Colossal Enhancement of Spin-Orbit Coupling in Weakly Hydrogenated Graphene

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Graphene's extremely small intrinsic spin-orbit (SO) interaction1 makes the realization of many interesting phenomena such as topological/quantum spin Hall states and the spin Hall Effect (SHE) practically impossible. Recently, it was predicted that the introduction of adatoms in graphene would enhance the SO interaction by the conversion of sp2 to sp3 bonds. However, introducing adatoms and yet keeping graphene metallic, i.e., without creating electronic (Anderson) localization8, is experimentally challenging. Here, we show that the controlled addition of small amounts of covalently bonded hydrogen atoms is sufficient to induce a colossal enhancement of the SO interaction by three orders of magnitude. This results in a SHE at zero external magnetic fields at room temperature, with non-local spin signals up to 100 Ω; orders of magnitude larger than in metals. The non-local SHE is, further, directly confirmed by the Larmor spin-precession measurements. From this and the length dependence of the non-local signal we extract a spin relaxation length ~ 1 μm, a spin relaxation time ~ 90 ps and a SO strength of 2.5 meV.