Gate-tunable black phosphorus spin valve with nanosecond spin lifetimes

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Two-dimensional materials offer new opportunities for both fundamental science and technological applications, by exploiting the electron's spin. While monolayer graphene has already been investigated very extensively in the spintronics community since the first unequivocal demonstration of room temperature (RT) spin injection [1], the lack of a band gap restricts its prospects for semiconducting spin devices such as spin diodes and bipolar spin transistors. In this conference, I will introduce ultra-thin, semiconducting black phosphorus (BP) for the first time as a new and highly promising material for such devices requiring rectification and amplification actions. In the non-local spin valve geometry we measure Hanle spin precession and observe spin relaxation times as high as 4 ns, with spin relaxation lengths exceeding 6 μm [2]. These values and their temperature dependency are in a very good agreement with first-principles calculations based on the Elliott-Yafet spin relaxation mechanism which involves only the spin orbit coupling of the host lattice, confirm that the obtained results are indeed intrinsic properties of BP. Obtained spin lifetimes and non-local spin signals are an order of magnitude higher than what has been measured in typical graphene spin valve devices [1, 3]. I will demonstrate that spin transport in ultra-thin BP depends strongly on the charge carrier concentration (Figure 1), and can be manipulated in a transistor-like manner by controlling the electric field effect even at RT. If the time permits, I will present a similar electric field control effect in high mobility, dual-gated bilayer graphene spin valves.

References

[1] N. Tombros et al. Nature 448, 571–4 (2007).
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Figures

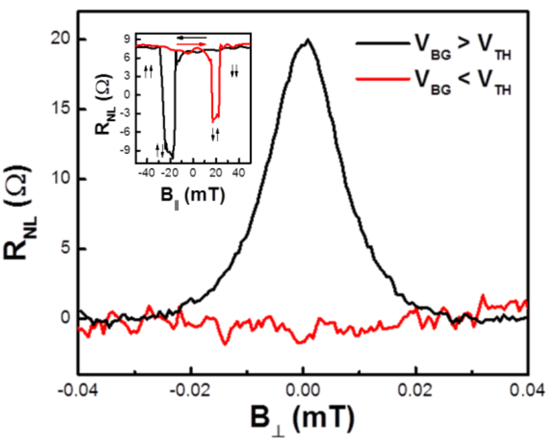

Figure 1: Non-local signal as a function of perpendicular magnetic field in a BP spin valve. Red and black lines were measured at gate voltages before and after threshold voltage. Inset shows the in plane magnetic field dependency of non-local signal. Black and red horizontal arrows represent the magnetic field sweeping directions. Measurements are performed with an injected current of 0.5 μA at 100 K.