18p-B3-8

Interface electronic and transport properties in liquid-gated TMD thin flakes

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Two-dimensional materials such as transition metal dichalcogenides (TMDs) have attracted substantial interest since the discovery of graphene. By mechanical cleavage, atomically flat and chemically stable thin flakes of TMDs have been extracted from bulk crystals and employed as ideal channel materials for field effect transistor (FET) devices. Recently, coupling with novel functioned ionic liquid (IL) dielectrics, TMD thin flakes have exhibited extraordinary electronic and optoelectronic properties in the form of electrical double layer transistors (EDLTs), owing to the powerful capability of accumulating high density of carriers at the solid/liquid interfaces. As an example, MoS_2 thin flake EDLT has showed gate-induced superconductivity and circular polarized electroluminescence[1, 2]. However, there has not much been done to explore the TMD thin layers systematically so as to clarify the underlying mechanism of electronic state modulation at the interfaces and also the fundamental physics of related new exotic quantum phenomena. Here, we report a comprehensive study of several TMDs, specifically MoX_2 (X = S, Se, Te), with the same IL dielectrics. In comparison, $MoSe_2$ EDLT displayed a balanced ambipolar transistor operation while the other two showed opposite predominance in electron and hole accumulation respectively, as shown in Figure 1. The distinct transfer characteristic can be explained by a reasonable mechanism of energy level alignments at the solid/liquid interfaces. On the other hand, carrier modulation at the interfaces enables new quantum phase transitions at low temperatures. Particularly gate-induced superconductivity is found in $MoSe_2$, showing an universal dome-shaped phase diagram as MoS_2[1]. These results suggest TMD thin flake EDLTs as a unique and well controlled 2D platform not only for realizing new device functionalities but also for studying fundamental quantum effects.

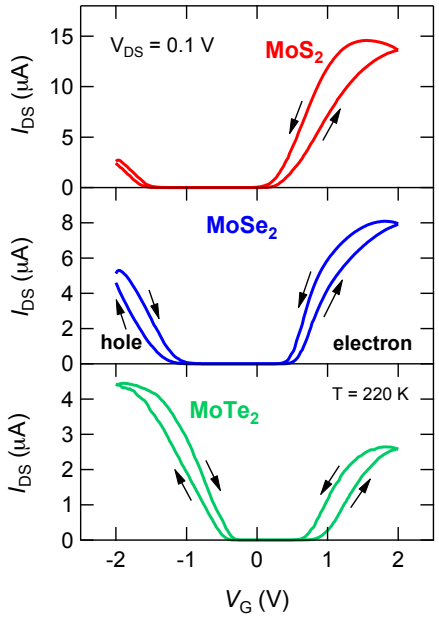

Figure 1. Ambipolar transfer characteristics of MoS_2, $MoSe_2$ and $MoTe_2$ thin flake EDLTs.

[1] J. T. Ye, Y. J. Zhang, R. Akashi, M. S. Bahramy, R. Arita, Y. Iwasa, Science **338**, 1193 (2012)

[2] Y. J. Zhang, T. Oka, R. Suzuki, J. T. Ye, Y. Iwasa, Science **344**, 725 (2014).