2D materials in transistors, memories, and phototransistors

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Two-dimensional materials hold great promises for electronics and optoelectronics applications. Their atomic thickness enables highly scaled field-effect transistors with reduced short-channel effects and relatively high carrier mobility. The intrinsic electrical transport properties of 2D materials are commonly investigated using back-gated field-effect transistors, due to the low density of process-induced defects and the easy fabrication.

In this presentation, the electrical and optical properties of several 2D materials are discussed. The focus is on the wide family of transition-metal dichalcogenides (TMDs), such as MoS_2, $PtSe_2$, $PdSe_2$, WSe_2, $ReSe_2$, [1-3] and on black phosphorus (BP).[4] Electrical transport, modulation of the conductivity by a back-gate, effect of electron irradiation, the role of surface adsorbates and the photoresponse are investigated in nanosheets obtained by either mechanical exfoliation or chemical vapor deposition on SiO_2/Si substrates.

The formation of low-resistance contacts and the control of process-induced defects or interface states are issues to consider in the electrical characterization of 2D materials. It is shown that the contact resistance can be tuned by electron irradiation that reduces the Schottky barrier and improves the 2D material/metal contacts.[5-7] It is demonstrated that adsorbates can change the polarity of the charge-carriers and enhance the hysteresis in the transfer characteristics of TMD-based field-effect transistors.[8] It shown that slow excitation from intrinsic or extrinsic trap states enables slow optical response and persistent photoconductivity.[2] It is highlighted how positive and negative photoconductivity can coexist in the same device, the dominance of one type over the other being controlled by the adsorbed oxygen.

The strong dependence of the channel conductance on the environmental gas, air pressure, light and electrical stress make 2D materials-based devices suitable for memory, gas and light sensing applications.

Finally, the tunable conductivity and the sharp-edge geometry facilitate the extraction of electrons (field emission) from 2D materials upon application of an electric field.[9-10] It is shown that several 2D materials are effective field emitters and that their emission current can be modulated by a back-gate.

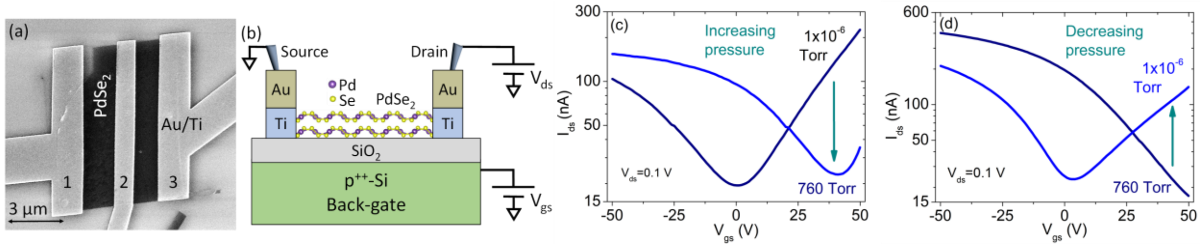

Fig. 1. (a) SEM top view and (b) schematic cross section and measurement setup of a back-gate $PdSe_2$ field-effect transistor. Effects of air pressure on the transfer characteristics of the $PdSe_2$ transistor (a) for increasing and (b) decreasing pressure.

References

[1] E. Faella, K. Intonti, L. Viscardi, F. Giubileo, A. Kumar, H. T. Lam, K. Anastasiou, M. F. Craciun, S. Russo and A. Di Bartolomeo, *Electric Transport in Few-Layer ReSe2 Transistors Modulated by Air Pressure and Light* Nanomaterials **12** (2022) 1886 (feature paper)

[2] A. Grillo, E. Faella, A. Pelella, F. Giubileo, L. Ansari, F. Gity, P.K. Hurley, N. McEvoy, and A. Di Bartolomeo *Coexistence of negative and positive photoconductivity in few-layer PtSe2 field-effect transistors* Advanced Functional Materials 31 (2021) 2105722

[3] A. Pelella, A. Grillo, F. Urban, F. Giubileo, M. Passacantando, E. Pollmann, S. Sleziona, M. Schleberger, and A.Di Bartolomeo *Gate-controlled field emission current from MoS2 nanosheets* Advanced Electronic Materials 7 (2021) 2000838.

[4] A. Grillo, A. Pelella, E. Faella, F. Giubileo, S. Sleziona, O. Kharsah, M.Schleberger, A Di Bartolomeo *Memory effects in black phosphorus field effect transistors* 2D Materials 9 (2022) 015028

[5] A. Di Bartolomeo, F. Urban, A. Pelella, A. Grillo, M. Passacantando, X. Liu, F. Giubileo *Electron irradiation on multilayer PdSe2 field effect transistors* Nanotechnology 31 (2020) 375204

[6] A. Pelella, O. Kharsah, A. Grillo, F. Urban, M. Passacantando, F. Giubileo, L. Iemmo, S. Sleziona, E. Pollmann, L. Madauß, M. Schleberger, and A. Di Bartolomeo *Electron irradiation of metal contacts in monolayer MoS2 Field-Effect Transistors* ACS Applied Materials and Interfaces 2020, 12 (36) 40532–40540

[7] A. Grillo and A. Di Bartolomeo *A current-voltage model for double Schottky barrier devices* Advanced Electronic Materials, 7 (2021) 2000979.

[8] A. Di Bartolomeo, A. Pelella, A. Grillo, F. Urban, F. Giubileo *Air pressure, gas exposure and electron beam irradiation of 2D transition-metal dichalcogenides* Applied Sciences 2020, 10, 5840

[9] A. Di Bartolomeo, A. Grillo, F. Giubileo, L. Camilli, J. Sun, D. Capista, M. Passacantando *Field emission from two-dimensional GeAs* Journal of Physics D: Applied Physics 54 (2021) 105302

[10] A. Di Bartolomeo, A. Pelella, F. Urban, A. Grillo, L. Iemmo, M. Passacantando, X. Liu, F. Giubileo *Field emission in ultrathin PdSe2 back-gated transistors* Advanced Electronic Materials 6 (2020) 2000094