Spin Transport and Spin Precession in Bilayer Graphene with Transparent and Tunneling Ferromagnetic Contacts

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We achieved electrical spin injection by employing a DC current from a ferromagnetic contact (Co) into bilayer graphene, both with and without tunneling barrier. The graphene flakes were mechanically exfoliated from natural graphite by using adhesive tape on a SiO_2/p-doped Si substrate where the Si is used as a backgate. The ferromagnetic and normal metal (Pd) electrodes were defined by standard electron beam lithography (Fig. 1). In the case of directly connected ferromagnetic stripes onto bilayer graphene the contact resistance was about 450 Ohm, determined in a three point measurement which indicates that the Co/graphene junctions are transparent [1]. In order to increase the spin injection efficiency and the spin signal ΔR which is defined as the difference of the non-local resistance between parallel and antiparallel magnetization of the ferromagnetic electrodes, tunneling contacts were produced to overcome the conductivity mismatch problem [2]. An approximately 1.4 nm thick AlOx tunneling barrier was produced by depositing Al over the entire sample at 180K and subsequent oxidation at room temperature for 30 minutes. AFM pictures reveal that the Al deposition at low temperature leads to a homogenous barrier. The I-V-characteristics of this Co/AlOx/graphene junction show non-linear behavior suggesting the absence of pinholes. The induced spin accumulation diffuses away from the injection point and is probed in a non-local four terminal scheme where the charge and spin currents are completely separated from each other. For both transparent and tunneling contacts we obtain a clear switching of the non-local resistance whose sign depends on the magnetization orientation (parallel/antiparallel) of the ferromagnetic electrodes (Fig. 2). By applying a perpendicular magnetic field we also detect spin precession (Hanle effect) which confirms that the non-local spin signal originates from spin injection and spin transport. Fitting of these Hanle curves yields the spin relaxation time and length as well as the spin injection efficiency. By comparing the results for transparent and tunneling contacts we find that the tunnel barrier enhances the spin signal by a factor of 30 and the spin injection efficiency increases from 1.7 to 5 percent whereas the spin relaxtion times are in the same range [3].

References

[1] W. Han et al. , Appl. Phys. Lett. **94**, 222 109 (2009)
[2] N. Tombros et al. , Nature (London) **448**, 571 (2007)
[3] W. Han et al. ,Phys. Rev. Lett. **105**, 167 202 (2010)

Figures

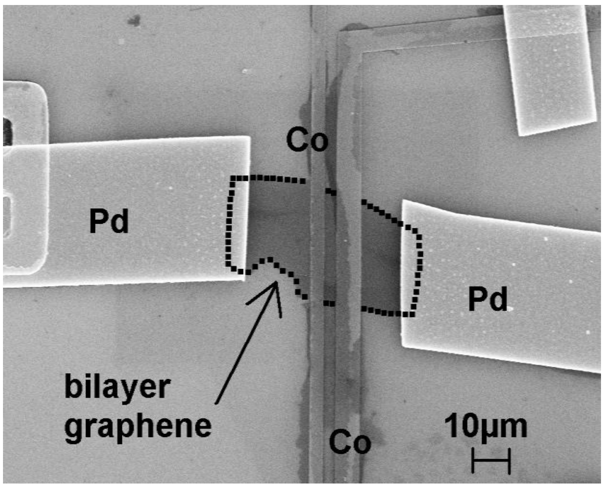

Fig. 1: REM picture of the non-local spin valve structure

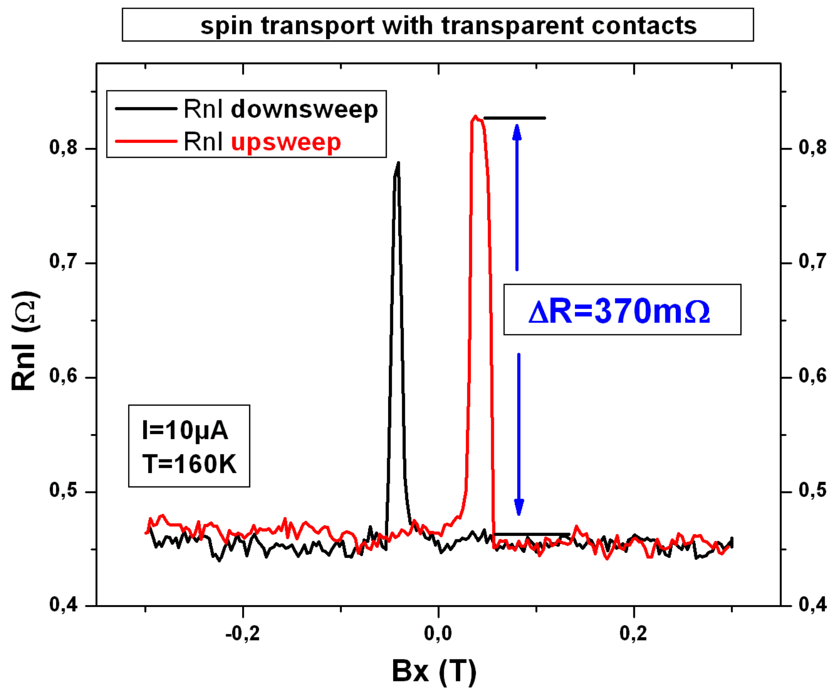

Fig. 2a) : Non-local resistance switching with transparent contacts

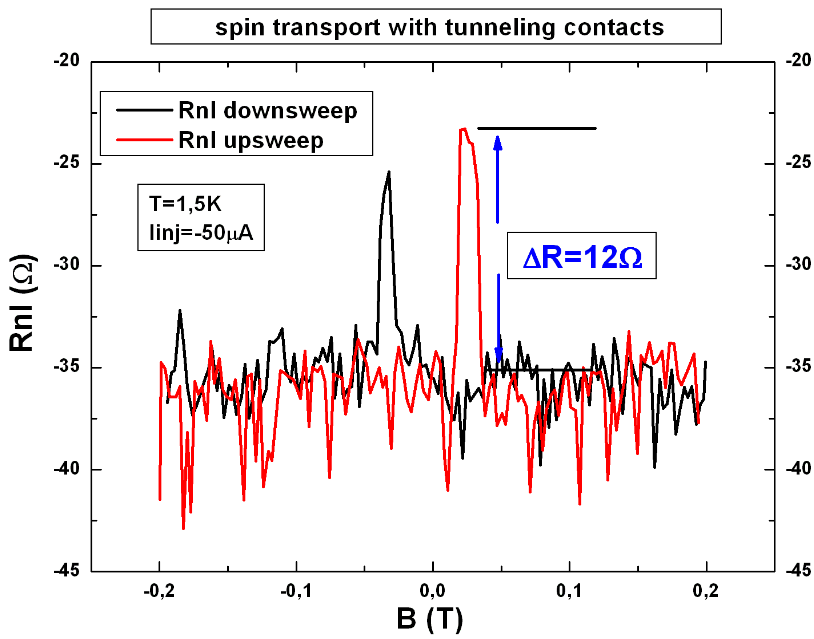

Fig.2b) : Non-local resistance switching with tunneling contacts.