Unveiling Multiferroic Proximity Effect in Graphene

Fatima Ibrahim[1]
Ali Hallal[1], Daniel Solis Lerma[1], Xavier Waintal[2], Evgeny Y. Tsymbal[3], Mairbek Chshiev[1]
[1] Univ. Grenoble Alpes, CEA, CNRS, SPINTEC, F-38000 Grenoble, FRANCE. [2] Univ. Grenoble Alpes, CEA, PHELIQS, F-38000 Grenoble, FRANCE. [3] Department of Physics and Astronomy and Nebraska Center for Materials and Nanoscience, University of Nebraska, Lincoln, NE, 68588-0299, USA.
fatima.ibrahim@cea.fr

Graphene spintronics has become a promising direction of innovation that attracts a growing attention in the scientific community [1, 2]. Many efforts have been devoted to induce magnetism in graphene via different means, one of which is the exchange-proximity interaction with magnetic insulators [3]. In this talk, we present recent breakthrough developments on proximity induced magnetic phenomena in graphene in particular novel transport phenomena based on proximity effects induced by multiferroics. Multiferroics co-exhibiting a magnetic and ferroelectric order constitute an interesting class of magnetic insulators that bring about an additional parameter in play that is the electric polarization. In this context, the multiferroic-induced proximity effect (MFPE) in graphene proposing the concept of controlling electronic and magnetic properties of graphene via multiferroic substrate will be introduced. Calculations performed both with and without spin-orbit coupling clearly show that by contacting graphene with bismuth ferrite $BiFeO_3$ (BFO) film, the spin-dependent electronic structure of graphene is strongly impacted both by the magnetic order and by the ferroelectric polarization in the underlying BFO. Based on extracted Hamiltonian parameters obtained from the graphene band structure, a concept of six-resistance device based on exploring multiferroic proximity effect is proposed giving rise to significant proximity electro- (PER), magneto- (PMR), and multiferroic (PMER) resistance effects as shown in Fig. 1 [4]. These findings pave the way towards possible engineering of graphene spin gating by multiferroic proximity effect especially in view of recent experimental advancements in the field.
We acknowledge support from European Union's Horizon 2020 research and innovation program under Grant agreements No. 696656 and 785219 (Graphene Flagship).

References

[1] S. Roche et al., 2D Mater. 2, (2015) 030202.
[2] W. Han et al., Nat. Nanontechnol. 9, (2014) 794.
[3] A. Hallal et al., 2D Mater. 4, (2017) 025074.
[4] F. Ibrahim et al., 2D Mater. 7, (2020) 015020.

Figures

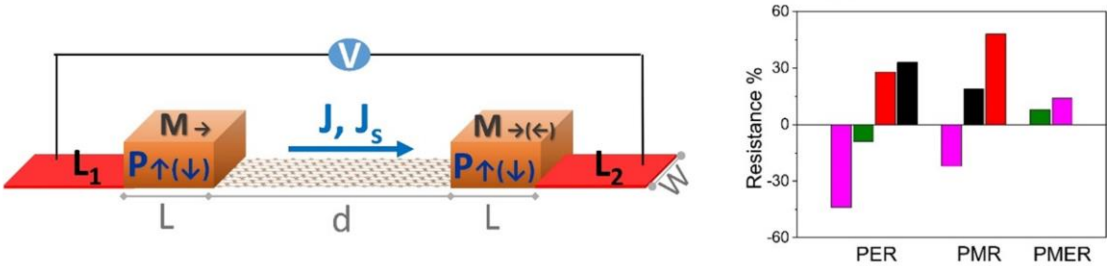

Figure 1: (Left panel) Model spintronic device consisting of two multiferroic regions on top of a graphene sheet. The relative orientation of magnetization M and electric polarization P, in the multiferroic regions, give rise to proximity electro (PER)-, magneto- (PMR), and multiferroic (PMER) resistances (Right panel).