Spin Transport and Spin Precession in Graphene

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Abstract

Spin degree of freedom of electrons is one of the alternative state variables under consideration for processing information, beyond the charge based CMOS technology. The potential of spintronics based research lies in the possibilities for a new generation of computers that can be non-volatile, faster, smaller, and capable of simultaneous data storage and processing - all with reduced energy consumption [1]. The strong interest in Graphene based spintronic devices stems from their proposed long spin coherence lengths (100 µm), because of the absence of hyperfine interactions and weak spin-orbit coupling. A novel concept called all spin logic uses spin in ferromagnets to store information and communicate between them using a spin current [2]. All spin logic is particularly powerful in that it combines various spin related phenomena such as spin-injection, spin-transport and spin-detection with that of magnetization dynamics.

Pure spin transport in Graphene and multilayer graphene on SiO_2 substrate has been demonstrated at room temperature [3, 4], and more recently with high mobility Graphene devices [5-7]. The spin life time is found to be around few 100 pico seconds on all these measurements. Recently, a large spin-valve signal in two-terminal geometry at low temperature has also been demonstrated, using high resistive tunnel contacts [8]. In spite of all these advances, very little progress has been made in basic understanding of spin injection, transport and detection process in Graphene and its nanostructures. The observed spin life time differ by orders of magnitude than theoretical prediction. Furthermore, the basic functions such as large magnetoresistance in two-terminal spin-valve geometry at room temperature have not been demonstrated, and the spin manipulation has not yet been realized.

Here we present pure spin transport and precession measurements in multilayer Graphene (around 10 layers) at room temperature. Graphene-ferromagnet nano devices with multiple contacts were prepared on SiO_2 substrate by standard electron beam lithography and lift off technique. Ferromagnetic contacts on graphene with and without a tunnel barrier are tested to achieve high current densities and also larger spin signal, for realization of spin torque switching in all spin logic device [2]. The spin transport and spin precession measurements are performed in non-local spin-valve and Hanle geometries respectively [3]. We also compare the spin life time obtained from nonlocal measurements with the spin precession measurements in three-terminal Hanle geometry [9].

To perform the spin-transport measurements we use a non-local geometry where the charge current path is separated from the voltage contacts to exclude spurious signals such as AMR and stray Hall voltage. Figure 1a shows a typical non-local spin valve signal at room temperature by sweeping the in-plane magnetic field. Different switching fields of injector and detector ferromagnetic electrodes allow us to achieve a parallel or antiparallel configuration by a field sweep. To extract the spin relaxation time, we perform Hanle precession measurements and fit the data with the solutions for the Bloch equations in the diffusive regime. The Hanle precession measurements are done by measuring the non-local resistance as a function of an applied perpendicular magnetic field (Figure 1b). The spin life time were found to be around 100 pico seconds at room temperature. We also compare the spin life time measured in three-terminal Hanle geometry [9], in which the same tunnel interface is used for injection and detection of spin accumulation in Graphene. To be noted, very similar spin life times were extracted from both the non-local and three-terminal Hanle measurements.

Nonlocal measurements were also performed at higher perpendicular magnetic fields up to 2T, where the rotation and saturation of ferromagnet occurs in the perpendicular direction. As shown in figure 1c, we observe anisotropy in spin relaxation in multilayer graphene between the parallel and perpendicular injected spin direction [10]. The perpendicularly injected spin at 2T magnetic field shows a decrease of signal amplitude compared to spins parallel to the layer at zero magnetic field. Furthermore, we will discuss the detailed investigation of spin-valve and Hanle measurements at different temperatures and bias voltages.

References

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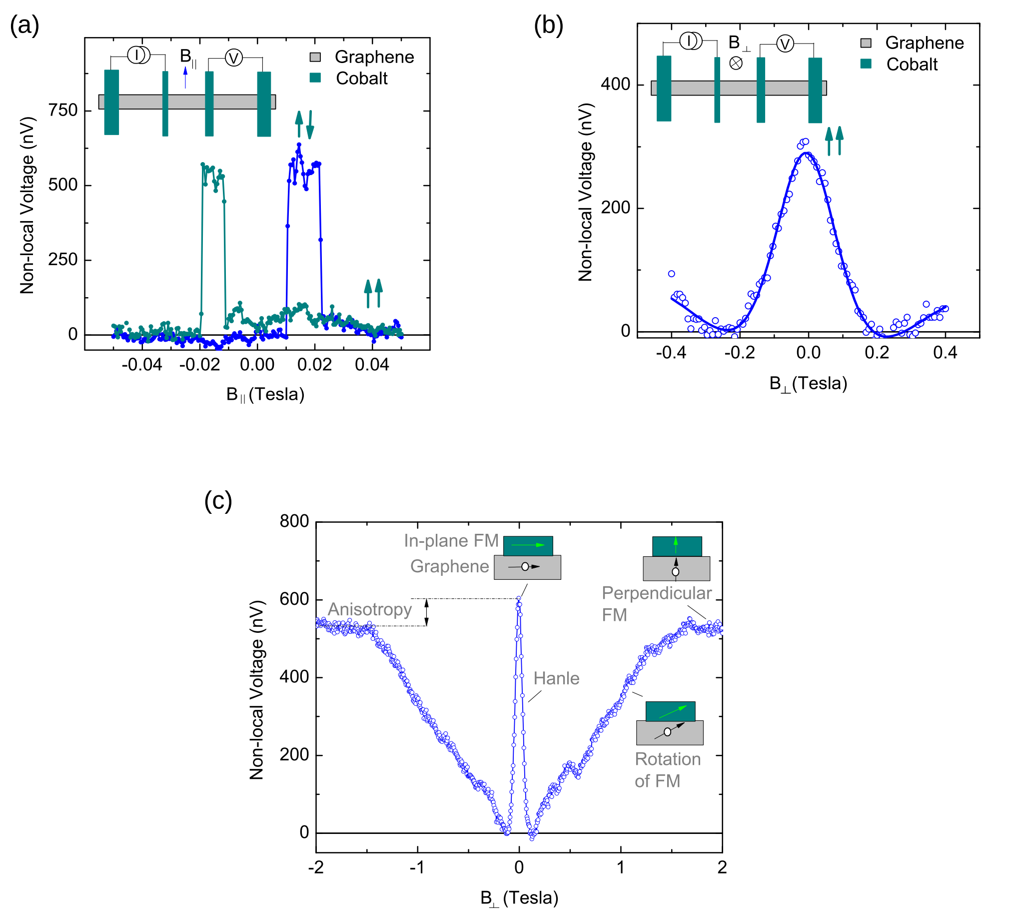

Figure 1. Nonlocal spin transport and spin precession measurements in multilayer Graphene devices. (a) Nonlocal spin valve measurement as a function of the in-plane magnetic field at room temperature, (b) Nonlocal Hanle measurement as a function of perpendicular magnetic field at room temperature, (c) Nonlocal measurement with higher perpendicular magnetic field, showing anisotropy in spin signal.