Tuneable spin-to-charge interconversion and valley effects in ex-so-tic and twisted graphene-based VdW heterostructures

Anna Dyrdal
Izabella Wojciechowska

Faculty of Physics, ISQI, Adam Mickiewicz University in Poznan, ul. Uniwersytetu Poznanskiego 2, 61-614 Poznan, Poland

adyrdal@amu.edu.pl

The efficient spin-to-charge interconversion is currently one of the most important issues in spin electronics. The two main effects responsible for all-electrical charge-to-spin conversion are current-induced spin polarization and spin Hall effect as well as their inverse counterparts [1]. Many recent experiments performed on graphene-based hybrid structures revealed spin-orbit proximity effects strong enough to measure spin currents or spin polarization up to room temperature [2]. This, in turn, opened a new era of spintronics, i.e., a van-der-Waals spintronics, that couples charge, spin, and valley degrees of freedom.

An important feature of spin-to-charge interconversion effects in graphene-based van-der-Waals systems is their strong tunability by external fields, e.g., by gating in the so-called ex-so-tic structures [3], or by mechanical forces that can induce either a twist of graphene with respect to adjacent vdW layers [4] or strain in vdW layers that can significantly change the spin-orbital and magnetic proximity effects in graphene.

In the first part of our presentation we will discuss our recent results concerning anomalous, spin, valley and spin-valley Hall effects controlled by gate voltage in the ex-so-tic vdW system consisting of bilayer graphene sandwiched between semiconducting monolayer of transition metal dichalcogenide, TMDC, (e.g., WS2) and monolayer of Cr2Ge2Te6 [5]. We have found that in such a case, both A(S)HE and VHE are simultaneously nonzero and strongly picked in a specific range of chemical potential and gate voltage.

In the second part of the talk, we will present a detailed study of spin and valley Hall effects as well as spin polarization in graphene twisted with respect to monolayer of semiconducting TMDCs (we discuss results for twisted graphene on MoS2, WS2, MoSe2, and WSe2) and show that spin-to charge conversion strongly depends on the twist angle [6].

Our theoretical calculations are based on Green function formalism in the linear response limit adapted to effective low-energy Hamiltonians derived from symmetry analysis and DFT calculation [7].

This work has been supported by the Norwegian Financial Mechanism 2014-2021 under the Polish-Norwegian Research Project NCN GRIEG "2Dtronics" no. 2019/34/H/ST3/00515

References

[1] J. Sinova, Rev. Mod. Phys. 87, 1213 (2015)
[2] A. Avsar et al., Nature Commun. 5:4875 (2014); T. S. Ghiasi et al. , Nano Lett. 19, 5959 (2019), B. Zhao et al., Appl. Phys. Lett. 117, 242401 (2020)
[3] Authors, Journal, Issue (Year) page
[4] K. Zollner et al., Phys. Rev. B 108, 235166 (2023)
[5] I. Wojciechowska, A. Dyrdal, to be published
[6] I. Wojciechowska, A. Dyrdal, to be published
[7] A. Dyrdal, J. Barnas, 2D Materials 4, 034003 (2017)