A versatile fabrication protocol for graphene gated field effect transistor-based smart biological sensors on arbitrary substrates

A. Hugo[1,2], Zheng Han[1,2], Julien Renard[3], Vincent Bouchiat[3], Pascal Mailley[1,2], Thomas Alava[1,2]

1 Univ. Grenoble Alpes, F-38000 Grenoble, France
2 CEA, LETI, Minatec Campus, F-38054 Grenoble, France
3 Institut Néel, Université Grenoble Alpes – CNRS:UPR 2940, F-38042 Grenoble, France. C.A de Coulomb

The demand for novel sensing bricks that can be adapted to various applications cases is continuously growing in the field of chemical and biological sensing applications. To mention a few, sensors that can be biodegradable, passive, flexible or remotely addressable are nowadays regularly requested. Single layer graphene check most of these requirements and is an ideal candidate for next-generation biological sensors. In this study we present the establishment of a novel fabrication protocol for graphene solution gated field effect transistor (SGFET) that can be adapted to arbitrary substrates, we report fabrication of large surface capture SGFET sensors on printed circuit boards substrates using the exact same protocol. The host PCBs contain a radar antenna in order to perform remote interrogation of the graphene channel.

Cr/Au electrodes are evaporated on the target substrates and consecutively graphene is transferred onto the electrodes. Graphene is then patterned to be localized in between the electrodes and avoid deleterious leakage current. The innovative patterning step we introduced is described in figure 1. Although containing several photoresist and material coating of the graphene layer for different photolithography steps we report low level of contamination resulting in Dirac peaks very close to the level of undoped graphene SGFET. The fabrication process bring little to none openings in the graphene lattice (inset figure 2). We performed liquid gating experiment thanks to a bipotentiostat in a dedicated liquid set-up and the light shift of the Dirac point towards n-doped graphene testify a low level of electron scatterers associated with little level of surface contamination (I_{ds}-V_g curve in figure 3,a). Finally, we fabricated similar devices on printed circuit boards containing copper-made radar antenna for remote interrogation of graphene biological sensors embedded in a liquid vessel with no physical access (similar situation than a body implanted device). We performed back gating experiment to confirm the proper behavior of the graphene devices assembled on PCBs, transconductance levels are in good comparison with state of the art (figure 3).

Work is ongoing to demonstrate remote interrogation of the graphene device connected to the radar antenna and characterize associated sensitivity to biological molecules adsorption. Equally, we are investigating biological functionalization of the graphene devices to operate as specific biological sensors.

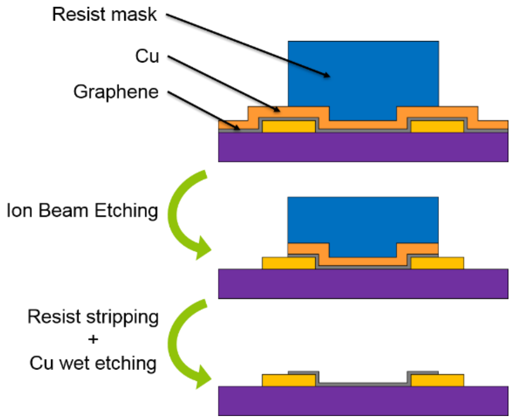

Figure 1: Scheme of the fabrication protocol for graphene patterning using copper hard mask. Copper cleans well from the graphene surface through classical Ammonium Persulfate wet etching step. Photoresist/Copper/Graphene stack is etched through physical Ion Beam Etching.

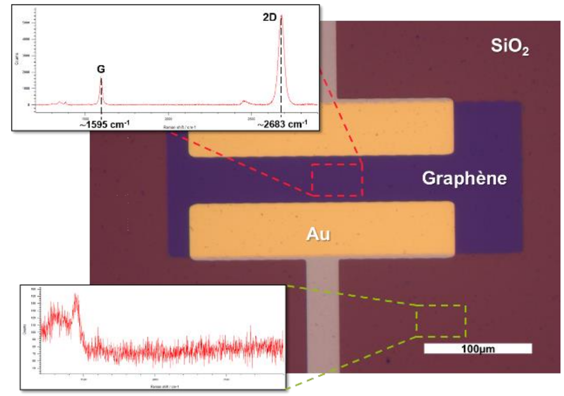

Figure 2: Photograph of patterned graphene through our copper based patterning technique. A very low D peak amplitude (~1350 cm^{-1}) on the Raman spectra testify low damage to the graphene lattice.

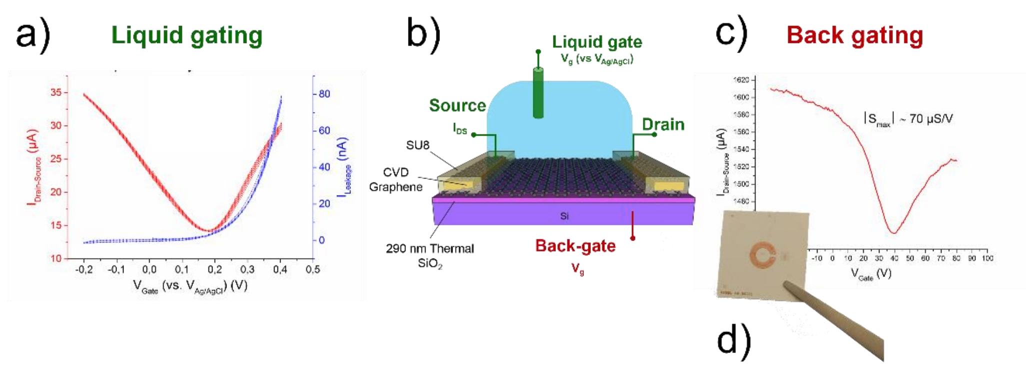

Figure 3: The experimental principle of liquid gating and back gating of a graphene transistor is presented in (b). Inset (a) shows the I_{DS}-V_g curves obtained from liquid gating a 100 µm x 230 µm SGFET fabricated on a silicon substrate. Reproducibility over five scans is exposed as well as low leakage current levels. Inset (c) represent the I_{DS}-V_g curves obtained from back-gating a 800 µm x 300 µm graphene FET assembled on a PCB board containing a radar antenna, displayed in inset (d).