# Charge density waves in atomically thin transition metal dichalcogenides

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Understanding complex electronic phases, such as charge density wave (CDW), superconductivity (SC), exciton condensate, and Mott insulator, in two-dimensional (2D) confined geometry offers an interesting perspective toward a comprehensive account of collective electron interactions. Transition metal dichalcogenides (TMDCs) provide an ideal platform for investigating how CDW order evolves in a true 2D limit, often accompanied by competing orders of similar temperature and energy scales. An outstanding question would be how the CDW order evolves as the quantum confinement increases and electron screening reduces with dimensionality approaching 2D and how the competing orders would affect such evolution.

Our approach to this question is to investigate the electronic structure and CDW transition using angle-resolved photoemission (ARPES), scanning tunneling microscopy and spectroscopy (STM/STS), and density functional theory (DFT) calculations on the TMDC samples grown by molecular beam epitaxy (MBE). For example, we have found that CDW order persists in single layers of 2*H*-$NbSe_2$ [1] and 2*H*-$TaSe_2$ [2] with only a moderate increase in transition temperature despite dramatic changes in the low energy electronic structures and Fermi surface topologies. In 1*T*-$TaSe_2$, a robust Mott insulating phase with unusual orbital texture is found in the single layer on top of the well-known star-of-David CDW order [3].

In this talk, I will present more recent examples of CDW orders with exotic origins. In monolayer $IrTe_2$, we have found a large-gap insulating dimer ground state, in which lattice and charge instabilities, as well as local bond formation, collectively enhance and stabilize a charge-ordered ground state [4]. In monolayer $ZrTe_2$, we have discovered a novel band- and energy-dependent folding behavior in ARPES that results in a two-step CDW, which we interpret as the formation of excitonic gas and its condensation into a final CDW state [5].

References

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