Drift-Diffusion Simulation of MoS_2 channel FETs

Ferran Jovell, Xavier Cartoixà

Departament d'Enginyeria Electrònica, Universitat Autònoma de Barcelona, Bellaterra, Spain
Ferran.Jovell@uab.cat

Abstract

Planar materials, such as graphene [1,2], have recently raised a great deal of interest due to the exceptional electronic properties, in particular a high electron mobility [3], which render them very attractive as the channel material for a field effect transistor (FET). On the other hand, graphene has a semimetallic character, with the bands crossing at the Fermi point, which causes a residual non-negligible conductivity even in the off state. Thus, great efforts have been made in order to open a gap in graphene and render it a semiconductor. These include adding an extra dimension of confinement, obtaining graphene nanoribbons (GNRs) [4], electrostatic patterning [5], chemical decoration [6], etc., but that has been at a cost to the electronic transport properties [7].

A different approach is to choose a different planar material with a semiconductor character from the onset in order to fabricate an FET channel, such as Radisavljevic *et al.* have recently made [7] using MoS_2, with an experimental direct gap of 1.8 eV [8].

The first experimental devices [7] have channels long enough that they are expected to operate in the drift-diffusion regime. From this point of view, drift-diffusion simulation of a 2D-FET can provide insight on technological parameters, such as the trap density inside the oxide, the quality of the interfaces, the presence of interface charges, the onset of short channel effects, etc.

We have carried out these simulations, obtaining good agreement with the measurements of Radisavljevic *et al.* [7]. From these simulations we obtain that the electron affinity in MoS_2 is about 5.25 eV (ca. 1 eV higher than the experimental value in [9]). Also, in order to reproduce the highly negative threshold voltage, a channel/HfO_2 interface charge of $+8\times10^{12}$ q_e/cm^{-2} must be included, pointing to a highly defective interface.

We acknowledge financial support by the Spanish Ministerio de Economía y Competitividad under Project No. TEC2012-31330. Also, the research leading to these results has received funding from the European Union Seventh Framework Programme under grant agreement No. 604391 Graphene Flagship.

References

[1] A. K. Geim and K. S. Novoselov. Nature Materials **6** (2007) 183.
[2] K. S. Novoselov et al., Science **306** (2004) 666.
[3] K. I. Bolotkin et al., Solid State Commun. **146** (2008) 351.
[4] L. Brey and H. A. Fertig, Phys. Rev. B (2006) **73**:235411
[5] Jeroen B. Oostinga, Hubert B. Heersche, Xinglan Liu, Alberto F. Morpurgo & Lieven M. K. Vandersypen, Nature Materials (2007) **7**:151 – 157
[6] Xiaochen Dong, Yumeng Shi, Yang Zhao, Dongmeng Chen, Jun Ye, Yugui Yao, Fang Gao, Zhenhua Ni, Ting Yu, Zexiang Shen, Yinxi Huang, Peng Chen, and Lain-Jong Li, Phys. Rev. Lett. (2009) **102**:135501
[7] B. Radisavljevic at al., Nature Nanotechnology **6** (2011) 147.
[8] K. F. Mak et al., Phys. Rev. Lett. **105** (2010) 136805.
[9] Min Sup Choi et al., Nature Comm. **4** (2013) 1624.

