Carrier Transport at the Interface of 2-Dimensional Materials

Won Jong Yoo

SKKU Advance Institute of Nano Technology (SAINT), Sungkyunkwan University, 2066 Seobu-ro, Jangan-gu, Suwon, 16419 Korea, (email) yoowj@skku.edu

Two dimensional (2D) materials are recently being investigated very intensively, with some of them holding great promise as semiconducting materials for future nano-electronics, beyond current Si technology which face hard limitation in performance enhancement due to excessive power dissipation during high frequency operation, as they present a range of achievable bandgaps and high electrical carrier mobility, and ultra-thin body with efficient electrostatic control. These properties, combined with mechanical flexibility, enable 2D materials to be very promising candidates that can meet major requirements for electronic and photonic devices operated in emerging future mobile and IoT environment.

However, formation of proper electrical contacts to nanoscale 2D materials (e.g. transition metal dichalcogenides: TMDs) is becoming a major challenge in realizing the performance of the 2D material-based devices. According to recent studies, the observed two-terminal mobility in single-layer TMD devices is unexpectedly low [1], due to high contact resistance (R_c) induced between metal contact and TMDs. It is known that many 2D crystals are subjected to strong Fermi level pinning when they are in contact with metals. That is, the pinning is responsible for the observed high Schottky barrier height and high R_c. In this work, we investigate Schottky barrier heights at the interfaces [2] formed between mono- or bi-layer molybdenum dichalcogenides and Ti, Cr, Au, Pd. For MoS_2 and $MoTe_2$, by obtaining I – V characteristics for various temperatures. According to our results, it is interesting to find that the pinned energy level was located near the conduction band edge for MoS_2 whereas it was near the intrinsic level for $MoTe_2$.

Meanwhile, we explore the different metal MoS_2 contacts and investigate the charge carrier injection mechanisms and their transition from one to another across the interfacial barrier [3]. Low temperature measurements on MoS_2 field effect transistor are carried out and R_c as the function of temperature is studied. As the result, the obvious transition from thermionic emission at high temperature to quantum mechanically tunneling of charge carriers at low temperature along the junction is observed. Furthermore, at a low temperature, the nature of the tunneling behavior is spotted by the current-voltage dependency. Interestingly, direct tunneling at a low bias and Fowler-Nordheim tunneling at a high bias is realized for a Pd-MoS_2 contact due to the effective barrier shape modulation by biasing. However, at the same bias conditions only direct tunneling is observed for a Cr-MoS_2 contact.

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