Supporting Information

Growth of wafer-scale MoS_2 monolayer by magnetron sputtering

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Synthesis of atomically thin MoS_2 layers: A schematic setup for synthesizing the MoS_2 atomic layers is illustrated in Fig. S1. The MoS_2 films are grown at high temperatures (> 700 ^{o}C) using Mo metal target sputtered in vaporized sulfur ambient. Sulfur was vaporized using heating tape wrapping around the sulfur container before leaking into the chamber. The base pressure of the chamber was 3×10^{-7} mbar. The Argon pressure was fixed at 6.0×10^{-4} mbar and the sputtering power was as low as 6 W. At this low power, the growth rate was extremely low so as to achieve mono- to few-layers growth. The layer number of the resulting MoS_2 films can be controlled by tuning the sputtering power and deposition time. SiO_2/Si and *c*-plane sapphire (Al_2O_3) were used as substrates. They were pre-cleaned using H_2SO_4, acetone, and deionized (DI) water in an ultrasonic bath prior to loading into the deposition chamber and pre-heated at 700 ^{o}C before the growth.

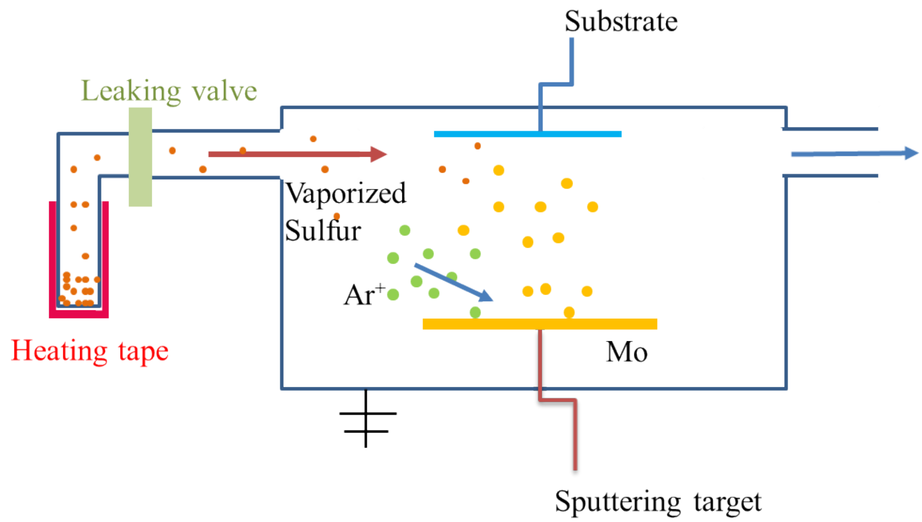

Fig. S1. Schematic drawing of the growth setup.

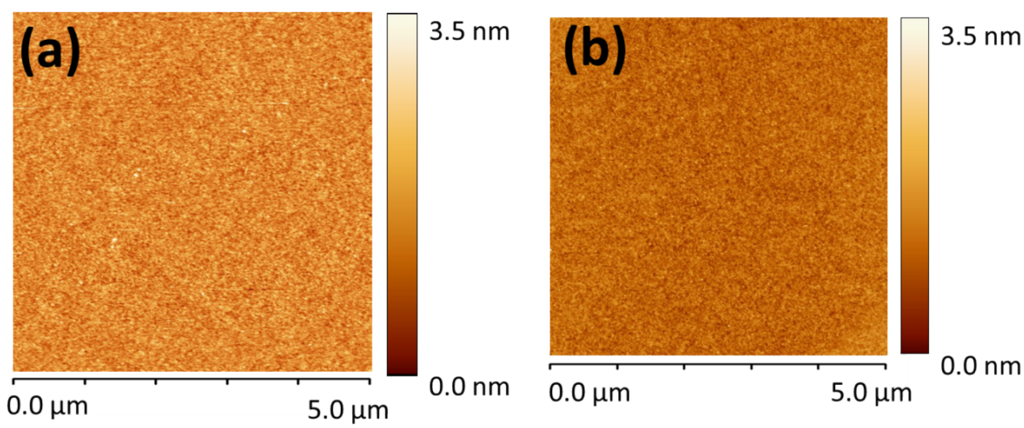

Fig. S2. AFM image of the (a) as-growth bilayer (2L) and (b) trilayer (3L) MoS_2 films. The root-mean-square (RMS) roughness is 0.31 nm and 0.28 nm, respectively.

