Biosensing using wafer-scaled electrolyte-gated graphene field-effect transistors

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Abstract

Since the discovery of graphene, its extraordinary properties have led to many promising applications. In biosensing, graphene's high sensitivity to the charges in the immediate environment, combined with a high chemical stability, opened up a path to applications where graphene is establishing itself as a consistent alternative to existing technologies. Screen-printed graphene electrodes available commercially are widely used to benchmark graphene sensor properties against other technologies. However, sensors based on single-layer chemical vapor deposited (CVD) graphene, fabricated by photolithography still encounter several hindrances that prevent them from going into production. These limitations stem from the difficulty to obtain uniform adhesion and electronic properties when transferring graphene from his native metallic substrate, normally involving a temporary polymeric substrate, or when going through extensive fabrication processes.

In this work, we report on the fabrication, operation and modeling of electrolyte-gated graphene field-effect transistors (EGFETs). The sensor fabrication process uses 200 mm oxidized silicon wafers for the contacts, and 150 mm copper foils for the CVD growth of graphene. The conventional wire used for the gate electrode is replaced by an integrated gate coplanar to the source and drain (Figure 1a). The contacts were processed in standard UV-optical lithography and clean-room processes. To render the graphene process more compatible with the cleanroom fabrication, contacts, gate and insulation lines are fabricated using the full range of clean room fabrication techniques, while graphene transfer is postponed as much as possible, going through one patterning step only.

The EGFET gate capacitance is a series combination of the electrical double layer capacitance formed at the electrolyte/contact and at the electrolyte/channel interfaces, and the quantum capacitance of graphene. Both capacitances are comparable in size and are not readily accessible for measurement [1]. 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 [2]. 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}).

As a proof of principle, the devices were tested in two configurations. In a first test, the ionic force of the solution was changed, and the shift in graphene Dirac point was used to sense this change. In a second test, the non-selective detection of microcystin-LR in water was tested in order to evaluate the possible use of the devices in a label-free detection scheme. Preliminary results of this study will be presented (Figure 1b).

References

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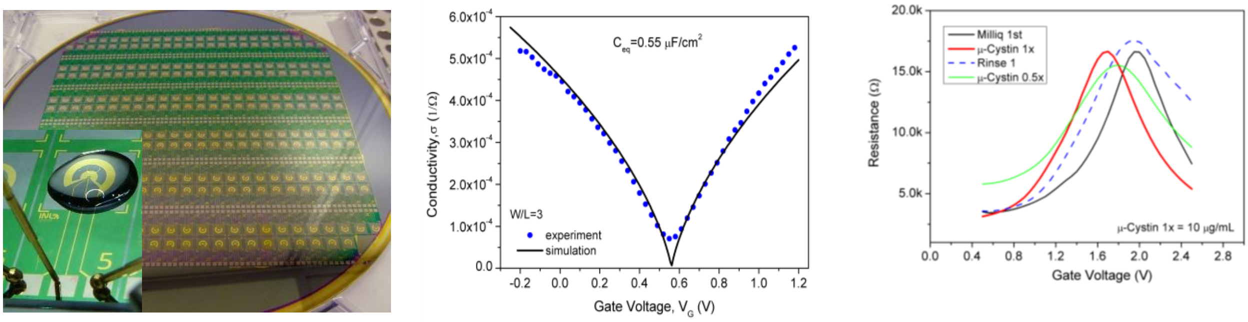
Figure 1



a **b** **c**