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Spin phase protection in interference of electron spin waves in lightly hydrogenated graphene

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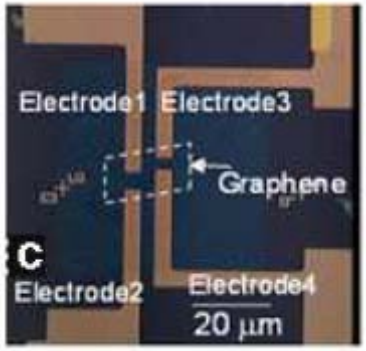
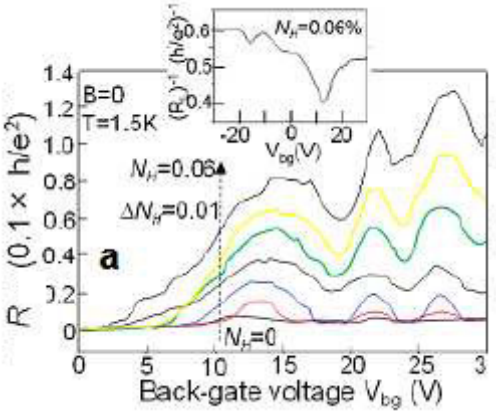
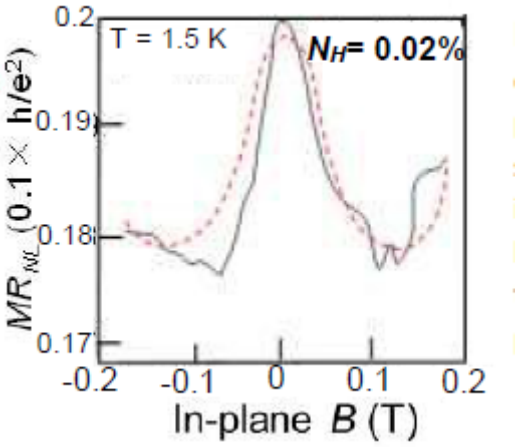
Electron spin transport in graphene is extremely sensitive to foreign atoms and ripples of SiO_2 substrate. Indeed, observed spin diffusion- and relaxation-length (time) were smaller than theoretically expected one owing to them, although a large spin diffusion length has been recently realized in graphene synthesized on SiC substrate. It is, thus, crucial to enhance spin phase coherence and spin diffusion (relaxation) length of graphene/SiO_2 substrate particularly for future graphene spintronics. One of approaches to realize them is investigation of spin phase in phase interference phenomena of electron spin waves (such as weak localization (WL)) and its correlation with spin-orbit-interaction (SOI). However, those coexistence in graphene is difficult to be realized experimentally. Here, we have realized extremely light hydrogenation of graphene surface (<< 0.1%) on SiO_2 by precisely controlling the amount of electron beam (EB) irradiation to a specific EB resist including hydrogen atoms, treated on graphene. It allows coexistence of WL and SOI. We find spin phase protection (suppression of dephasing) of electron-spin-waves in WL on temperature and external magnetic-field dependence in the graphenes with hydrogenation volume (N_H) as small as 0.06%. As an origin, correlation of the WL with Rashba-type SOI, which can be introduced by out-of-plane symmetry breaking due to formation of sp^3 bonds derived from the small N_H, is discussed. The present finding in lightly hydrogenated graphene must be beneficial for graphene spintronics, which requests long spin diffusion- and coherence-length. It will realize a possible 2D-topological insulating state in graphene.







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