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High performance dual-gate bilayer graphene FET with neutral channel for logic applications

A. Nourbakhsh[1, 2], A. Klekachev[1, 2], C. Lockhart de la Rosa[1, 2], M. Politou[1, 2], I. Asselberghs[1,] M. Heyns[1, 2], and S. De Gendt[1, 2],
[1] imec, Kapeldreef 75, B-3001 Leuven, Belgium
[2] KULeuven, Celestijnenlaan 200, B-3001 Leuven, Belgium,
Email: nourbakh@imec.be

The use of bilayer graphene (BLG) is considered as an interesting alternative to circumvent the zero-bandgap problem in single-layer graphene. In fact, the application of a transverse electric field (***E***) in BLG allows for the breaking of the inversion symmetry and therefore the occurrence of an electronic bandgap, whose magnitude can be tuned by the strength of the applied field [1,2]. In addition to the electrostatic gating, chemical doping of the BLG top surface induces an additional electric field that enhances the vertical displacement field [3,4].

In this work, we report a novel dual-gate BLG-FET architecture with neutral channel, in which the electrostatic control of the BLG active channel is enhanced by the use of chemical functionalization by (F_4TCNQ). In this way, the BLG-FET achieves a I_{on}/I_{off} ~60 and an electron mobility up to ~1600 $cm^2V^{-1}s^{-1}$. The total charge in our devices is as low as 10^{11} cm^{-2}.

Fig. 1 shows a schematic of a F4TCNQ-doped, dual-gate BLG-FET. A top gate high-k/metal stack (Ti/Pd/Al_2O_3) is directly deposited on a BLG film covered with F4TCNQ. The bottom gate is represented by the 300nm SiO_2/Si stack on which BLG was previously exfoliated and identified by a combination of optical microscopy and Raman spectroscopy.

The transfer characteristics I_d vs. V_{TG} (parameterized by V_{BG}) are shown in Fig. 2. The BLG top layer is "chemically gated" by the F_4TCNQ layer, which generates a permanent ***E*** perpendicular to the BLG planes, responsible for a 30–50 meV bandgap. This ***E*** yields the asymmetry between the two BLG layers and results in a significant bandgap opening. In fact, this already results in an I_{on}/I_{off} ~10 at V_{BG}=0 and a total channel charge density n~4×10^{12} cm^{-2}. For V_{BG}<0, n increases to ~ 6.5x10^{12} cm^{-2} due to hole injection in the bottom BLG layer. At the same time, the application of a negative V_{BG} generates an ***E*** aligned in the opposite direction to that arising by the F_4TCNQ chemical gating. Therefore, the bandgap vanishes, I_{on}/I_{off} decreases (Fig. 2). For V_{BG}>0, the ***E*** enhances the ***E*** generated by the F_4TCNQ layer, therefore increasing the bandgap magnitude and boosting the I_{on}/I_{off} to values up to ~60. Our BLG-FETs are normally OFF (V_{TG} ~ 0). To switch them on, we only need to apply a V_{TG}~3V. In the non-neutral channel BLG-FETs reported in literature, I_{on}/I_{off} switching occurs at very high voltages [2], thus dramatically increasing the static power needed to drive the devices. In conditions of channel charge neutrality (n~10^{11} cm^{-2}). The electron mobility increases from ~400 to ~1600 $cm^2V^{-1}s^{-1}$ upon restoring the channel charge neutrality from n~4×10^{12} cm^{-2}.

In summary, we report a novel dual-gate BLG-FET architecture that significantly improves the state-of-the art BLG devices relying on the application of an external ***E*** for bandgap opening. Our devices achieve I_{on}/I_{off}~60 without significantly suppressing the carrier mobility, and, more importantly, preserving charge neutrality in the device channel. The I_{on}/I_{off} well benchmarks with the record-high values already reported in literature

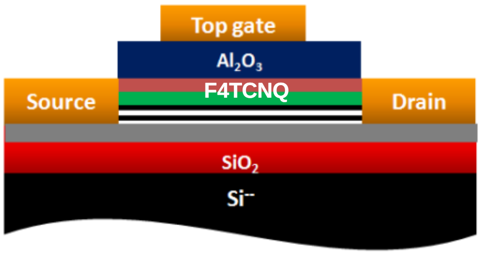

Fig. 1 Schematic of BLG-FET structure studied in this work.

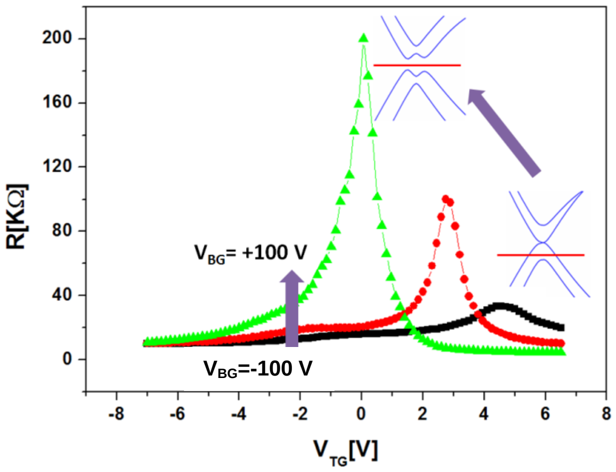

Fig. 2 Room temperature transfer characteristics (R vs. V_{TG}) of the BLG-FET described in this work. V_{BG} is varied from -100 to +100 V. The black curve corresponds to V_{BG}=0 V. The neutrality point voltage V_{NP} towards positive values is due to the effect of F_4TCNQ functionalization. The green and black curves are measured at V_{BG}= +100V and V_{BG}= –100V, respectively.

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