line) and device sensitivity (red line) as function of front liquid gate potential measured in cell culture medium. c) Detection of 1 ms long 250 µV Gaussian potential spike applied to the medium through a Pt-electrode using graphene FET.