ABSTRACT

Erbium-Intercalated Graphene: Flat Bands, Magnetic Properties, and Heavy Fermions

Laurent Simon

Institut de Science de Matériaux de Mulhouse (IS2M-UMR CNRS-UHA-73061)
CNRS UMR 7361, 3bis rue Alfred Werner 68093 Mulhouse Cedex France
E-mail : laurent.simon@uha.fr

This work is part of the ongoing efforts to explore graphene and its behavior at a critical point in its Brillouin zone—the van Hove singularity—where the Lifshitz transition occurs. The aim is to access "flat" electronic bands, which are expected to exhibit strong electron-electron correlation effects, potentially giving rise to novel physical phenomena such as unconventional superconductivity.

Graphene doping can be achieved through various methods, one of which is atom intercalation—introducing atoms between two graphene layers or between graphene and its substrate. This technique, known as functionalization by intercalation, is particularly relevant for graphene grown on SiC(0001) [1]. Intercalation is typically performed by evaporating the desired element under ultra-high vacuum, followed by annealing at different temperatures. Many elements can be intercalated, and, drawing on analogies with graphite intercalation compounds (GICs), this approach holds promise not only for battery applications but also for observing superconducting transitions. Alkali metals such as Li, Na, K, Rb, and Cs are widely studied in this context.

Our group, among others, has focused on the lanthanide series, which enables record doping levels—as demonstrated with terbium (Tb) intercalation [2]. More recently, ytterbium (Yb) intercalation followed by potassium (K) deposition on the surface allowed us to reach and even surpass the Lifshitz transition [3].

In this talk, we present a new ordered structure—referred to as "supergraphene"—formed by the ordered intercalation of erbium (Er) atoms beneath the graphene layer [4]. This 1.4 nm non-Bravais (honeycomb) lattice features a Fermi surface topology that includes a flat band surpassing the Lifshitz transition. Notably, this is achieved for the first time without adding dopant atoms on top of the graphene.

We will discuss the implications of such a Fermi surface topology on quasiparticle interference (QPI) patterns and local scanning tunneling spectroscopy (STS) measurements. The magnetic properties of this system were also investigated using XMCD (X-ray magnetic circular dichroism) measurements at the M4,5 edge of erbium, performed at a synchrotron facility. Our results show the presence of a diluted phase of individual Er^{3+} atoms that retain their magnetic character, exhibiting a significant out-of-plane magnetic moment. Finally, we demonstrate the ability to functionalize the top graphene layer and tune the Fermi level from the Dirac point to the Lifshitz transition, thereby modifying magnetic interactions mediated by delocalized graphene π-states.

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