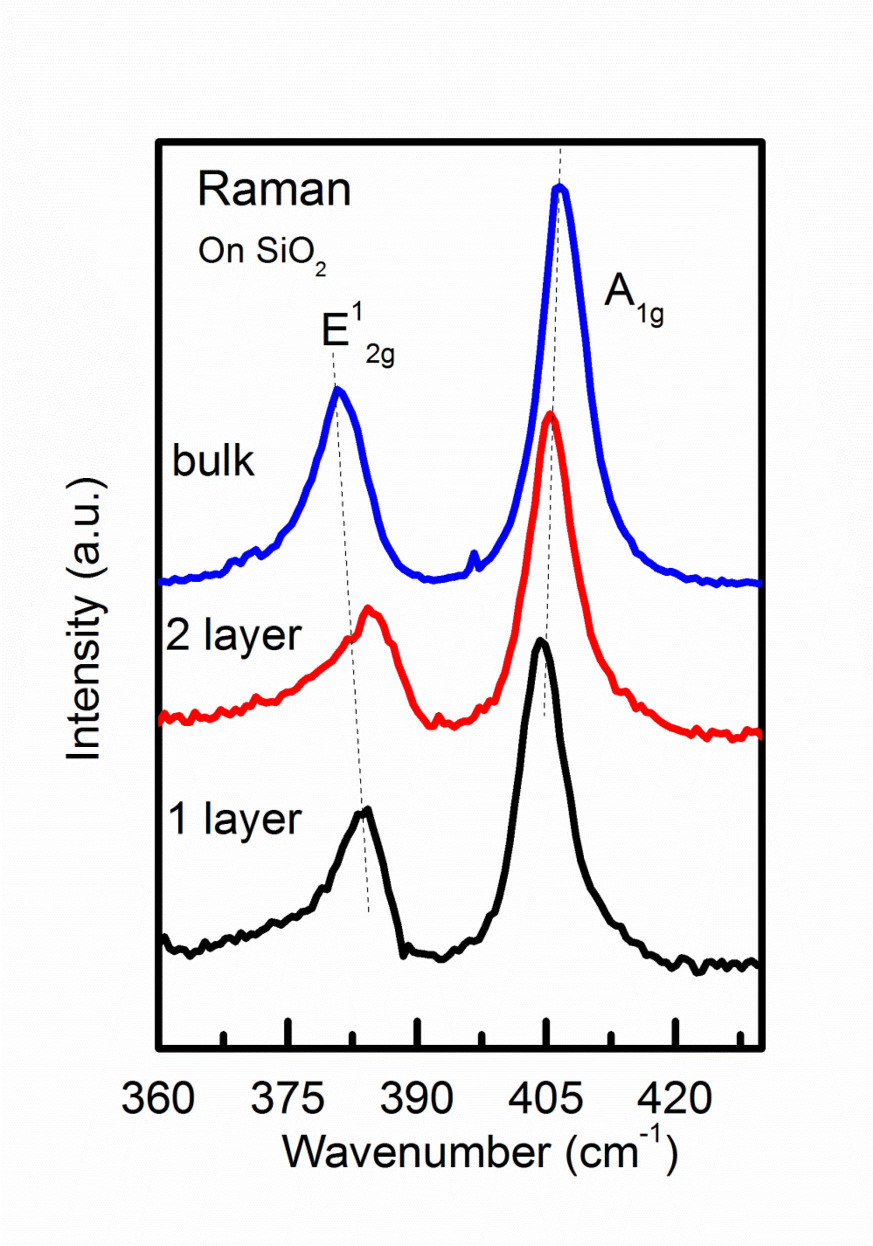

Fig. S3. Development of Raman spectra with thickness of the as-grown MoS_2 on SiO_2/Si. The dashed line are drawn to guild the eyes to show the shift of the Raman peaks as a function of the layer thickness.

