Drain-Backgate-Enhanced TFET Based on In-Plane $MoTe_2/MoS_2$ Heterojunction

J. Choukroun[1], D. Logoteta[1,2], M. Pala[1], P. Dollfus[1]
[1]*C2N, CNRS, Univ. Paris-Sud, Université Paris-Saclay, Palaiseau, France*
[2]*Dipartimento di Ingegneria dell'Informazione, Università di Pisa, Pisa, Italy*
philippe.dollfus@u-psud.fr

Thanks to their ability to yield subthreshold swings (*SS*) below the thermionic limit of 60 mV/dec at room temperature [1], Tunnel Field Effect Transistors (TFETs) are recognized to be a promising avenue for the scaling of power supply. However, since TFETs rely on band-to-band tunneling (BTBT), the on-state current I_{ON} they provide is often severely lower than that of MOSFETs, which limits their possible applications [2]. Encouraging experimental results have been obtained for III-V TFETs [3], but the use of 2D materials offers the advantage of using electrostatic doping of leads via backgates, and a better control of the heterojunction interface. Vertical and in-plane heterojunction TFETs based on 2D materials have demonstrated promising results [4]. Recently, we have shown that TFETs based on in-plane heterostructures of transition metal dichalcogenides (TMDs) may offer both excellent SS and high I_{ON}, particularly in the case of strained $MoTe_2/MoS_2$ system [5] that provides appropriate "broken gap" configuration of bandstructure. However, the performance of this device depends on the gate length and the SS strongly degrades when reducing the gate length below 20 nm.

Here, we propose a new design of this in-plane heterojunction TFET (see Fig. 1), where top gate and drain backgate are interconnected and both used to control the current through the device. TMDs were modeled with an atomistic 11-band tight-binding (TB) model including strain effects due to lattice mismatch between $MoTe_2$ and MoS_2 [6]. These TB Hamiltonians were introduced in an NEGF solver to compute the quantum transport (here in the ballistic approximation) self-consistently coupled to 2D Poisson's equation. As shown in Fig. 2, excellent *I-V* characteristics are obtained with SS as low as 5 mV/dec. More importantly, this performance is nearly independent of channel length, in contrast with standard TFET with same materials (Fig. 3). This Drain-Backgate Enhanced (DBE) TFET indeed provides an excellent control of the off-state whatever the channel length, as illustrated by LDOS pictures of Fig. 4.

[1] D. Esseni et al., Semicond. Sci. Technol. **32**, 083005 (2017).
[2] U. E. Avci et al., IEEE J. Electron Devices Soc. **3**, 88-95 (2015).
[3] A. W. Dey et al., IEEE Electron Device Lett. **34**. 211-213 (2013).
[4] Y. Gong et al., Nat. Mater. **13**, 1135-1142 (2014).
[5] J. Choukroun et al., Nanotechnol. **30**, 025201 (2019).
[6] S. Fang et al., Phys. Rev. B **98**, 075106 (2018).

