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High mobility field-effect transistors based on MoS2 crystals grown by the flux method

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Abstract

Two-dimensional (2D) molybdenum disulphide (MoS2) transition metal dichalcogenides (TMDs) have great potential for use in optical and electronic device applications; however, the performance of MoS2 is limited by its crystal quality, which serves as a measure of the defects and grain boundaries in the grown material. Therefore, the high-quality growth of MoS2 crystals continues to be a critical issue. In this context, we propose the formation of high-quality MoS2 crystals via the flux method. The resulting electrical properties demonstrate the significant impact of crystal morphology on the performance of MoS2 field-effect transistors. MoS2 made with a relatively higher concentration of sulphur (a molar ratio of 2.2) and at a cooling rate of 2.5 °C h−1 yielded good quality and optimally sized crystals. The room-temperature and low-temperature (77 K) electrical transport properties of MoS2 field-effect transistors (FETs) were studied in detail, with and without the use of a hexagonal boron nitride (h-BN) dielectric to address the mobility degradation issue due to scattering at the SiO2/2D material interface. A maximum field-effect mobility of 113 cm2 V−1 s−1 was achieved at 77 K for the MoS2/h-BN FET following high-quality crystal formation by the flux method. Our results confirm the achievement of large-scale high-quality crystal growth with reduced defect density using the flux method and are key to achieving higher mobility in MoS2 FET devices in parallel with commercially accessible MoS2 crystals.

Atomically thin forms of layered materials, such as conducting graphene, insulating hexagonal boron nitride (hBN), and semiconducting molybdenum disulfide (MoS2), have generated great interests recently due to the possibility of combining diverse atomic layers by mechanical “stacking” to create novel materials and devices. In this work, we demonstrate field-effect transistors (FETs) with MoS2 channels, hBN dielectric, and graphene gate electrodes. These devices show field-effect mobilities of up to 45 cm2/Vs and operating gate voltage below 10 V, with greatly reduced hysteresis. Taking advantage of the mechanical strength and flexibility of these materials, we demonstrate integration onto a polymer substrate to create flexible and transparent FETs that show unchanged performance up to 1.5% strain. These heterostructure devices consisting of ultrathin two-dimensional (2D) materials open up a new route toward high-performance flexible and transparent electronics.

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