Spin injection control in High quality Graphene 1D-contact systems

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To deliver spintronics applications, spins need to undergo controlled injection, transport, and detection. Progress on high-quality graphene structures [1] opened the route towards ballistic channels and spin coherence phenomena in graphene. Employing a 1D contact architecture [2], fully hBN-encapsulated graphene is contacted via electrodes by means of its edge (Fig. 1a). Our devices yield exceptionally clean spin-transport channels, with minimal doped regions within ~100 nm near the contacts, by virtue of the metallic contacts touching the graphene channel only at its edge between the encapsulating hBN layers (Fig. 1b). We report spin transport at low temperature with mobilities up to ~ 130 000 $\mathrm{cm^2/Vs}$, spin relaxation lengths of ~ 18 $\mu\mathrm{m}$, and mean a free path of ~ 1 $\mu\mathrm{m}$. Thanks to the 1D contact resistance, R_c, ranging from $3 - 15\ \mathrm{k\Omega}$, and a smaller spin resistance of the channel, R_s, we observe different values of the R_c/R_s ratio, and the corresponding efficiency of spin injection, at different carrier densities which leads to the tunability of the measured spin signal (Fig. 1c) [4]. Finally, we demonstrate the introduction of an out-of-plane spin component onto graphene. In the geometry of our device the electrode climbs up the hBN-Gr-hBN heterostructure acquiring a partially vertical magnetization. As a result, we simultaneously observe both spin precession and spin-valve phenomena implying spins possess components both inside the plane of the device and perpendicular to it (Fig 1d), permitting alternative anisotropy studies to those currently in use [3]. Together, these observations demonstrate a system where ballistic spin injection, tunable spin signal and effective oblique spin injection is possible by exploiting the device architecture.

References

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[3] B. Raes *et al.*, (2016). *Nat. Commun.*, 7(1), 11444.
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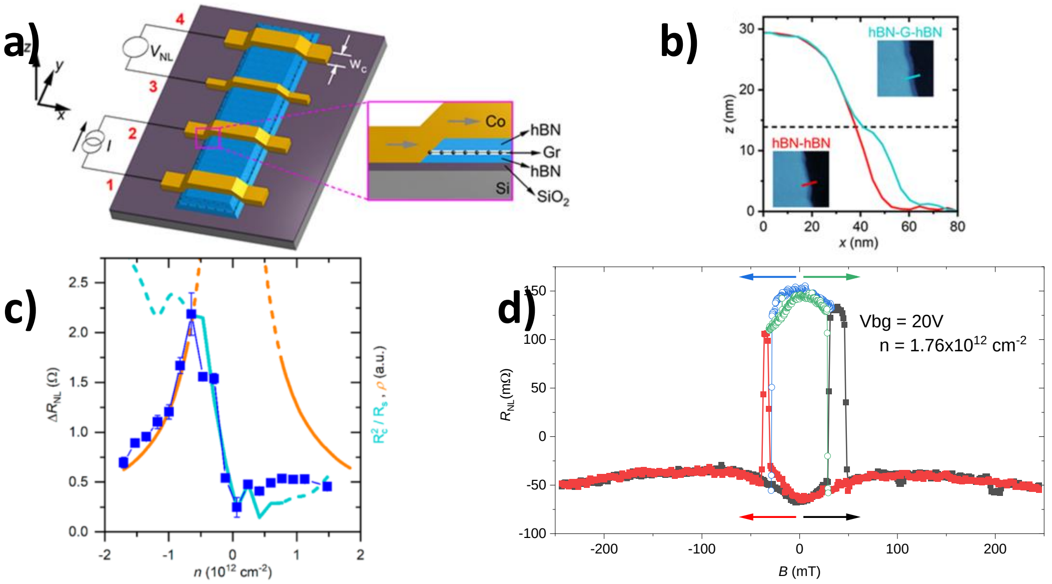

Figure 1: (a) Schematic of our device with a typical non-local connection showing a cross section of the 1D contact. (b) AFM profile of the edges of a device comparing hBN-only vs hBN-encapsulated graphene. (c) Spin signal ΔR_{NL} as a function of charge carrier density, compared to trends in resistivity(orange) and the contact-to-spin-resistance ratio (cyan). (d) Spin-valve measurement showing a Hanle-like baseline revealing presence of spin components in-plane and out-of-plane.