Electrochemical characterization of graphene gated field effect transistors: route for smart biological sensors

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Biosensors have an increasing role in medical science. To be competitive these biosensors have to be highly sensitive, easily adaptable for various type of detections, compact, unexpansive and mass-producable. Through past decades, rise of microelectronic has enable the production of highly sensitive sensors at low cost with mass-production capacities. In this context, the discovery of highly conductive, lightweight, flexible, transparent, mechanically robust, CVD graphene has brought interest from the biosensors community. Its high specific area, due to its atomic thickness is particularly appealing for the detection of charged biological species. Previous work in our group demonstrated a unique fabrication protocol for graphene solution gated field effect transistor (SGFET) that can be adapted to arbitrary substrates. This study presents the electrochemical characterization and first biological detection campaign of our SGFET sensors. In Phosphate Buffer Saline (PBS) 0.01X, V_{GS} was swept to characterize the I_{DS} *vs.* V_{GS} evolution (Fig.1a) but also the current leakage in the solution (Fig.1b). Data post processing allowed also to measure V_{Dirac} and the sensitivity of the sensor. Graphene based sensors are known to drift rapidly which can be followed by looking at the evolution of the leakage current (I_{leakge}). Our characterizations showed a very low I_{leakge}, between 2 and 10nA made possible by the passivation with SU-8 resin of all the chip except for the sensing areas. This passivation prevents any electrochemical reaction to occurs during the sensor operation in liquid and avoid the exposition of the edges of the graphene to the electrolyte (unwanted reaction and principal source of $I_{leakage}$). For the biological detection campaign, different layers of charged molecules[1] were anchored on a unique tripodal molecular compound[2], functionalized on the graphene. The direction and magnitude of the shift of V_{Dirac} from one functionalization steps to another helped to understanding the intrinsic mechanisms of the detection. As the first round of tests gave interesting results, our group is now moving to small molecules like hormones detection using aptamers (small and single DNA strand) as a probe.

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[1] T. Alava et al., "Control of the Graphene–Protein Interface Is Required To Preserve Adsorbed Protein Function" Anal. Chem. 5 (2013) 2754.

[2] C J. A. Mann et al., "Preservation of antibody selectivity on graphene by conjugation to a tripod monolayer" Angew. Chem. Int. Ed. 11 (2013) 3177

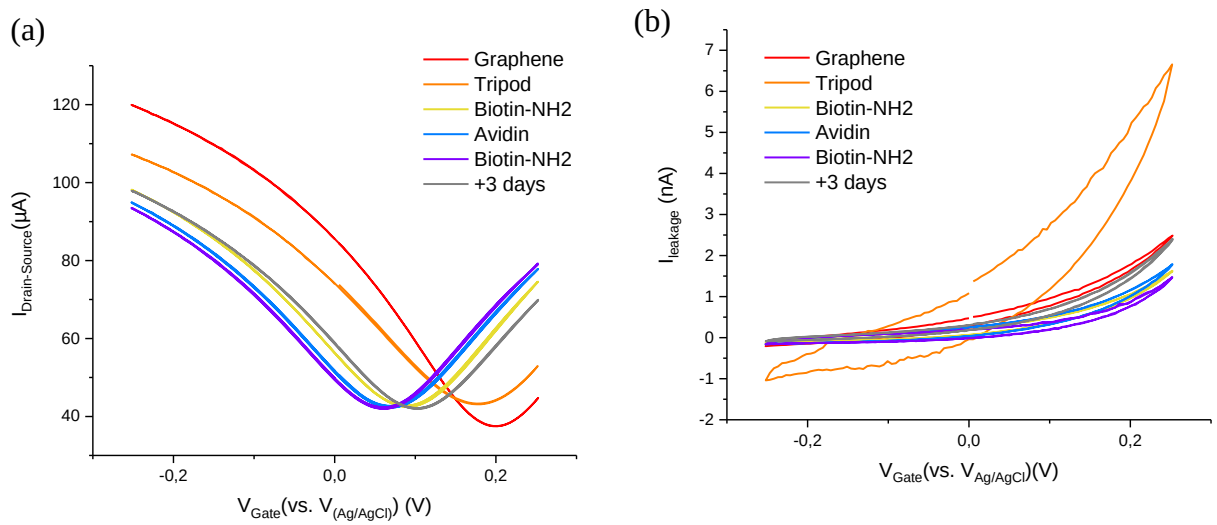

Figure 1. (a) I_{DS}-V_g curves obtained from liquid gating a 500 µm x 250 µm SGFET fabricated on a silicon substrate. Dirac peak shift through the functionalization steps. In PBS solution 0,01X (pH=7,6), avidin is positively charged and induced here a shift although negative potential (n-doping of the Gr). (b) $I_{leakage}$ evolution through functionalization steps. Bare graphene has a leakage current of 7nA. First functionalization passivates the graphene and screens the eventual defects of the graphene (holes) to the electrolyte.