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Metastable Phases in 2D Layered Material

2D material-based microdevices are lab-on-a-chips to explore novel states of matter in ultrathin layered materials that are apparently worn-out in their bulk forms. As demonstrated in graphene and related materials, 2D material is a new system to engineer its peculiar electronic band structure to realize exotic electronic state. In addition to such static properties, recent studies have revealed the unique dynamical properties of 2D material, suggesting that the 2D material is a platform to explore its metastable properties which are difficult to realize in its bulk counterpart. Here, we present three examples that highlight the new story of 2D material. First, we discovered that the reduction in thickness corresponds to rapid cooling in first-order phase transition systems, and that thin flakes show the supercooled phase which are difficult to access in macroscopic bulk crystals [1,2]. For instance, we demonstrated the thinning-induced metastable superconductivity in the thin flakes of 1T-$IrTe_2$, where the charge-ordering competes with superconductivity (see Fig. 1) [3]. Second, in thin flakes of TaS_2, we discovered a metastable crystal phase that is not yet found in its bulk counterpart [4]. We mechanically exfoliated a 2Ha-TaS_2 bulk crystal and fabricated microdevices for the thin flakes, followed by the discovery of the thin flake with a metastable polymorph which is possibly 2Hb. Strikingly, its charge-density-wave (CDW) ordering temperature is three times higher than that of the well-known 2Ha. Third, we discovered a nonvolatile current-induced phase transition in a CDW material 1T-TaS_2, followed by the creation of a novel metastable CDW state [2]. The current-induced metastable state is highly conducting, distinct from thermodynamically stable semiconducting or insulating CDW phases [5]. It is likely that the transition is triggered by the unprecedented depinning of CDWs from the underlying atomic lattice [5]. Probably the CDW sheets slide to form a metastable stacking configuration which has a metallic electronic structure [6].

References

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Figures

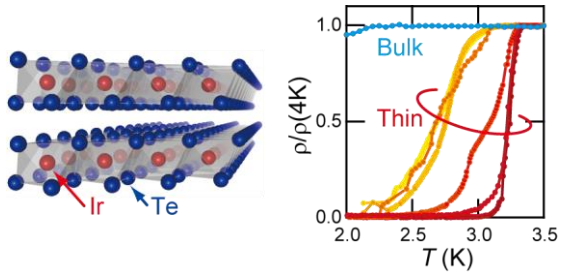

Figure 1: Thinning-induced metastable superconductivity in 2D layered 1T-$IrTe_2$. 2D material is a platform to explore metastable phases that are inaccessible in its bulk counterpart.