Encapsulated MoS_2 FETs with Improved Performance and Reliability

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Considerable progress in the fabrication of MoS_2 FETs has been demonstrated recently [1]. However, available device prototypes still suffer from a sizable hysteresis of the I_D-V_G characteristics [2,3] and long-term drifts of threshold voltage V_{th} [3,4], known as bias-temperature instabilities (BTI). As such, these issues must be addressed prior to commercialization of MoS_2 technologies.

Here we report on the improvement of the properties of MoS_2/SiO_2(25 nm) FETs [5] introduced by the encapsulation with high-quality Al_2O_3(15 nm) based on a modified recipe of [6]. The I_{on}/I_{off} ratio of these devices is as high as 10^9 (Fig.1a), which is already close to predicted values [7]. At the same time, the hysteresis is two orders of magnitude smaller than in bare exfoliated devices (Fig.1b). Furthermore, positive BTI (PBTI) in encapsulated CVD devices is weakly pronounced (Fig.1c), which is important for MoS_2 n-FETs. Quite remarkably, PBTI is weaker than in previously reported exfoliated bare MoS_2/SiO_2 [3], stacked MoS_2/hBN [3] and encapsulated BP/SiO_2 FETs [8] (Fig.1d). The reason for the reduced hysteresis and BTI, as well as for the improved device perfromance, is that the encapsulation layer efficiently protects the device from adsorbent-type trapping sites on top of the MoS_2 channel [3].

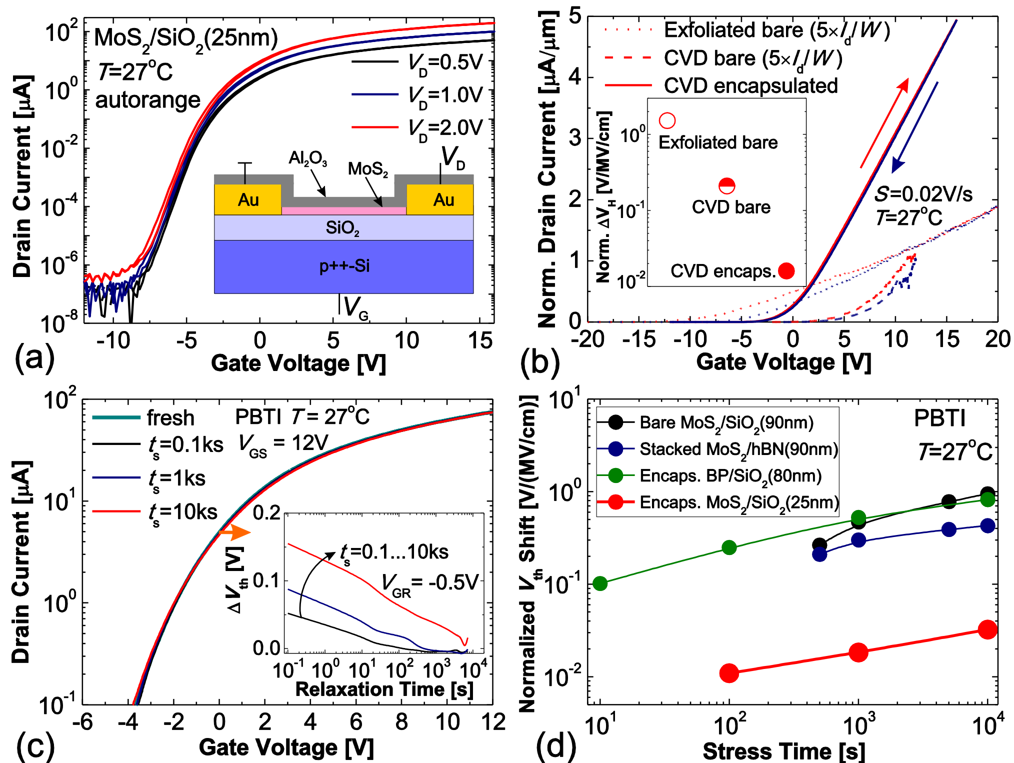

Fig. 1. (a) The I_D-V_G characteristics of encapsulated MoS_2 FETs and schematic device layout (inset). (b) The I_D-V_G characteristics (normalized by device width W) of exfoliated bare MoS_2/SiO_2(90 nm) and CVD grown bare and encapsulated MoS_2/SiO_2(25 nm) FETs (sweep rate S=0.02 V/s). (c) Evolution of the I_D-V_G characteristics after subsequent PBTI stresses with V_{GS}=12 V and V_{th} recovery traces measured using V_{GR}=-0.5 V (inset). (d) The PBTI shifts normalized by the stress oxide field are the smallest for encapsulated CVD grown MoS_2/SiO_2(25 nm) FETs.

Overall, we conclude that encapsulation of MoS_2 FETs strongly improves their reliability and performance, making this an important technological step toward reaching commercial quality standards.

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