


Iontronics
Field effect study of nanodevices using ionic liquid gating

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Ionic liquids (IL's) are non-volatile fluids, consisting of cations and anions, which are ionically conducting, but electrically insulating and nowadays widely used for high field-effect carrier injection. Allowing conformal surface doping, IL's are very suitable gate dielectrics for nanodevices such as nanotubes and nanowires. Good candidates are the atomically flat inorganic transition metal dichalcogenide nanotubes (TMDC INTs). Astonishingly, in spite of the considerable amount of work devoted to carbon nanotubes, the potential of TMDC INTs for electronic and optoelectronic device applications has been widely overlooked.

Other candidates are III-V semiconductor nanowires, where advanced field effect control represents a key aspect for both fundamental studies and technological application.

In this project, we realized high-quality ambipolar IL-gated field-effect transistors (FETs) based on multi-walled WS2 nanotubes (Fig. 1a). A FET transfer characteristic is displayed in Fig. 1b. The operation performances of our INT FETs are comparable to that of best electrical double layer gated WS2 thin flakes. We obtained mobility up to 80 $cm^2V^{-1}s^{-1}$ for both p- and n-type charge carriers and on-off current ratios exceeding 10^5. The IL-gate allowed us to establish a pn-junction in the INT, leading to a light-emitting diode. Fig. 1c shows the same device before the measurement and in the light emission regime. An electroluminescence (EL) spot appeared on the INT between drain and source electrodes.

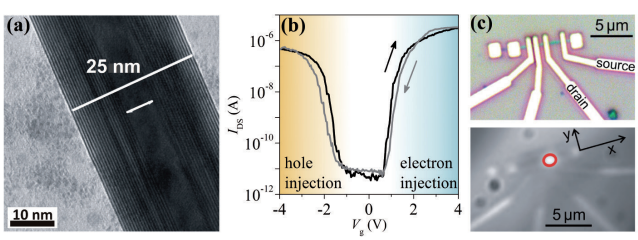

Fig. 1: WS2 NT's: a) TEM image of a WS2 nanotube. b) FET transfer characteristic. c) Optical image of a device before the measurement and in the light emission regime.

Additionally, we realized new IL-gated FETs based on single InAs nanowires (Fig. 2a–c). Fig. 2d displays a transistor transfer characteristic, showing an on-off current ratio of 10^3 when going from complete electron depletion to high electron injection. The nanowires undergo a transition from insulating to metallic at high electron doping levels. The promising performances resulting from the conformal doping open an avenue for new IL-gated III-V nanowire devices.

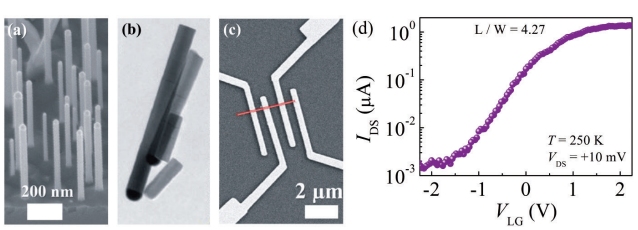

Fig. 2: InAs nanowires: a) and b) SEM and STEM image of individual InAs nanowires. c) SEM image of a NW device. d) FET transfer characteristic.

OUTCOMES

Publications:

[1] Electric-field assisted depinning and nucleation of magnetic domain walls in FePt/Al_2O_3/liquid gate structures, Appl. Phys. Lett. 104, 082413 (2014).

[2] High field termination of a Cooper-pair insulator , Phys. Rev. B 91, 220508(R) (2015).

[3] Electric field controlled domain wall dynamics and magnetic easy axis switching in liquid gated CoFeB/MgO films, J. Appl. Phys. 122 (2017) 0133907.

[4] Ionic-liquid gating of perpendicularly magnetised CoFeB/MgO thin films J. Appl. Phys. 120 (2016) 023901.

[5] Quantum meets classical phase transition: Low-temperature anomaly in disordered superconductors near B_{c2}, to appear in Nature Physics

Invited presentation:

- 2D Materials Worskhop, MINATEC, Nov. 2016
- International Workshop on Localization, Interactions and Superconductivity, Landau Institute for Theoretical Physics, June 2018

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Leverage: under discussion with CRIEPI for a continuation of the collaboration