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Transport in bilayer and trilayer graphene: band gap engineering and band structure tuning

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Controlling the stacking order of atomically thin 2D materials offers a powerful tool to control their properties. Linearly dispersed bands become hyperbolic in Bernal (AB) stacked bilayer graphene (BLG). Both Bernal (ABA) and rhombohedral (ABC) stacking occur in trilayer graphene (TLG), producing distinct band structures and electronic properties. A symmetry-breaking electric field perpendicular to the sample plane can further modify the band structures of BLG and TLG. In this talk, I will describe our experimental effort in these directions using dual-gated devices. Using thin HfO_2 film deposited by ALD as gate dielectric, we are able to apply large displacement fields D $>$ 6 V/nm and observe the opening and saturation of the field-induced band gap E_g in bilayer and ABC-stacked trilayer graphene, where the conduction in the mid gap changes by more than six decades. Its field and temperature dependence highlights the crucial role played by Coulomb disorder in facilitating hopping conduction and suppressing the effect of E_g in the tens of meV regime. In contrast, mid-gap conduction decreases with increasing D much more rapidly in clean h-BN dual-gated devices. Our studies also show the evolution of the band structure in ABA-stacked TLG, in particular the splitting of the Dirac-like bands in large D field and the signatures of two-band transport at high carrier densities. Comparison to theory reveals the need for more sophisticated treatment of electronic screening beyond self-consistent Hartree calculations to accurately predict the band structures of trilayer graphene and graphenic materials in general. In collaboration with: Ke Zou, Jing Li, Fan Zhang, C Clapp, and Allan MacDonald. References: Zou and Zhu, PRB 82, 081407 (2010) Zou et al, Nano Letters, 13, 369 (2013)