Spin relaxation anisotropy in graphene

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Abstract

In recent years, graphene-based spintronics have shown impressive progress [1,2,3]. Spin relaxation lengths in graphene have been observed to be larger than several tens of micrometers and are already within the required range for technological applications [3,4]. This has been accomplished by a steady improvement of the quality of graphene and of the interfaces with contacting materials [1,3]. However, the microscopic mechanisms that determine the spin lifetime, and spin relaxation length, are still under heated debate [1,2]. This lack of understanding hampers graphene spintronics in reaching its full potential, as for applications it is desirable to achieve full control of the spin dynamics. The spin relaxation anisotropy, which can be quantified by the ratio between the spin lifetimes for perpendicular and parallel spin components to the graphene plane, is a key property that can provide information on the microscopic mechanisms that is not accessible by other means [1]. This is so because the anisotropy is determined by the preferential direction of the spin-orbit fields that may cause the spin relaxation. Despite such inherent interest, measurements of the spin lifetime anisotropy are scarce and limited to large carrier densities [5]. Here, we demonstrate a conceptually new approach that overcomes this limitation. The concept relies on spin precession measurements under oblique magnetic fields that generate an out-of-plane spin population, which is further used to evaluate the out-of-plane spin lifetime [6]. Our experiments demonstrate that the spin relaxation anisotropy of graphene on silicon oxide is independent of carrier density and temperature, and much lower than previously reported; indeed, within the experimental uncertainty, the spin relaxation is isotropic. Together with the gate dependence of the spin lifetime, this indicates that the spin relaxation is driven either by magnetic impurities or by randomly oriented spin-orbit fields, relative to the spin. These findings open the way for systematic anisotropy studies with tailored impurities and on different substrates, which are crucial to find a route to manipulate the spin lifetime in graphene and as such has important implications for both fundamental science and technological applications.

References

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