Figures

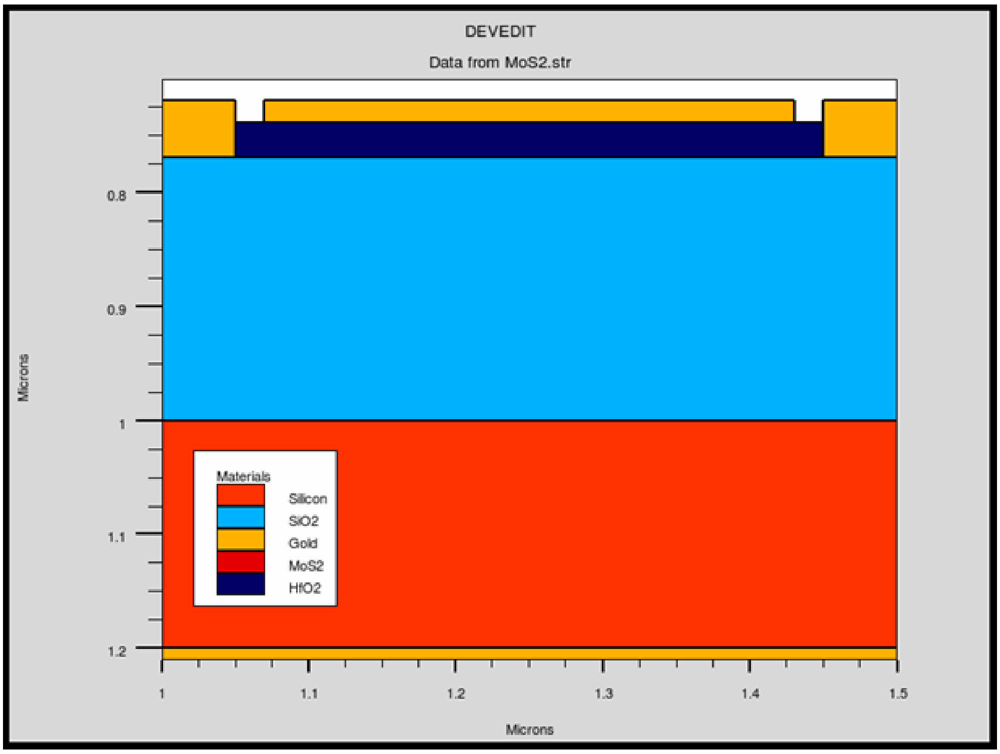

Fig. 1: The simulated MoS_2FET transistor diagram. The channel is so narrow that cannot be appreciated in the diagram.

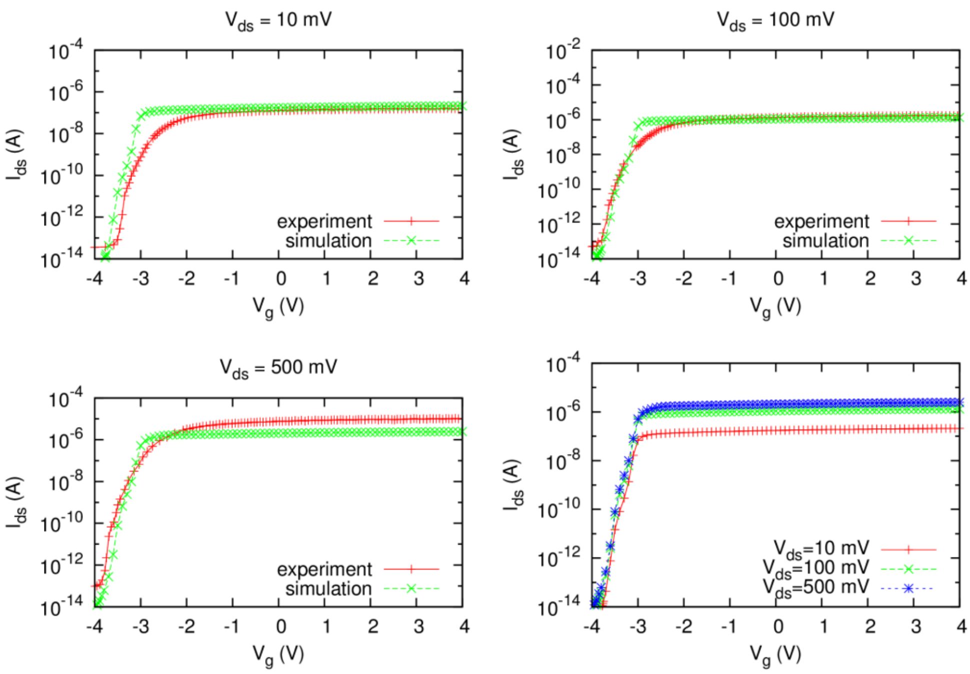

Fig. 2: Experimental [7] and simulated I_{ds} vs. V_g curves, showing good agreement.