Universal approach to achieve enhanced ambipolar behaviour in all TMDs and CVD monolayer MoS_2 based Field Effect Transistors (FETs)

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Abstract

Large electronic bandgap and large density of surface states in monolayer CVD MoS_2 lead to fermi-level pinning (FLP) near the conduction band and unipolar N-type behaviour in CVD monolayer MoS_2 FETs. In principle, it is not trivial to achieve decent hole conduction in monolayer CVD MoS_2 FETs. However, significant work has been done to achieve P-type conduction in MoS_2 FETs which are otherwise N-type [1]. In order to achieve a "non-trivial" device behaviour, fundamental understanding of metal-semiconductor interface is of prime importance. Based on atomistic simulations we intend to understand physics at the metal-TMD interface and possibility of inducing significant P-type conduction in all Transition Metal Dichalcogenides (TMDs) based FETs and hence experimentally demonstrate an approach to enhance hole conduction in all TMD based 2D FETs. It turns out that the approach is universal for all TMDs and proves to be equally effective for CVD monolayer MoS_2 FETs which makes the approach of high fundamental as well as technological significance. It involves a Chalcogen precursor to expose the contact region before contact metal deposition. Unexposed devices are called standard device whereas exposed devices are contact engineered or engineered devices. Unlike anion based chemical doping techniques [2] where surface transfer leads to higher hole concentration in the channel, this approach focusses to controllably and selectively introduce appropriate surface states at the interface (figure 1)that affects Fermi-level pinning in a way that reduces barrier height for holes. As a result, hole current (3 orders improvement) is established at relatively lower gate electric field (figure 2) which is usually not the case in CVD monolayer MoS_2 FETs.

References

[1] Ankur Nipane et al, ACS Nano, 2016, 10 (2), pp 2128–2137.

[2] Rastogi P. et al, J. Phys. Chem. C 2014, 118, 30309−30314.

Figures

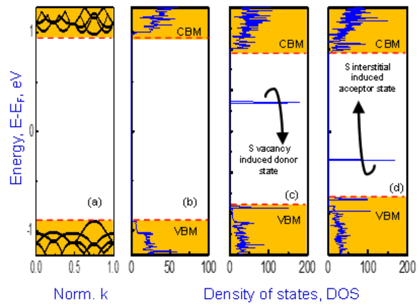

Figure 1: Bandstructure and Density of states in monolayer MoS_2 for three different defect conditions.

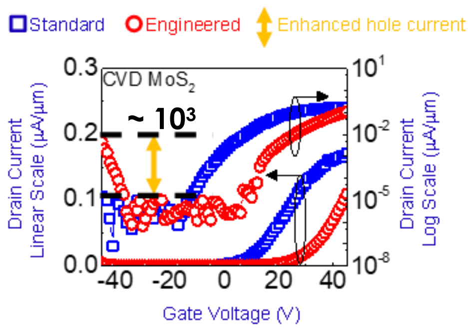

Figure 2: Transfer characteristics for standard and contact engineered monolayer CVD MoS_2 FETs.