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ABSTRACT:

Proximity coupling in epitaxial graphene on SiC(0001) by intercalation and nanostructuring: Doping, strong correlation, interface electronic structure

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Wafer scale epitaxial graphene (EG) grown on Silicon Carbide (SiC) has proven to be a suitable candidate for carbon based electronics. Homogeneous graphene layers can be prepared with defined atomic thickness on a wafer scale. The functionalization of the graphene/SiC interface on an atomic scale enables tuning of the electronic and structural properties of the graphene layer.

Intercalation under the first carbon layer relieves its covalent bonds to the SiC(0001) substrate and the π-band structure can be manipulated in a large range of aspects [1]. In addition, the structure of the intercalated layer can be precisely defined. Au and Ag intercalation generate a highly ordered graphene/intercalant/substrate system with a noticeable charge transfer to the graphene and many-body interactions renormalizing its π-bands. A sharp two-dimensional (2D) band structure can be resolved for the interface layer. A monoatomic Ag layer turns out to be semiconducting in contrast to its 3D bulk equivalent [2]. By varying the Au thickness a semiconductor to metal transition is induced in the interface layer [3]. Pb-intercalation leads to an essentially charge neutral quasi-free graphene layer, while the Pb interlayer develops its own 2D metallic band structure [4]. These Pb bands show indication of a strong spin structure. Pb intercalation is viewed as potential source for proximity induced superconductivity (SC) in graphene, since thin Pb islands grown ontop of hydrogen intercalated graphene show SC, similar to bulk Pb, and indeed induce proximity SC into the surrounding graphene regions [5].

High doping regimes can be reached by the intercalation of rare earth elements, such as Gd or Yb. As a result, the Van-Hove singularity (VHS) of the π^*-bands reaches the Fermi level. The doping is accompanied by a strong bending of the bands at the Fermi level, which is attributed to strong electron-electron interaction [6]. By a combination of Yb intercalation and K adsorption, the EG layer can be n-doped even past the VHS.

Thereby a Lifshitz transition is completed, where the Fermi surface topology changes from two electron pockets into a giant hole pocket [7]. Crossing the VHS in this way allows access to potential exotic phases where unconventional superconductivity or charge and spin density waves are predicted.

By starting with a patterned SiC surface with mesas and trenches of 200 nm periodicity, EG nanoribbons (GNRs) can be grown on the mesa facets. High-resolution ARPES demonstrates the 1-dimensional behaviour of graphene on these facets: while the whole facet has a width of about 40 nm, it contains an array of mini-GNRs (≈ 2 nm wide) separated by nano-basal stripes. The subbands of these mini-ribbons reveal a sharp distribution of ribbon widths of around 18 dimers [8]. On the mesas, a conventional graphene buffer layer develops. By H-intercalation, both graphene types, on mesa and facet, are decoupled and transform into a single two-dimensional graphene sheet rolling over the mesa structures. Due to the different surface terminations of the basal and vicinal SiC surfaces, different types of charge carriers are locally induced into the graphene layer leading to two symmetrically n- and p-doped phases. Thus, a regular array of of graphene pn-junctions develops [9].

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