Electronic Supplementary Material

Barrier inhomogeneities at vertically stacked graphene-based heterostructures

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Figure S1: (a) Transfer characteristics of a graphene transistor (at 300 K). (b) and (c) display output and transfer characteristics of a thick MoS₂ transistor (at 300 K), respectively. The corresponding positions of both drain (D) and source (S) electrodes are marked in the optical microscope image, shown in the inset. The graphene mobility in (a) was estimated to be about $5 \times 10^3$ cm² V⁻¹ s⁻¹, which is comparable with previous report [1]. In addition, the symmetrical and linear relationship of $I_{ds}-V_{ds}$ demonstrates the formation of Ohmic contact between Ti and a thick MoS₂ flake. The carrier mobility of a thick MoS₂ flake was derived to be $10^1$ cm² V⁻¹ s⁻¹ in high consistent with the literature [2,3]. Though making the multiple-electrode configuration on the graphene-based heterostructures, it guarantees that the charge transport mechanism is dominated mainly by the vertically stacked heterostructure interface.

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Figure S2: (a) and (b) display output and transfer characteristics of a thick SnS$_2$ transistor (at 300 K), respectively. The corresponding positions of both drain (D) and source (S) electrodes are marked in the optical microscope image, shown in the inset of (a). The linear dependence of $I_\text{ds}$-$V_\text{ds}$ manifests negligible contribution of contact resistance in the Ti/SnS$_2$ interface. The estimated value of carrier mobility is about 3 cm$^2$ V$^{-1}$ s$^{-1}$, compared with the previous report [4].
Figure S3: AFM images of graphene/MoS$_2$ (a) and graphene/SnS$_2$ (b) heterostructure transistors with corresponding line profiles in (c) and (d)
Figure S4: $\ln(I_0/T^2)$ versus $qk_B/T$ plot for the graphene/SnS$_2$ heterostructure transistor. The solid line in red is guide to eyes. A temperature independence of Schottky barrier height cannot be derived from the plot.
Figure S5: Effective Schottky barrier height and ideality factor as a function of temperature for the graphene/SnS₂ heterostructure transistor. Clearly, the plot shows a strong temperature dependence of both fitting parameters. With decreasing temperature, the effective barrier varies from 0.49 down to 0.21 eV, while the ideality factor increases from 2.17 to 3.56.