Suspended two-dimensional MoS_2 transistor

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Two-dimensional (2D) materials attract increasing attention, due to their ultralow weight, high mobility, extraordinary mechanical properties and flexibility [1]. An intrinsic bandgap within the 2D semiconducting transition metal dichalcogenides (TMDs) [2,3], such as MoS_2 and WSe_2, makes them more promising in the electronic and optoelectronic devices applications. However, the trapped charges at the interface of 2D materials/substrates can screen the gate field and give rise to the Coulomb scattering [4], which negatively affect the carrier transport in the 2D materials. Thus, understanding of the intrinsic characteristics of MoS_2 field-effect transistors (FETs) without the effect of underlying substrate is essential [5].

A back gated MoS_2 FET has been fabricated on Si/SiO_2 substrate, as shown in Figure 1(a). After the 2D MoS_2 has been exfoliated and transferred onto the substrate, the 2D MoS_2 channel has been patterned with optical lithography and CF_4 plasma etching. The metal contact regions have been defined on negative photoresist with the help of alignments marks in SiO_2 [6]. Then Ti/Al metal stacks have been deposited by E-beam evaporation and lifted off. The device has been annealed in forming gas (N_2/H_2) at 300°C for 2 hours to remove adsorbed water and organic contamination before characterized in probe station. Figure 1(b) depicts the optical image of the fabricated MoS_2 FET that enables 4 point measurements. The fabricated MoS_2 FET exhibits the notable n-type semiconducting behavior with the ~15 V threshold voltage, as shown in Figure 1(c). A mild hysteresis is observed which is attributed to charge-trapping effects at the MoS_2/SiO_2 interface. The mobility of MoS_2 channel has been extracted as 1.76 cm^2V/s and 2.59 cm^2V/s from 2 point and 4 point measurements, respectively. From the I_{DS}-V_{DS} curves shown in Figure 1(d, e), the resistance of MoS_2 channel is determined to be 2.75 $\Omega\cdot cm$ (2 point measurement) and 2.03 $\Omega\cdot cm$ (4 point measurement) at a gate bias V_{GS} of 60 V. The above results show that the contact resistance between MoS_2 and Ti (2.7 $M\Omega$ when V_{GS}=60 V) possibly resulting from the Schottky barrier plays an important role in the current transport of MoS_2 FET. Therefore, in order to extract the intrinsic mobility of MoS_2, 4 point measurement needs to be applied.

In order to compare the mobility and resistance of MoS_2 sheet on the substrate and released from the substrate, the MoS_2 channel will be suspended with a vapour HF etching system (MEMSSTAR) and electrical characterization will be performed on the suspended MoS_2 FET. In addition, the effect of substrate on the hysteresis of FET will be investigated.

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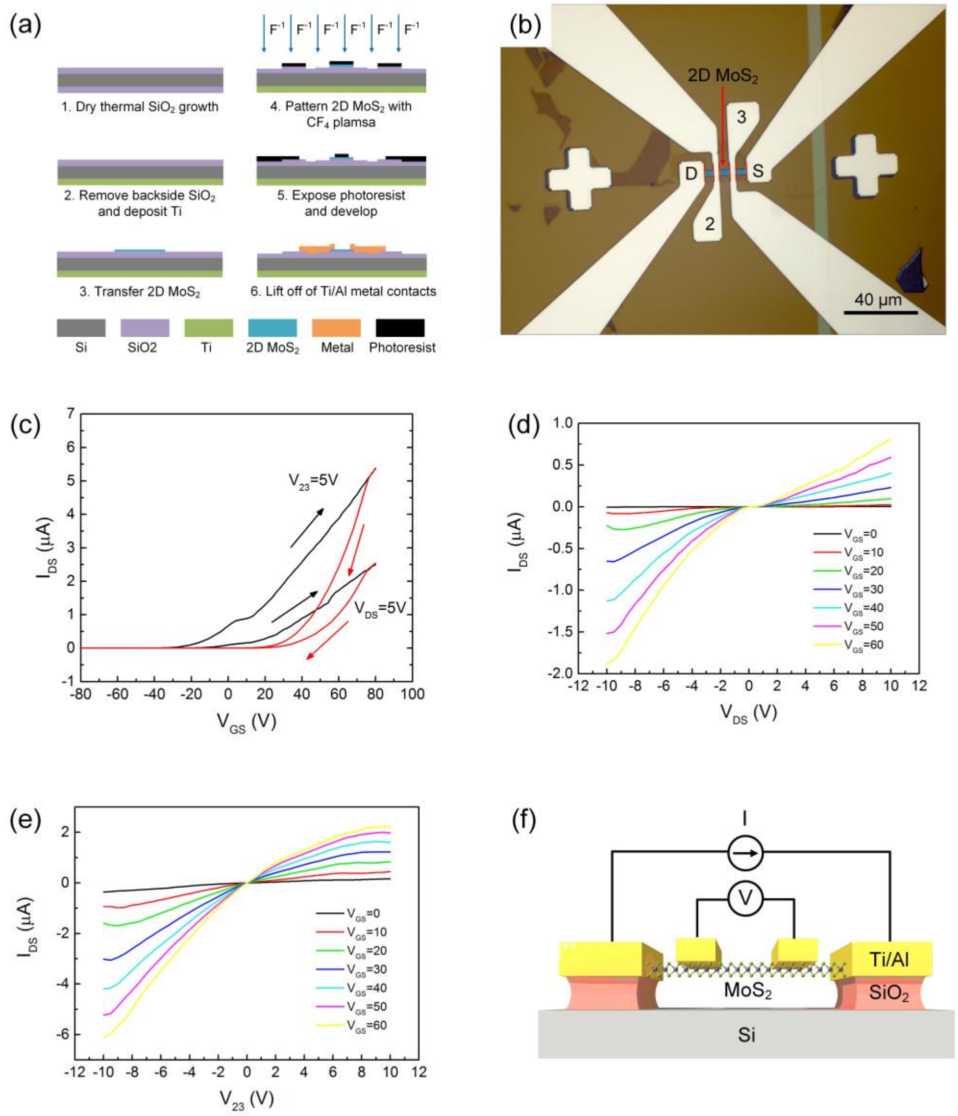

Figure 1: (a) Schematic of the back gated MoS_2 FET fabrication. (b) Optical image of the fabricated MoS_2 FET. (c) Transfer characteristics of the MoS_2 FET obtained from two/four point measurements. Output characteristics of the MoS_2 FET obtained from two point (d) and four point (e) measurements. (f) Schematic of a suspended MoS_2 FET.