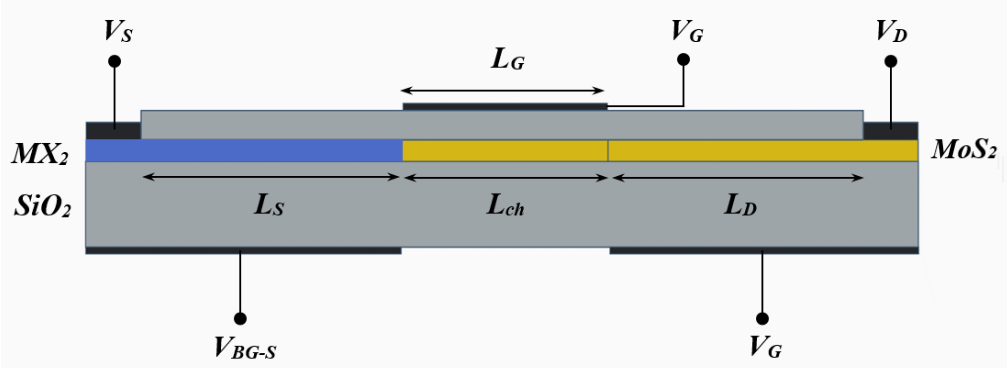

Fig.1: Device architecture for the considered DBE in-plane heterojunction TFETs. $MoTe_2$ is used for the source, and MoS_2 for channel and drain. 3.35 nm-thick SiO2 is used as a buried oxide, and a high-κ dielectric (EOT = 0.44 nm) as the top gate oxide. The same voltage is applied to the drain backgate and the top-gate so that $V_{BG\text{-}D} = V_G$.

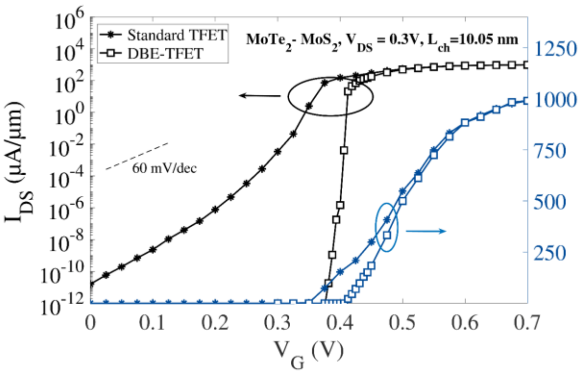

Fig. 2. I_D-V_{GS} characteristics of $MoTe_2/MoS_2$ standard-TFET and DBE-TFET with channel length L_{ch} = 10.05 nm for V_{DS} = 0.3V.

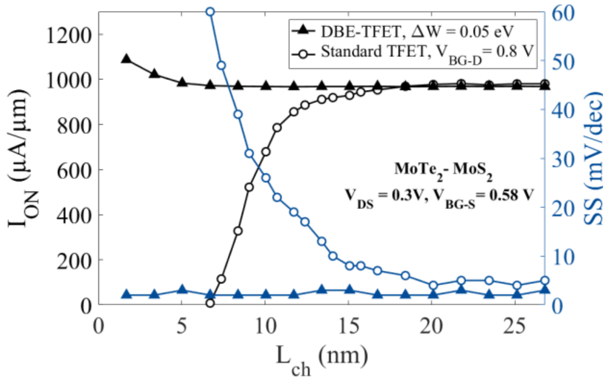

Fig. 3. Channel length dependence of I_{ON} and SS in standard-TFET and DBE-TFET (V_{DD} = 0.3 V).

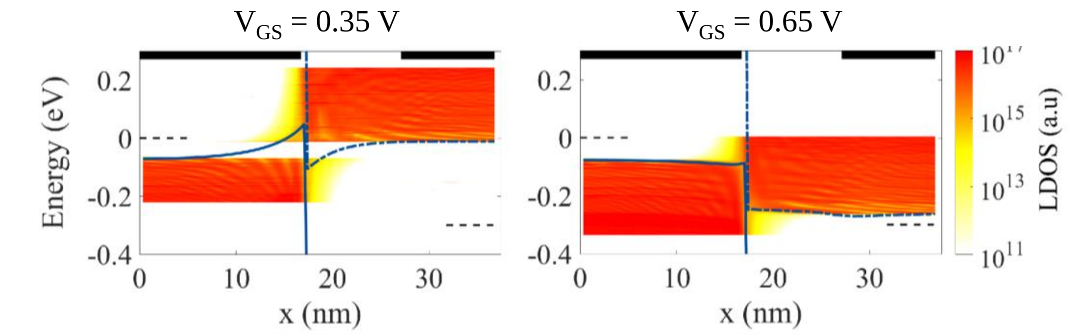

Fig. 4. LDOS, top of valence band (full lines) and bottom of conduction band (dotted lines) in DBE-TFET (L_{ch} = 10.05 nm) at V_{GS} = 0.35 V (left, off-state) and V_{GS} = 0.65 V (right, on-state), for V_{DS} = 0.3 V.