ElectronicSupplementary Information

Spatially composition-modulated two-dimensional $WS_{2x}Se_{2(1-x)}$nanosheets

Xueping Wu,‡[a] Honglai Li,‡[a] Hongjun Liu,‡[a]Xiujuan Zhuang,[a] Xiao Wang,[a,c] Xiaopeng Fan,[a] Xidong Duan,[a] Xiaoli Zhu,[a] Qinglin Zhang,[a] Alfred J. Meixner,[c] Xiangfeng Duan,[b] and Anlian Pan*[a]

[a]Key Laboratory for Micro-Nano Physics and Technology of Hunan Province, School of Physics and Electronic Science, and State Key Laboratory of Chemo/Biosensing and Chemometrics, Hunan University, Changsha, Hunan 410082, P. R. China

[b]Department of Chemistry and Biochemistry and California Nano Systems Institute, University of California at Los Angeles, Los Angeles, California 90095, United States

[c]Institute of Physical and Theoretical Chemistry and LISA+, University of Tübingen, Auf der Morgenstelle 18, 72076 Tübingen, Germany

*Corresponding authors:anlian.pan@hnu.edu.cn

Experimental details

To synthesize the atomic layered composition modulated$WS_{2x}Se_{2(1-x)}$nanosheets and WS_2-$WS_{2x}Se_{2(1-x)}$heterostructures, an alumina boat loaded with WS_2 powder was placed into the heating zone of a slender quartz tube (inner diameter 22 mm, length 100 cm) and another boat loaded with selenium powder was placed at the upstream about 28.5 cm and far enough from the center of the furnace, with a quartz rod driven by a step motor through magnetic force to shift during the growth(Figure S1). A long (3 cm) piece of Si substrate (with 300 nm SiO_2) wasplaced in the downstream of the furnace to collect the deposited samples. Before heating, an Ar gas flow was introduced into the system for 10 min in order to eliminate the air and then maintained the flow at 70 sccm. The furnace was then rapidly heated to 1100 °C in 35 min, and slowly heated to 1150°C in 5 min. After keeping thegrowth at this temperature for several minutes, the furnace was then cooled down to room temperature naturally.In order to grow single-way composition-modulated$WS_{2x}Se_{2(1-x)}$, the Se powder was then shifted downstream (toward the furnace center) slowly by a motor from roomtemperature area to the region (250-350℃) for the evaporation at 35 min, and the heating temperature of Se source always increasing until the furnacebegin cooled. To synthesize both-way composition grated $WS_{2x}Se_{2(1-x)}$nanosheets, the Se powder was first shifted downstream (toward the furnace center) slowlyby a motor from roomtemperature area to the region (250-350℃) for the evaporation at 35 min, then shifted upstream slowly to roomtemperature area at 43 to 48 min.To synthesize WS_2-$WS_{2x}Se_{2(1-x)}$heterostructures, the Se powder was shifted downstream rapidly from roomtemperature area to the region (～350 °C) for the evaporationat 45 min.

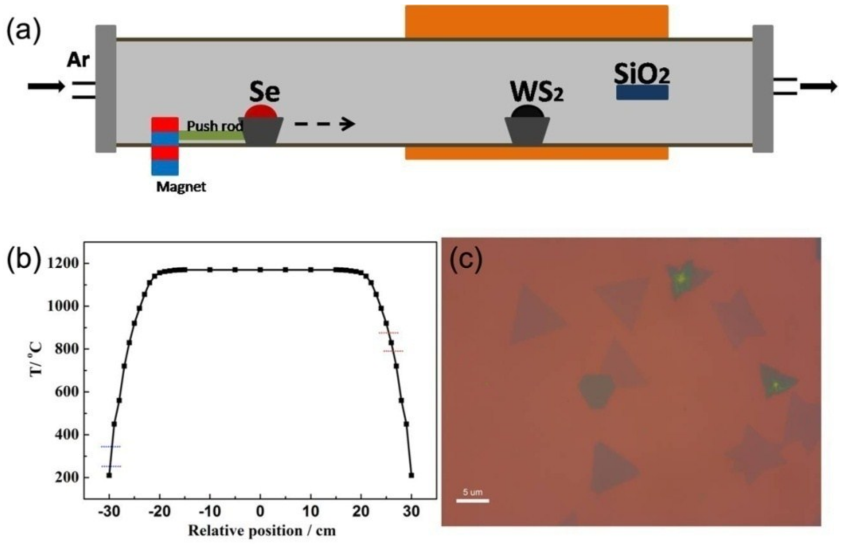

Fig.S1(a) CVD setup for the growth of the composition modulatedmonosheets. (b) The temperature profile along the growth tube. The blue dashed lines indicate the evaporation of the selenium source area and the red dashed lines indicate the growth zone region. (c) Optical image of a general view of the obtained sample.

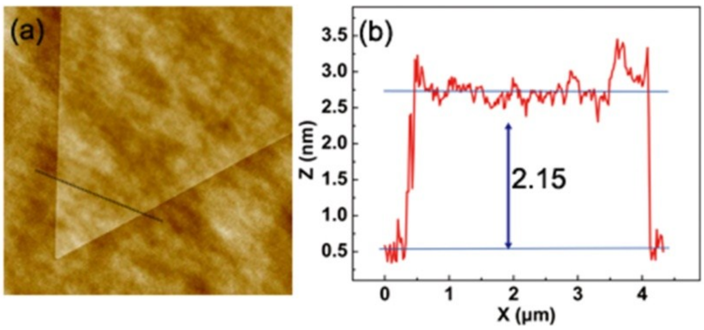

Fig. S2(a and b) AFM image of a typically single-way composition graded $WS_{2(1-x)}Se_{2x}$and its section analysis along the dashed line. The grown nanosheet has a uniform thickness of 2.15 nm, which is the height of trilayer WS_2.

