High on/off ratio of carbon nanotubes/transition metal dichalcogenides vertical field-effect transistors

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Recently, vertical field-effect transistors (VFETs) built up from graphene/Si [1] or graphene/transition metal dichalcogenides (TMD) junctions has been demonstrated [2]. Such VFETs offer a high current density and open up a possibility for three-dimensional integration in the future electronics. However, in those VFETs, on/off ratio is controlled based on modulation of graphene/Si or graphene/TMD Schottky barrier heights, which is usually limited because of the screening effect in graphene, leading to low on/off ratio at room temperature. In this study, we report a VFET is created by sandwiching few-layer MoS_2 as a semiconducting channel between a metallic-carbon nanotubes (m-SWCNTs) network layer and a metal contact as electrodes. Due to weak electrostatics screening effect in CNTs networks and artificial porous which allowed electric field modulate semiconducting channel, our VFETs show a high on/off ratio of $>10^4$ at room temperature. This approach provides a general strategy for fabricating 1D-2D hybrid structures for the future nano-electronics and photo-electronics devices.

References

[1] H. Yang, et al, Science 336 (2012), 1140
[2] W.J. Yu, et al, Nat. Mater 12 (2013), 246

Figures

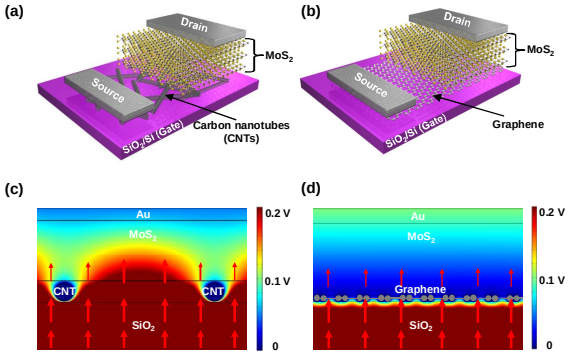

Figure 1: (a, b) A schematic illustration of the three-dimensional view of the CNT-MoS_2-metal (CNT-VFETs) and graphene-MoS_2-metal (Gr-FETs) device layout. (c, d) The corresponding simulated the electrostatics screening effect of the gate modulation as functioning as the electrode for (a) and (b), respectively.

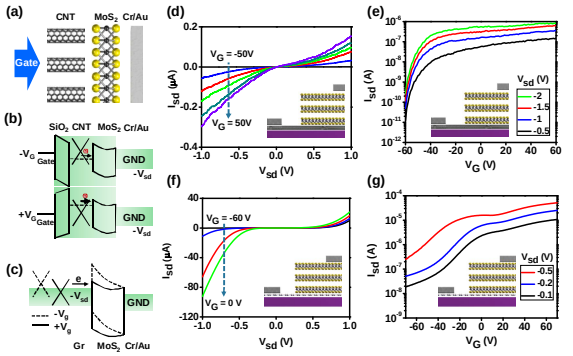

Figure 2: (a) Schematic illustration of a CNT/MoS_2 vertical transistor under gate electric field (Si back gate). (b, c) Band diagram of CNT-VFETs and Gr-VFETs with negative and positive gate. (d) Output characteristics of the CNT-VFETs at different gate voltages from -50 to 50 V in steps of 10 V. (e) Transfer characteristic of the CNT-VFETs at Vsd = -0.5, -1, -1.5, -2 V. (f) Output characteristics of the Gr-VFETs at different gate voltages from -60 to 0 V in steps of 20 V. (g) Transfer characteristic of the Gr-VFETs at Vsd = -0.1, -0.2, and -0.5 V.