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Dilute Magnetism in Graphene

Abstract

It is known that hydrogenated graphene exhibits a ferromagnetic phase when a carbon buffer layer is also present [1, 2]. The root to this magnetic ordering is the interplay between the itinerant electrons in graphene and the local magnetic moments induced by impurities. The resultant RKKY interaction is ferromagnetic for impurities on the same sub-lattice, and anti-ferromagnetic if the impurities sit on different sub-lattices. Whether the magnetic phases survive down to the lowest impurity densities, what is the effect of the disorder due to the random positions of the adatoms, and how does the critical temperature change with charge doping, are key questions that we have answered theoretically using a s-d like model [3].
For impurities on the same sub-lattice, we have obtained the phase diagram shown in Fig. 1. For low concentration of impurities, the Curie temperature decreases linearly, but this behavior changes considerably if we make the s-d interaction anisotropic. For the isotropic case, the fact that the Curie temperature is still finite for impurity densities as low as 1% is a non-trivial result. The dependence of the Curie temperature on the charge density in graphene Is shown in Fig. 2. Interestingly enough, one could switch the magnetization on and off through an electric field effect which changes the charge density.
We have applied this theory to the description of a recent experiment on graphene with sulfur impurities [4]. It provides an alternative explanation which circumvents some difficulties of the theory used in [4] to explain the experiment.
We have also simulated the case when the magnetic impurities distribute equally on both sub-lattices. We will also discuss this case.

References

[1] L. Xie et al., Applied Physics Letters, 98 (2011) 193113
[2] A. Giesbers et al., Phys. Rev. Lett., 111 (2013) 166101
[3] F. Sousa, B. Amorim, and E. V. Castro, submitted
[4] C. Hwang at al., Sci Re., 6 (2016) 21460

Figures

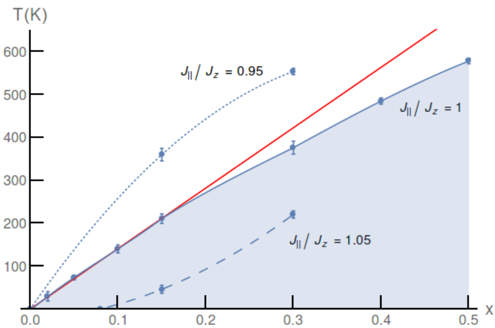

Figure 1: Critical temperature for one-lattice ferromagnetism at half-filling.

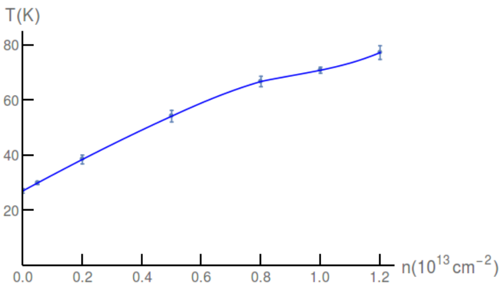

Figure 2: Critical temperature for one-lattice ferromagnetism as a function of electronic doping.