Spin wave in zigzag graphene and the stability of the edge ferromagnetism

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Graphene is being hailed as the big promise for nanoelectronics and spintronics. Its unique transport properties are expected to play a fundamental role in the development of new technologies [1-3]. New physics is also emerging from the interplay between low dimensionality, a bipartite lattice and electron-electron interaction. One of the most striking properties of graphene nanoribbons is the possibility of spontaneous magnetization [4-6]. This, combined with the long spin-coherence times of electrons propagating across graphene, indicates that this system is a strong candidate for future spintronics applications.

The ground state properties of magnetic graphene nanoribbons have been extensively explored by a variety of methods. Recent works have investigated the properties of static excited states based on adiabatic approximations [7, 8]. This approach has been employed to describe the lowest-lying excitations of magnetic metals with relative success. However, it is well known that it misses important features of the excited states, such as its finite lifetime. This arises due to the coupling between spin waves and Stoner excitations, a distinctive feature of itinerant magnets. Moreover, these recent investigations of excited states seem to have disregarded the antiferromagnetic coupling between the magnetizations on opposite edges of graphene nanoribbons. As we shall see, this leads to an incorrect prediction concerning the wave vector dependence of low energy spin excitations. This has already been demonstrated more than a decade ago in the seminal work by Wakabayashi et al. [9]. Those authors used an itinerant model to describe the π electrons in graphene nanoribbons of various widths. They showed clearly the presence of a linear term in the spin wave dispersion relation for small wave vector.

One interesting feature of magnetic graphene nanoribbons is that the spins along each border are ferromagnetically coupled to each other, but there is an antiferromagnetic exchange coupling between the two opposite borders. This coupling is mediated by the conduction electrons, and decreases as the ribbon width is increased Thus, it may appear, at first sight, that this antiferromagnetic. coupling should be unimportant in wide ribbons. It has been shown, however, that this coupling is extremely long ranged in graphene and other related materials [10-14]. Thus, even in rather wide nanoribbons this coupling asserts itself, as we shall see.

We point out that spin wave lifetimes are very long due to the semi-conducting nature of the electrically neutral nanoribbons. However, application of very modest gate voltages causes a discontinuous transition to a regime of finite spin wave lifetime. By further increasing doping the ferromagnetic alignments along the edge become unstable against transverse spin fluctuations. This makes the experimental detection of ferromagnetism is this class of systems very delicate, and poses a difficult challenge to the possible uses of these nanoribbons as basis for spintronic devices.

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