Direct observation of ultraclean tunable band gaps in bilayer

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Controlling both the charge carrier density and the band gap of a semiconductor opens the doors to a wide range of applications, including, e.g., highly-tunable transistors, photodetectors, and lasers. Bernal-stacked bilayer graphene is a unique van-der-Waals material that enables the opening and tuning a band gap by applying an out-of-plane electric field [1]. While the first evidence of the tunable gap was found ten years ago [2], it took until recently to fabricate sufficiently clean heterostructures in which the electrostatically induced gap could be used to fully suppress transport or confine charge carriers [3].
Here, we present a detailed study of the tunable band gap in bilayer graphene using temperature-activated transport and finite-bias spectroscopy measurements. The high sensitivity of the latter method allows comparing different gate materials and device technologies, which directly affects the disorder potential in bilayer graphene. We show that graphite-gated bilayer graphene displays extremely low disorder and shows as good as no subgap states resulting in ultraclean tunable band gaps up to 120 meV. The size of the band gaps is in good agreement with theory and allows complete current suppression enabling a wide range of semiconductor applications.

References

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Figures

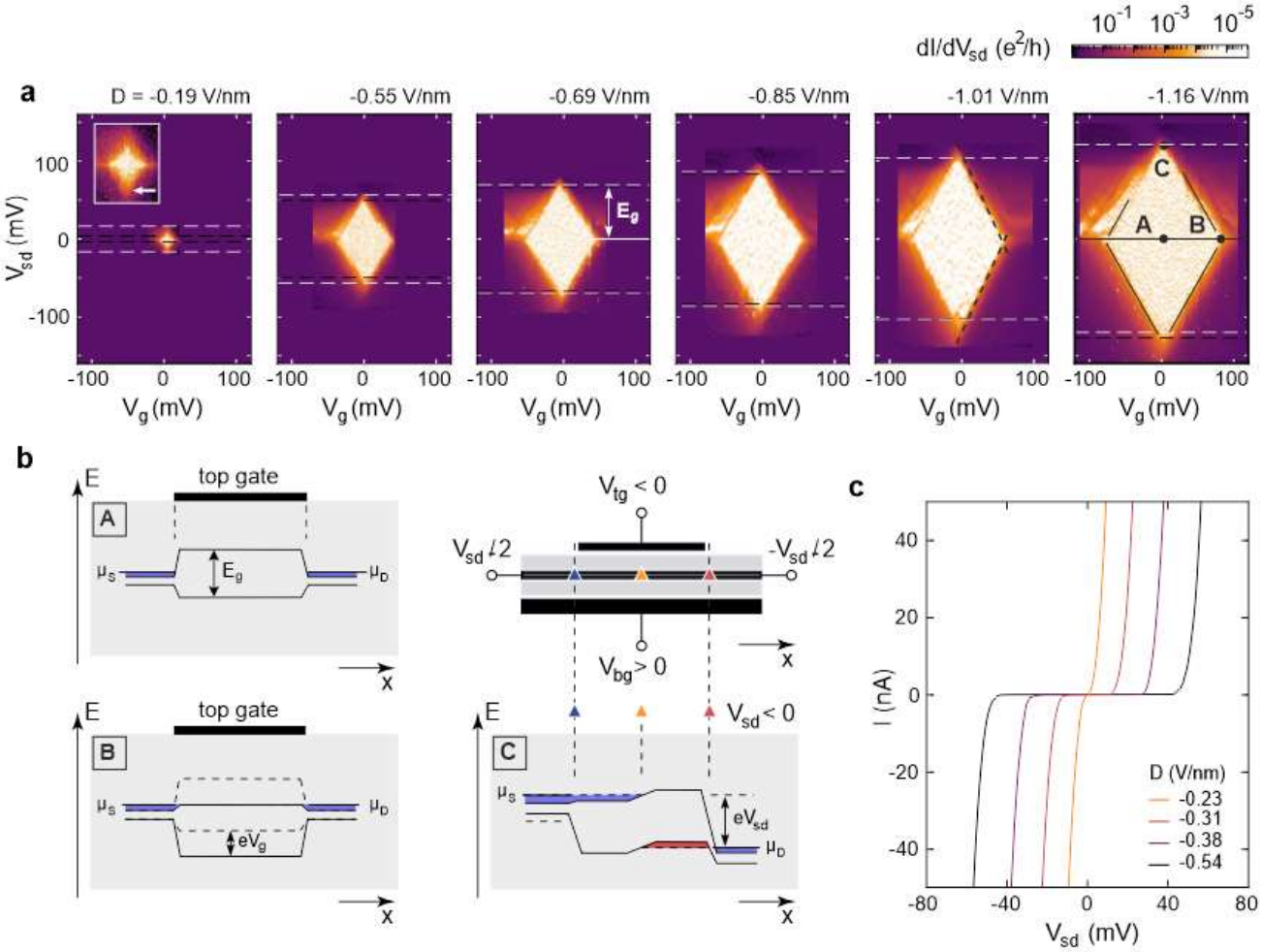

Figure 1: (a) Colour plot of the differential conductance dI/dV_{sd} of a Gr/hBN/BLG device, measured at T = 50 mK as a function of V_{sd} and V_g for different displacement fields (see labels). The white dashed lines denote the band gap predicted theory, the black dashed lines the effective band gap E^{eff}_g. The inset shows a magnification for displacement field D=−0.19 V/nm. Even at small displacement fields, the area of suppressed differential conductance presents a pronounced diamond shape. (b) Schematic representation of the various transport regimes at the points denoted as A, B, C in the rightmost diamond in panel (a). At $V_{sd} = 0$, the presence of the band gap strongly suppresses transport in the double-gated region (A). Transport is re-established either by changing the chemical potential in the double-gated region using the effective gate voltage V_g (B) or by applying a sufficiently large source-drain voltage V_{sd}, which changes the effective potential at the edges of the double-gated BLG, introducing charge carriers and forming a p-n junction. (c) I-V-characteristic of the Gr/hBN/BLG device for different values of D at constant V_g. The device shows a clear diode-like behaviour, with no appreciable sub-threshold current.