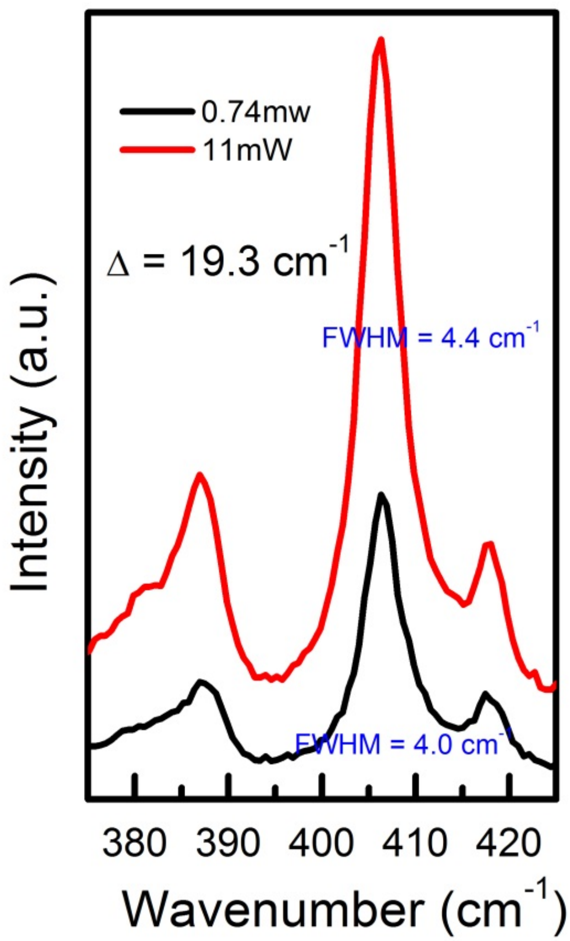

Fig. S4. Raman spectra of the as-grown MoS_2 on sapphire under different laser power. The full width at half maximum (FWHM) is 4.0 cm^{-1} and 4.4 cm^{-1} for 0.74 mW and 11 mW, respectively. The peak separation in both cases is 19.3 cm^{-1}, showing that the laser power does not affect the thickness assignment.

