Spin-relaxation in graphene: by covalently bonded adsorbates via EY mechanism

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We report spin-injection measurements in a direct-contact cobalt−single-layer-graphene nonlocal spin-valve system, overlaid with a top gate. The spin signal was controlled precisely in conformation with the top-gate-induced conductivity variation. No additional spin relaxation was observed as the carriers traversed the interface, particularly for the bipolar configuration of graphene. The spin relaxation for a homogeneous graphene configuration with neutral top gate was also studied via measurements of the Hanle spin-precession effect. Hanle analysis demonstrated that the ratio between spin and momentum relaxation times is proportional to the square of the density of states, which varies with the carrier density due to the unique linear dispersion relation of graphene. From the proportionality ratio, we determined spin-orbit coupling strength of ∼9−10 meV. These findings lead to the conclusion that the spin state is most likely relaxed by covalently bonded adsorbates on the graphene via the EY mechanism. We emphasize that taking into account the carrier-density dependence of the density of states is crucial to correctly identifying the spin-relaxation mechanism in graphene.

INVITED PAPER