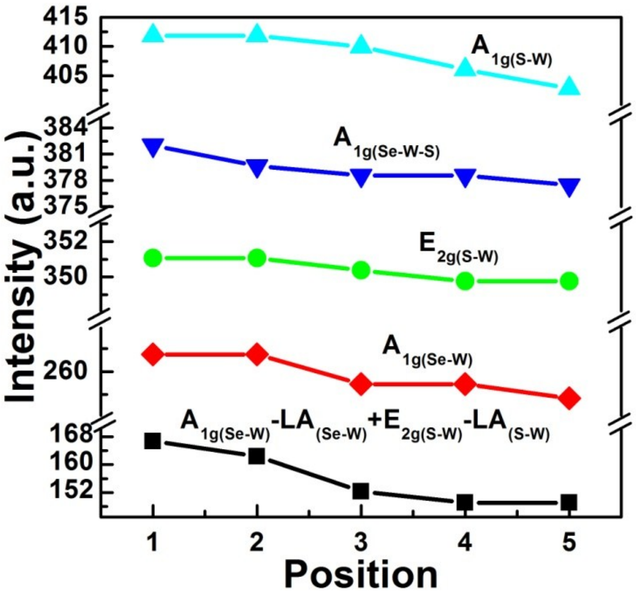

Fig.S3 The Raman modes shift with the positions along the nanosheet at figure 2(a).

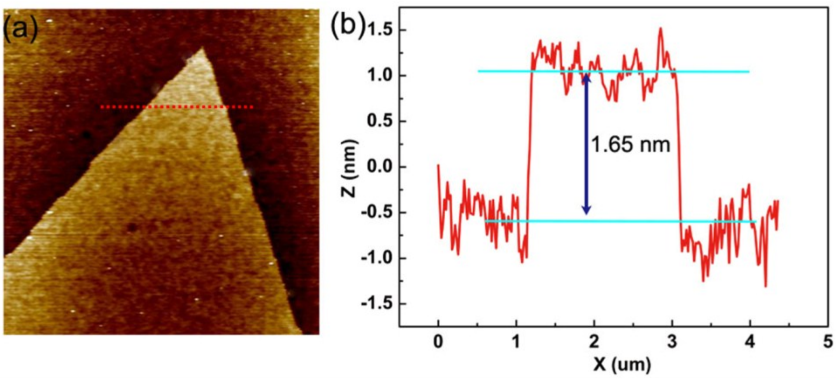

Fig. S4(a and b) AFM image of a typically both-way composition graded $WS_{2(1-x)}Se_{2x}$ and its section analysis along the red dashed line. The grown nanosheet has a uniform thickness of 1.65 nm, which is the height of bilayer WS_2.

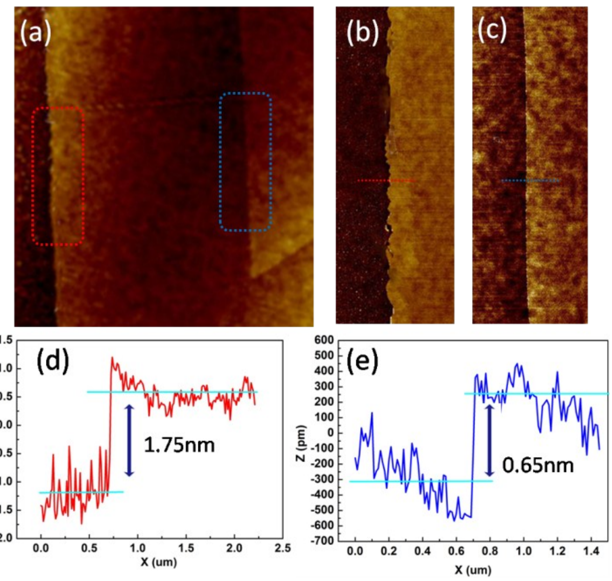

Fig. S5(a) AFM image of a typically WS_2-$WS_{2x}Se_{2(1-x)}$heterostructure.(b and c) AFM images ofedge (the red area in Fig. S3 (a)) and centre(the blue area in Fig. S3 (a)) area, respectively. (d and e) line profiles along the red dashed line in Fig. S3 (b) and the blue dashed line in in Fig.S3 (c), respectively.The thickness of the edge and centre are 1.75 nm and 2.4nm, which means the thickness of edge is bilayer and the thickness of centre is trilayer.

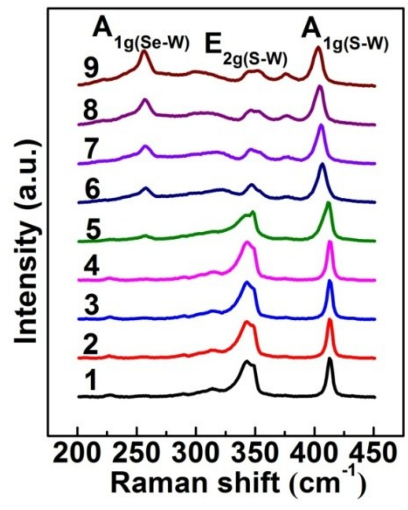

Fig.S6 Position-dependent micro-Raman spectra of a lateral composition graded $WS_{2x}Se_{2(1-x)}$nanosheet in figure 5a.