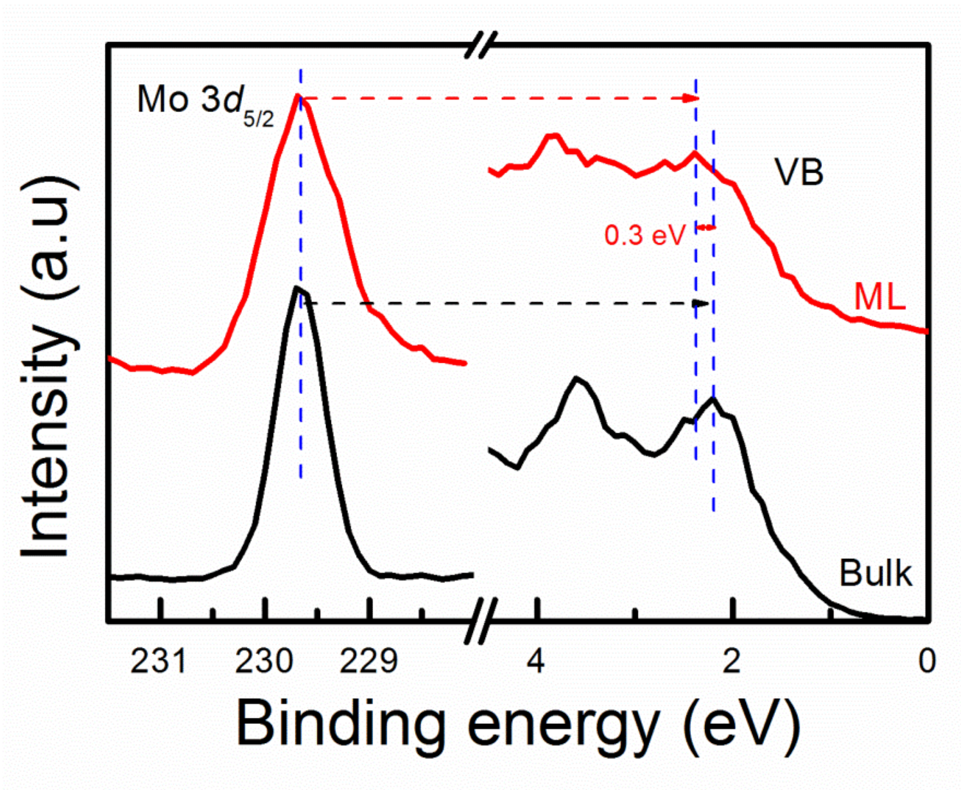

Fig. S5. The development of the Mo $3d_{5/2}$ and $4d_{z^2}$ peak with film thickness. The vertical dashed lines are drawn to highlight the binding energy difference between monolayer (ML) and bulk MoS_2.

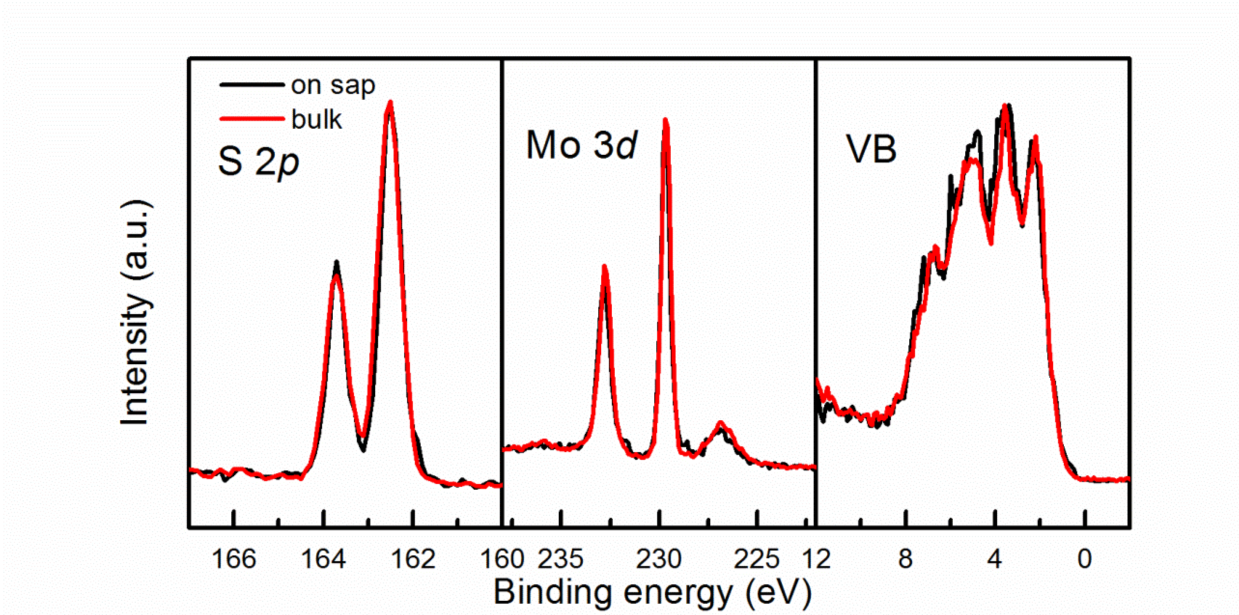

Fig. S6. Comparison of the XPS spectra of our synthesized thick MoS_2 film (black curves) with that of commercial bulk sample (red curves). The almost identical spectra indicate good crystalline quality of the synthesized film.