Spin transport and spin orbit coupling engineering in graphene and black phosphorus

Barbaros ÖZYILMAZ
Department of Physics, Department of Materials Science and Engineering,
Center for Advanced 2D Materials (CA2DM), National University of Singapore (NUS), Singapore.

Electric field control of spin transport is crucial for many novel device concepts. In contrast to bulk materials, two-dimensional material are inherently thin and thus, avoid or at least sufficiently minimize electric screening. They are also ideal to induce complementary properties by means of the proximity effect. For example, the combination of Rashba interaction, magnetic moments and electric field control of the density, is akin to dilute magnetic semiconductors. In a Dirac material this opens a route toward electric field control of magnetism and engineering topological magnetic states.

In this talk I will discuss efforts in inducing a large spin orbit coupling in graphene and black phosphorus. Pristine graphene has negligible spin-orbit coupling (SOC). However, strong SOC can be induced, e.g. by hybridization with heavy metals. I will discuss experiments where this has been achieved with Au intercalated van der Waals heterostructures of graphene and hexagonal boron nitride [1]. We observe spin-splitting of the graphene bands observed in quantum oscillation. The Rashba interaction is large (25 meV) for samples intercalated with 0.1 monolayers of Au. It is modulated by modest electric fields, thereby highlighting the requirement of hybridization with spin-split Au d-electrons.

In the second part of the talk I will show that the SOC in pristine black phosphorus is equally weak. In conjunction with its semiconducting nature, this makes it ideal for both proximity effect studies and spin transport studies. Based on measurements in the non-local spin valves geometry with pure spin currents, we show that the spin relaxation times can be as high as ~ 4ns with spin relaxation lengths exceeding 6 µm [2]. These values are an order of magnitude higher than what has been measured in graphene.

[1] Rashba Interaction and Local Magnetic Moments in a Graphene-BN Heterostructure Intercalated with Au; O'Farrell, E. C. T., Tan, J. Y., Yeo, Y., Koon, G. K. W., Özyilmaz, B., Watanabe, K. and Taniguchi, T. Phys. Rev. Lett. 117, 076603 (2016)

[2] Gate-tunable black phosphorus spin valve with nanosecond spin lifetimes; Avsar, A. ,Tan J. Y., Kurpas M., Gmitra M. , Watanabe K., Taniguchi T., Fabian J., Özyilmaz B., Nature Physics (2017).