New physics in spin and charge density wave systems

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Spin and charge density waves (SDW/CDW) are important quantum orders in condensed matter systems, but their underlying mechanism is diverse and not fully understood. In this talk, I will present new physics and mechanisms observed in several SDW/CDW materials:

1) The incommensurate SDW/CDW of Cr and their microscopic boundary structure are visualized by spin-polarized STM [1,2]. At the incommensurate SDW domain walls, we observed novel double-Q SDW accompanied by second-order CDW. In commensurate domains, an SDW gap is observed slightly above E_F, consistent with Fermi surface nesting picture. Intriguingly, screw dislocations can induce "half" vortices and antiphase domain walls. The spin density vanishes at the antiphase wall where SDW in-gap states emerge. All these unique SDW boundary structures can be viewed as interference of SDW with different Q or reversed phases. They thus represent a new category of magnetic domain walls which we refer as "interference wall" [2], with a mechanism rooted in itinerant magnetism.

2) Intertwined SDW/CDW orders have been observed in many high-Tc superconductors, but rarely identified in type-II Fe-based superconductor with electron pockets only. Here we discovered checkerboard-like charge order or CDW around the defects of (Li, Fe)OHFeSe (Tc~ 40K), whose wavevectors are along Fe-Fe directions [3]. It gradually evolves from a local order to an extended order with increased defect density. Our simulations indicate that such charge order is driven by multiple-Q SDW originating from spin fluctuations, similar as the case of Cr SDW domain walls. This competing order facilitates a unified understanding of iron-based superconductors.

3) The origin of CDW in Kagome metal FeGe is systematically studied. We observed long-ranged CDW in high-quality FeGe samples via low-temperature STM [4], in contrast to previously reported short-ranged ones [5]. The refined 2×2×2 CDW superstructure is characterized by strong dimerization of Ge atoms in neighboring Kagome planes [4]. ARPES study does not show Fermi surface nesting or sizeable energy gap at E_F. Instead, significant band shifts after CDW transition are observed [6]. Accompanied by DFT calculations, our results indicate the CDW in FeGe is driven by saving magnetic energies via a first-order structural transition [7]. It represents a new CDW mechanism conspired by magnetism and lattice, distinct from conventional Fermi surface nesting picture.

References:

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