Engineering correlated quantum phases in 2D charge-density-wave 1T-TMDs

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Strongly interacting electrons in 1T-transition metal dichalcogenides (TMD) with half-filled flat band exhibit rich phase diagrams of exotic quantum states, including Mott state, superconductivity and correlated topological orders intermixed with magnetic orders. In the first part, I' d like to introduce an approach to realize artificial hexagonal and kagome lattices by metal adsorption on a 2D Mott insulator 1T-TaS2. Alkali, alkali-earth, and group-13 metal atoms are deposited stably in $(\sqrt{3}\times\sqrt{3})R30^{\circ}$ and 2×2 TaS2 superstructures of honeycomb- and kagome-lattice symmetries exhibiting Dirac and kagome bands, respectively. The strong electron correlation of 1T-TaS2 drives the honeycomb and kagome systems into correlated topological phases. The band filling of these Mott Dirac and flat bands can be tuned by proper choice of adsorbates. Especially, the 2/3- or 3/4-filled system can be achieved with a proper concentration of Mg adsorbates, which can lead to unconventional superconductivity. Furthermore, I'd like to show that the systematic tuning of a trivial insulator into a Mott insulator and a Mott insulator into a correlated metallic and a pseudogap state in 1T-TaS2 upon the surface K doping. Moving on to the second part, I'll show that novel anion-centered David star structure manifestly breaks inversion symmetry, resulting in flat bands with pronounced Rashba spin-orbit couplings. These distinctive features unlock novel possibilities and functionalities for 1T-TMDs, including the giant spin Hall effect, the emergence of Chern bands, and spin liquid that spontaneously breaks crystalline rotational symmetry. Our findings establish promising avenues for exploring emerging quantum phenomena of monolayer 1T-TMDs with this novel noncentrosymmetric structure.

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