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Atomically Thin Tunneling Layer for Improved Contact Resistance and Dual Channel Transport in MoS_2/WSe_2 van der Waals Heterostructure

Two-dimensional (2D) material-based heterostructures provide a unique platform where interactions between stacked 2D layers can enhance the electrical and opto-electrical properties as well as give rise to interesting new phenomena. Here, the operation of a van der Waals heterostructure device comprising of vertically stacked bilayer MoS_2 and few layered WSe_2 has been demonstrated in which an atomically thin MoS_2 layer has been employed as a tunneling layer to the underlying WSe_2 layer. In this way, simultaneous contacts to both MoS_2 and WSe_2 2D layers have been established by forming a direct metal−semiconductor to MoS_2 and a tunneling-based metal−insulator−semiconductor contacts to WSe_2, respectively. The use of MoS_2 as a dielectric tunneling layer results in an improved contact resistance (80 kΩ μm) for WSe_2 contact, which is attributed to reduction in the effective Schottky barrier height and is also confirmed from the temperature-dependent measurement. Furthermore, this unique contact engineering and type-II band alignment between MoS_2 and WSe_2 enables a selective and independent carrier transport across the respective layers. This contact engineered dual channel heterostructure exhibits an excellent gate control and both channel current and carrier types can be modulated by the vertical electric field of the gate electrode, which is also reflected in the on/off ratio of 10^4 for both electron (MoS_2) and hole (WSe_2) channels.[1] Moreover, the charge transfer at the heterointerface is studied quantitatively from the shift in the threshold voltage of the pristine MoS_2 and the heterostructure device, which agrees with the carrier recombination-induced optical quenching as observed in the Raman spectra of the pristine and heterostructure layers. This observation of dual channel ambipolar transport enabled by the hybrid tunneling contacts and strong interlayer coupling can be utilized for high-performance opto-electrical devices and applications.

References

[1] Muhammad Atif Khan, Servin Rathi, Changhee Lee, Dongsuk Lim, Yunseob Kim, Sun Jin Yun, Doo-Hyeb Youn, and Gil-Ho Kim, ACS Appl. Mater. Interfaces 10 (2018) 23961−23967

