Chiral Spin Texture in the Charge-Density-Wave Phase of the Correlated Metallic Pb/Si(111) Monolayer

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In a metal, the repulsive interaction between electrons (Coulomb interaction) is screened by the presence of many other electrons. As the electron density decreases this repulsive interaction increases. If it becomes sufficiently strong, it can prevent the formation of a metallic state in favor of an insulating one, called Mott Insulator. Recent works have highlighted the amazing properties of these materials characterized by strong electronic correlations, opening the possibility to interesting industrial applications (i.e. non-volatile memories). Theoretical description of the electronic properties of these materials represents a challenge due to the difficulty of modeling the strong interactions between electrons. This difficulty is even greater when it comes to a low-dimensional system manufactured on a substrate-support: the role of the atoms of the substrate must also be considered.
An ideal system to study those effects is represented by group IV atoms on group IV substrates as they are considered to be on the verge of the Mott-transition. In our work we investigated the 1/3 monolayer α-Pb/Si(111) surface by scanning tunneling spectroscopy (STS) and fully relativistic first-principles calculations. We study both the high-temperature $\sqrt{3}\times\sqrt{3}$ and low-temperature 3×3 reconstructions highlighting the important role of spin-orbit interaction responsible for an energy splitting as large as 25% of the valence-band bandwidth. Relativistic effects, electronic correlations, and Pb-substrate interaction cooperate to stabilize a correlated low-temperature paramagnetic phase with 3×3 periodicity. By comparing the Fourier transform of STS conductance maps at the Fermi level with calculated quasi-particle interference we demonstrate the occurrence of two large hexagonal Fermi sheets with in-plane spin polarizations and opposite helicities.

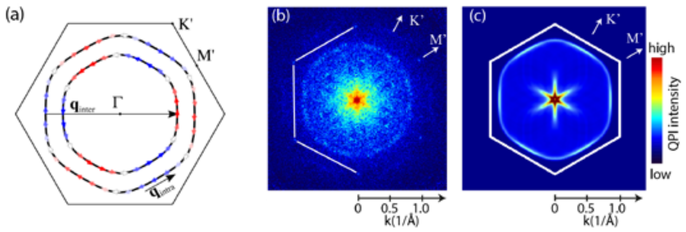

Fig. 1: (a) Fermi surface of Pb-3×3/Si(111) including spins polarization (arrows). White arrows, 100% in-plane polarization; blue and red arrows, opposite out-of-plane components. Black arrows are the scattering vectors. (b) Fourier transform map measured by STS at T=0.3 K, corresponding to quasiparticle interference at $E=E_F$. (c) Calculated quasiparticle interference map at $E=E_F$ assuming scalar impurity scattering.