Highlights

Electronic and thermal transport from the nanoscale to the macroscale - 2019

A WSe_2 vertical field emission transistor

Antonio Di Bartolomeo [a,b,c], Francesca Urban [a,b,c], Maurizio Passacantando [d], Niall McEvoy [e], Lisanne Peters [e], Laura Iemmo [a,b,c], Giuseppe Luongo [a,b,c], Francesco Romeo [a,c] and Filippo Giubileo [c].

[a] Physics Department "E. R. Caianiello", University of Salerno, via Giovanni Paolo II n. 132, Fisciano 84084, Italy
[b] Interdepartmental Centre NanoMates, University of Salerno, via Giovanni Paolo II n. 132, Fisciano 84084, Italy
[c] CNR-SPIN c/o University of Salerno, via Giovanni Paolo II n. 132, Fisciano 84084, Italy
[d] Department of Physical and Chemical Science, University of L'Aquila, and CNR-SPIN L'Aquila, via Vetoio, Coppito 67100, L'Aquila, Italy
[e] AMBER & School of Chemistry, Trinity College Dublin, Dublin 2, Ireland

NANOSCALE 11 (2019) 1538

The recent observation of metallic edges in atomically thin WSe_2 monolayers grown by CVD, the lower bandgap (~1.6 vs. ~1.8 eV), effective electron mass (0.33 vs. 0.57 m_0, the rest mass of the electron) and electron affinity (~3.9 vs. ~4.2 eV) would suggest that WSe_2 is a far better field emitter than MoS_2. In this paper, we use CVD to fabricate monolayer and few-layer WSe_2 flakes on a SiO_2/Si substrate and investigate their electrical properties, under high vacuum, using back-gated transistor structures. We show that the WSe_2 flakes, contacted by Ni, exhibit n-type conduction, with conductivity highly controlled by the back-gate voltage. Taking advantage of the gate-controlled n-type doping, we locally probe the field effect (FE) current from a monolayer WSe_2 and we achieve a FE current in the range of µA from the flat part of the flake. More importantly, we demonstrate that the FE current can be modulated by the back-gate voltage, thus realizing the first vertical FE transistor based on a WSe_2 monolayer. We unveil the physics mechanisms underlying the operation of such a device and give indications for its optimization to enhance its driving current capability and to lower the applied voltage. This study can pave the way to the further exploitation of WSe_2 in a new generation of devices for vacuum electronics.

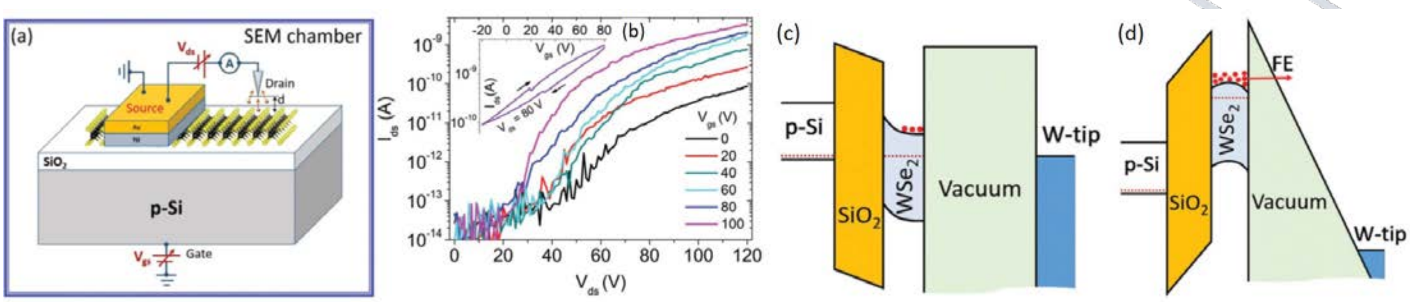

Fig. 1: (a) Layout of a back-gate FE transistor with a WSe_2 monolayer channel over a SiO_2/Si substrate. The W-tip labelled as the drain, which collects field emitted electrons and monitors the current, is kept at a distance d from the sample, while the voltage is ramped up. (b) FE current measured at given back-gate voltages (V_{ds} steps of 1 V). (c) Band diagram for (c) the unbiased device and for (d) the device under $V_{ds} > V_{gs} > 0$ V bias conditions.