Single-spin flat bands in cobalt-supported graphene

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Due to the fundamental and technological implications in driving the appearance of non-trivial, exotic topological spin textures and emerging symmetry-broken phases, flat electronic bands in 2D materials, including graphene, are a hot topic in the field of spintronics.

By means of spin-resolved angle-resolved photoemission spectroscopy (ARPES) experiments combined with density functional theory (DFT) calculations, we investigated the role of europium in modifying the spin-dependent electronic properties of monolayer Gr on Co(0001). Manifold effects can be revealed: i) an enhancement of the charge transfer into Gr via Eu doping (Fig. 1 top right); ii) the existence of a spin-polarized Gr-Co hybrid state formed by positioning Eu on top or beneath the Gr monolayer in both cases with a single spin (majority) character. While in the former case, the low-dispersive parabolic Gr-Co hybrid band is observed close to Fermi energy (Fig. 1 top right), extending all over the surface Brillouin zone (SBZ), when Eu is intercalated, the π^* band becomes flat (Fig. 1 bottom left); iii) the large exchange coupling due to the presence of Eu induces the splitting of the π band that crosses the 4f states into minority and majority branches bending towards higher and lower binding energies respectively, accompanied by a bandgap opening at the Dirac point of about 0.36 eV.

In addition, if graphene is sandwiched between two Eu layers, the europium 5d majority bands from the uppermost layer hybridize with graphene, forming single-spin electron pockets, while the hybridization of the minority Eu bands induces hybridization gaps in the π^* bands of graphene. Additionally, the spin-resolved measurements reveal a noteworthy single-spin dispersionless contribution near the Fermi level, hinting at the intriguing coupling between the single-spin polarized bands of graphene and optical phonons. This observation expands the understanding of the electronic structure of heavily doped graphene and suggests avenues for exploring novel optical and electronic functionalities.

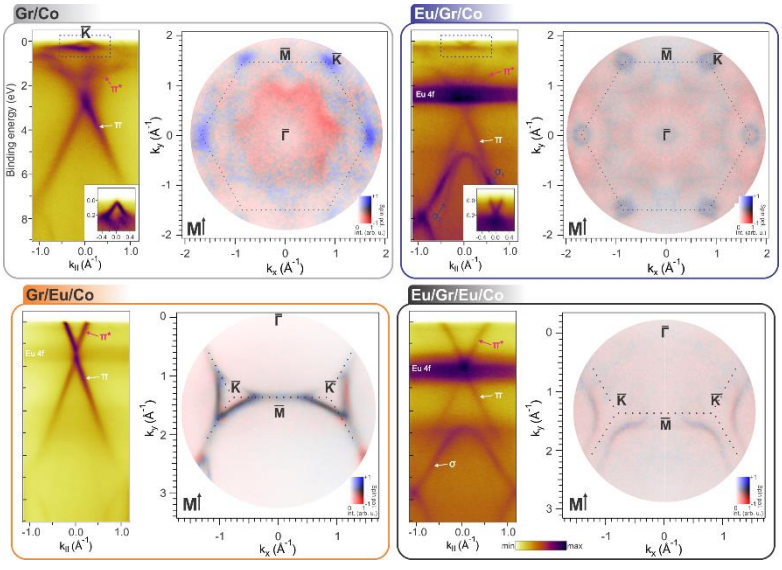

Figure 1. ARPES energy vs. momentum map acquired at the K point of the first Brillouin zone and 2D spin resolved momentum map at the Fermi level of: monolayer graphene/cobalt (top left), Eu deposited on Gr/Co (top right), intercalated Eu at the Gr/Co interface (bottom left) graphene sandwiched between two Eu layers (bottom right)