Electrolyte-gated graphene field-effect transistors for biosensing applications fabricated at the wafer scale

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Abstract

Since the discovery of graphene more than ten years ago [1] considerable progress was made in the elucidation of its unique physical properties and in the use of these properties in the construction of useful devices. However, graphene devices designed for mass-production are lagging behind such fundamental and applied research achievements [2]. This is due in part to the difficulty in obtaining graphene over large-areas with uniform electronic properties, after suffering a transfer process that uses a polymeric temporary substrate and after being submitted to a sequence of lithographic steps for patterning.

In this work, we report the fabrication, operation, and modeling of a fully-integrated electrolyte-gated graphene field-effect transistor (EGFET), where the conventional wire gate electrode is replaced by an in-plane recessed metallic gate (Figure 1a). The devices are replicated 280 times in an array that covers the surface of a 200 mm oxidized silicon wafer by means of a standard UV-optical lithography clean-room process, which is rendered compatible with graphene. The proposed integrated gate geometry provides an efficient transistor gating, confines the droplet used as gate dielectric inside the transistor active zone, and provides a platform of high sensitivity for detection of chemical and biomolecules that can be dissolved in the liquid gate dielectric. The EGFET gate capacitance is a series combination of the electrical double layer capacitance of the electrolyte and the quantum capacitance of graphene. Both capacitances are comparable in size and are not readily accessible for measurement [3]. Therefore, we fitted the transistor conductivity data using a physical model that describes the dc conductivity of graphene as a function of the gate voltage (Figure 1b), based on carrier resonant scattering due to strong short-range potentials originating from impurities adsorbed at the graphene surface [4]. Using the results of the simulations, transistor performance parameters such as ambipolar carrier mobility, were extracted ($\mu_h \approx \mu_e \approx 1850$ cm^2 V^{-1} s^{-1}). Preliminary results show that the devices are highly sensitive to changes in the channel charge environment induced by chemical and biomolecules in solution, as illustrated in Figure 1c, where anti-body anti-gen bio-recognition events are transduced into changes in the position of the minimum conductivity point of the EGFET transfer curve.

References

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Figure 1

a b c