Searching for superconductivity in transition metal dichalcogenides: a high pressure study

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The search for the coexistence between superconductivity and other collective electronic states in many instances promoted the discovery of novel states of matter. The manner in which the different types of electronic order combine remains an ongoing puzzle. Here we address the coexistence/competition of the charge density wave instability (CDW) and superconductivity in transition metal dichalcogenides (TMDs). These are a class of layered materials, well known for the first discovery of the CDW instability in quasi two-dimensional systems several decades ago. It is important to note, however, that the CDW instabilities found in the TMD compounds may not share the same origin. We have investigated two representatives of TMDs: 1T-TaS_2, where the nesting of the Fermi surface is the driving mechanism and 1T-$TiSe_2$, where excitonic interactions drive the CDW.

1T-TaS_2 is the only TMD known to develop the Mott phase. We show the appearance of a series of low-temperature electronic states in 1T-TaS_2 with pressure: the Mott phase melts into a textured charge-density wave (CDW); superconductivity develops within the CDW state, and survives to very high pressures, insensitive to subsequent disappearance of the CDW state and, surprisingly, to the strong changes in the normal state. This is also the first reported case of superconductivity in a pristine 1T-TMD compound. We demonstrate that superconductivity first develops within the state marked by a commensurability-driven, Coulombically frustrated, electronic phase separation. In 1T-$TiSe_2$ superconductivity appears only in the 2-4 GPa pressure window where the fluctuating excitonic interactions are present. We suspect that these interactions are at the origin of superconductivity in this material.