Atomic scale STM/STS analysis on transition metal dichalcogenide heterostructures

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Transition-metal dichalcogenide layered materials, consisting of a transition-metal atomic layer sandwiched by two chalcogen atomic layers, have been attracting considerable attention because of their desirable physical properties for semiconductor devices, and a wide variety of pn junctions, which are essential building blocks for electronic and optoelectronic devices, have been realized using these atomically thin structures. Engineering the electronic/optical properties of semiconductors by using such heterojunctions has been a central concept in semiconductor science and technology. Here, we report the first scanning tunneling microscopy/spectroscopy (STM/STS) study on the electronic structures of a monolayer $WS_2/Mo_{1-x}W_xS_2$ heterojunction that provides a tunable band alignment[1]. Fig.1 shows a typical STM image of $Mo_{1-x}W_xS_2$ monolayer alloy with a triangular shape. Smaller bright triangular area inside monolayer is corresponds to $Mo_{1-x}W_xS_2$ which is surrounded by outer WS_2. Fig.2 shows the empty state STM image (Vs = +1.35V) around $WS_2/Mo_{1-x}W_xS_2$ heterojunction interface. $Mo_{1-x}W_xS_2$ side appears brighter due to lower energy of conduction band minimum (E_{CBM}) of MoS2 compared to that of WS_2. Fig. 3 shows a map of dI/dV calculated from the spatially resolved STS measured across the interface. The upper and lower edges of the band gap region, corresponding respectively to E_{CBM} and E_{VBM}, continuously shifted as a function of the distance across the interface, whose position was determined from the STM image and is indicated by the dashed line. The result clearly demonstrates that a type-II staggered gap heterojunction with a nanoscale built-in potential distribution was formed at the interface

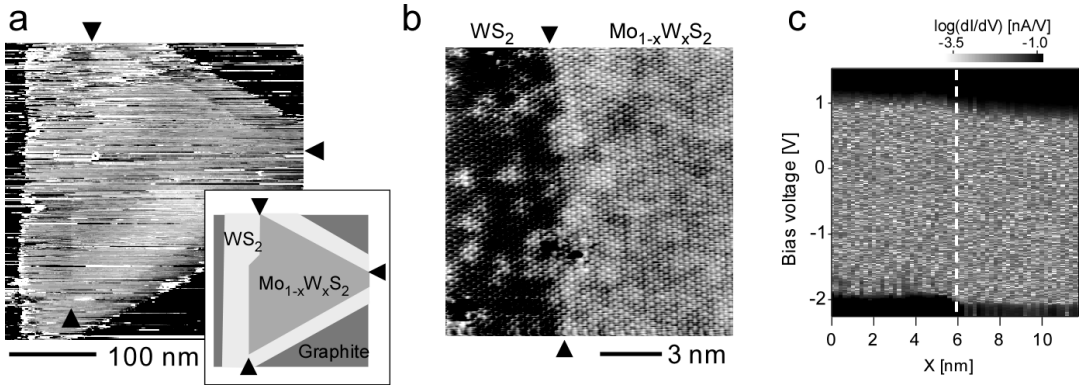

Fig a. STM image of a $WS_2/Mo_{1-x}W_xS_2$ monolayer on graphite b. Magnification of the part of the heterojunction interface c. dI/dV profile across the heterojunction interface

1. S.Yoshida, et al., Sci. Rep. 5, 14808 (2015)