Graphene-Integrated Steep-Slope Field-Effect Transistor

Dimitris Ioannou
Parameswari Raju, Qiliang Li, Hao Zhu
Department of Electrical & Computer Engineering, George Mason University, Fairfax, VA 22030, USA
School of Microelectronics, Fudan University, Shanghai 200433, China
hao_zhu@fudan.edu.cn; dioannou@gmu.edu

The continuous down-scaling of MOSFETs has generated the urgent demand for steep-slope transistors with reduced sub-threshold swing (SS) and low power consumption [1-3]. In this work, single-layer graphene is integrated in the gate structure of a MoS2 channel FET which led to a subthreshold swing as low as 31 mV/dec, well below the "fundamental" limit of 60mV/dec. Exploiting the negative electronic compressibility in single-layer graphene with low density of states, negative quantum capacitance was obtained within a certain gate voltage range. Similar to "traditional" negative capacitance obtained with ferroelectric materials, the negative quantum capacitance enables internal gate voltage amplification and subthreshold swing well below 60 mV/dec [4, 5]. Theoretical simulations reveal the fundamental mechanism which explains the negative quantum capacitance observed when a single-layer graphene is encapsulated (integrated) within the gate stack. The results point to a new pathway for the development high speed and low power transistor devices.

References

[1] Y. Zhai, Z. Feng, Y. Zhou, S.-T. Han, Mater. Horiz. 8 (2021) 1601
[2] J. Jo, W. Y. Choi, J.-D. Park, J. W. Shim, H.-Y. Yu, C. Shin, Nano Lett. 15 (2015) 4553
[3] A. M. Ionescu, Nature Nanotechnol. 13 (2017) 7
[4] Y. Yang, K. Zhang, Y. Gu, P. Raju, Q. Li, L. Ji, et al. IEDM 2022, 22.6.1-22.6.4
[5] P. Tsipas, S. A. Giamini, J. Marquez-Velasco, N. Kelaidis, D. Tsoutsou, K. E. Aretouli, et al. Adv. Electron. Mater. 2 (2016) 1500297

Figures

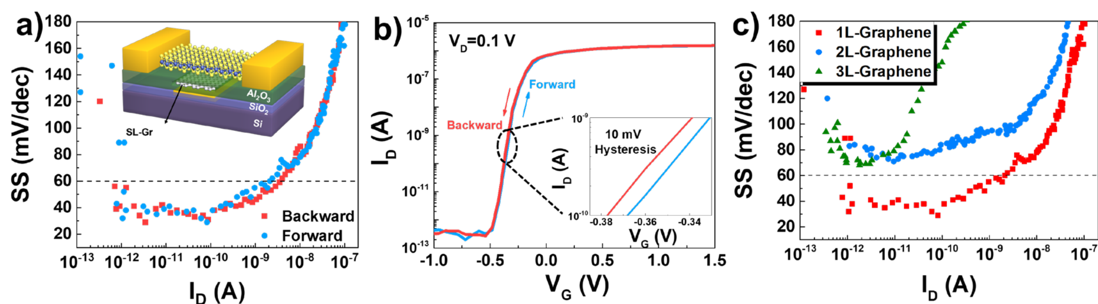

Figure 1: (a) SS values extracted from (b) ID-VG curves. (c) SS values of the device with different graphene layer thickness.

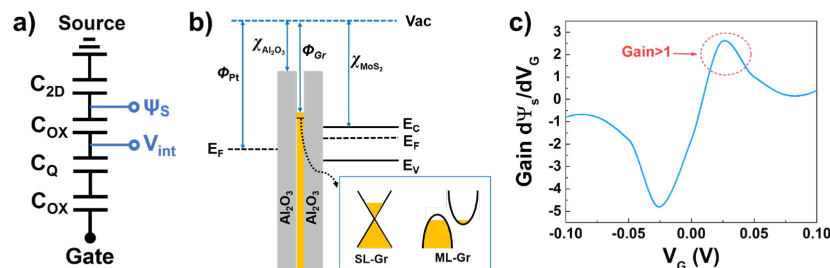

Figure 2: (a) Capacitor divider model and (b) band diagram of the gate stack. (c) Simulation results.