Proximity effects on the charge density wave order and superconductivity in single-layer $NbSe_2$

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Abstract

Collective electronic states such as the charge density wave (CDW) order and superconductivity (SC) respond sensitively to external perturbations. Such sensitivity is dramatically enhanced in two dimensions (2D), where 2D materials hosting such electronic states are largely exposed to the environment. In this regard, the ineludible presence of supporting substrates triggers various proximity effects on 2D materials that may ultimately compromise the stability and properties of the electronic ground state. In this work, we investigate the impact of proximity effects on the CDW and superconducting states in single-layer (SL) $NbSe_2$ on four substrates of diverse nature, namely bilayer graphene (BLG), SL-boron nitride (h-BN), Au(111) and bulk WSe_2. By combining low-temperature (340 mK) scanning tunneling microscopy/ spectroscopy (STM/STS) and angle-resolved photoemission spectroscopy (ARPES), we compare the electronic structure of this prototypical 2D superconductor on each substrate. We find that, even when the electronic band structure of SL-$NbSe_2$ remains largely unaffected by the substrate except when placed on Au(111), where a charge transfer occurs, both the CDW and SC show disparate behaviors. On the insulating h-BN/Ir(111) substrate and the metallic BLG/SiC(0001) substrate, both the 3x3 CDW and superconducting phases persist in SL-$NbSe_2$ with very similar properties, which reveals the negligible impact of graphene on these electronic phases. In contrast, the electronic phases of SL-$NbSe_2$ are severely weakened and even absent on the bulk insulating WSe_2 substrate and the metallic single-crystal Au(111) substrate. Our results provide valuable insight into the fragile stability of such electronic ground states in novel 2D materials.