Figures

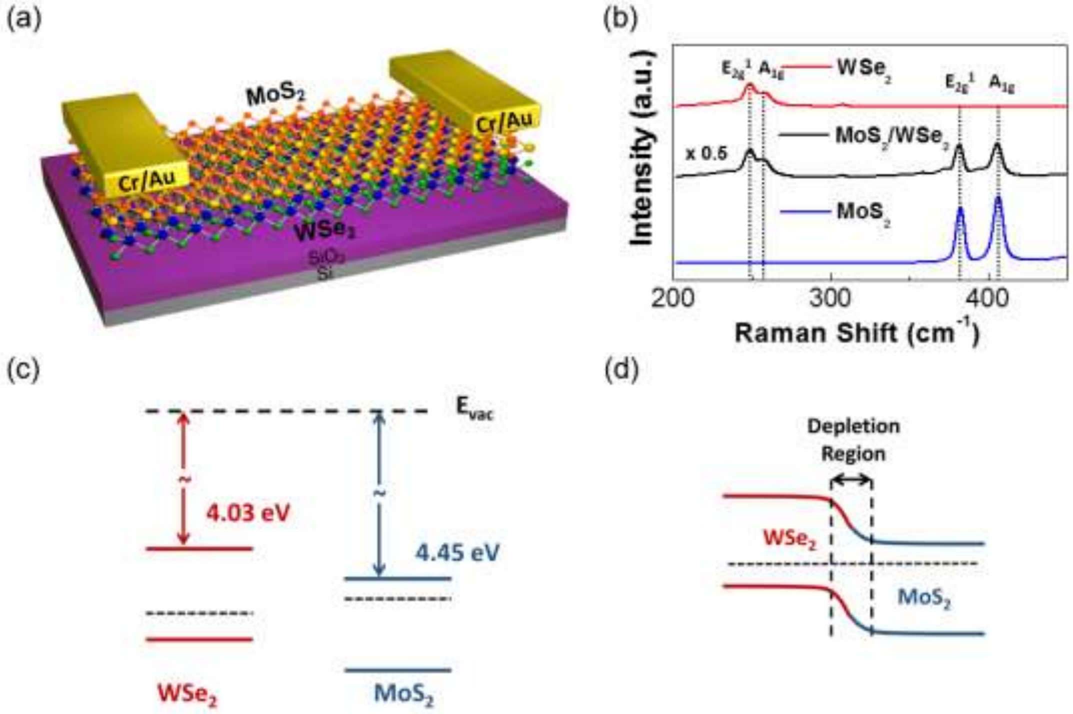

Figure 1: (a). Schematic diagram of dual channel MoS$_2$-WSe$_2$ heterostructure FET (b). Raman spectra of MoS$_2$, WSe$_2$ and overlapped MoS$_2$/WSe$_2$ region (the intensity of overlapped region is reduced by a factor of 0.5) (c) Band diagram showing band structure of pristine MoS$_2$ and WSe$_2$ before transfer (d) Band diagram of MoS$_2$/WSe$_2$ heterostructure illustrating the formation of depletion region.

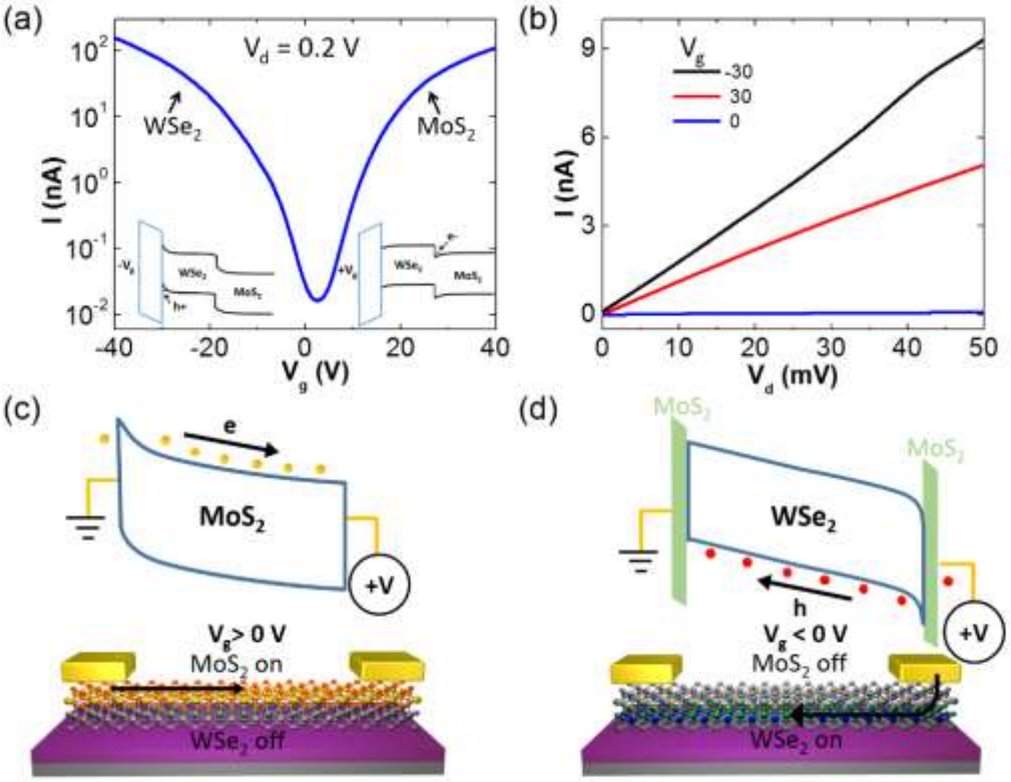

Figure 2: (a). Transfer characteristics curve of dual channel FET at V_d = 0.2 V in semi-logarithmic scale (b). Output characteristics curve of dual channel FET at different back gate voltages (c). Schematic band diagram and device schematic illustrating the band structure and current flow for positive V_g (d). Schematic band diagram and device schematic illustrating the band structure and current flow for positive V_g.