Electronic Supplementary Material (ESI) for Nanoscale.

Supporting Information for

Substrate modified thermal stability of mono- and few-layer MoS_2

Xuewen Wang[1,#], Wen Fan[2,#], Ziwei Fan[1], Wanyu Dai[1], Kunlei Zhu[1], Shengzhe Hong[1], Yufei Sun[1], Junqiao Wu[2], Kai Liu[1,]*

[1] State Key Laboratory of New Ceramics and Fine Processing, School of Materials Science and Enginnering, Beijing 100084, China

[2] Department of Materials Science and Engineering, University of California, Berkeley, California 94720, USA

* Corresponding author. E-mail: liuk@tsinghua.edu.cn

[#] These authors contributed equally to this work.

1. Experimental setup for thermal annealing

The exfoliated MoS_2 flakes on different substrates (mica, SiO_2/Si. Al_2O_3) were pushed into the thermostatic zone of a quartz tube, heated to 250, 270, 290 and 300 °C at a rate of 20 °C /min , and then held for 15 minutes before opening the lid to cool. See the methods for details.

Fig. S1 Schematic diagrams of the thermal annealing equipment setup.

2. Evidence of the presence of MoO_3 particles after thermal annealing

Comparing Fig. S2a and Fig. S2b, it was found that part of the bilayer region was thinned into a monolayer after thermal annealing at 290 °C. Meanwhile, particles appeared in the thinned area, as shown in Fig.S2c. These particles were most likely to be MoO_3.

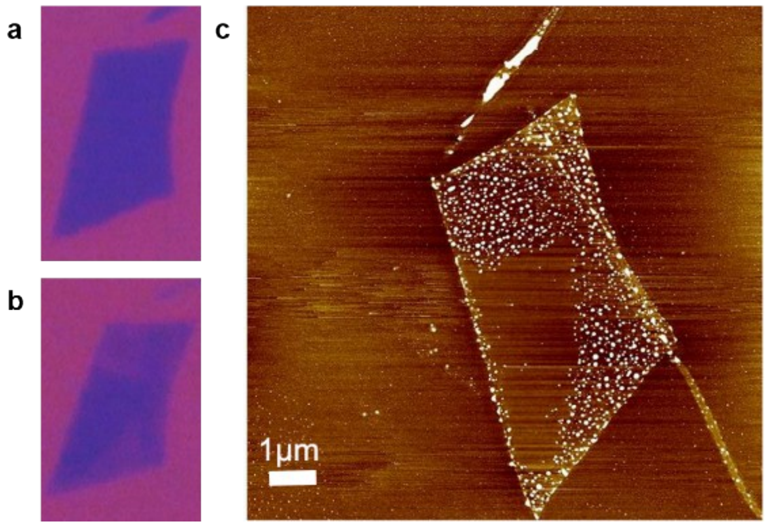

Fig. S2 MoO_3 particles on SiO_2 substrate after thermal annealing. Optical images of a bilayer MoS_2 before **(a)** and after **(b)** annealed at 290 °C under 10 kPa pressure. **(c)** AFM topography image after the annealing at 290 °C.

3. Method of calculating the length of etching

Equation s1.1 shows the calculation of the average length of etched triangles, where L1, L2 and L3 represent the three side lengths of a triangle. Fig. S3 specifically describes the measurement of one of the triangles.

$$L = \frac{\{(L_1 + L_2 + L_3)_1 + (L_1 + L_2 + L_3)_2 + \ ... + (L_1 + L_2 + L_3)_N\}}{3N} \qquad (s\ 1.1)$$

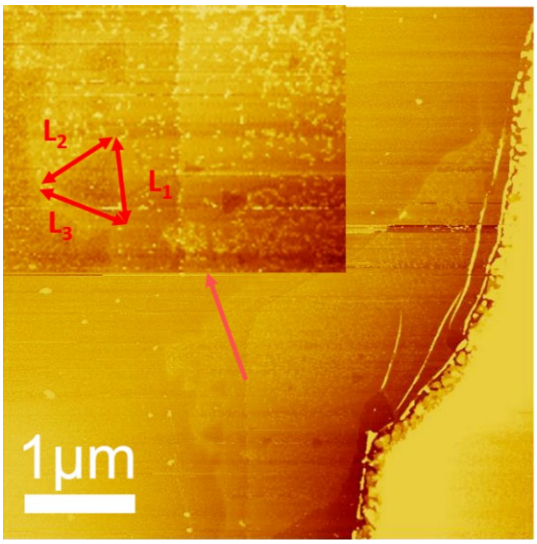

Fig. S3 The calculation of average triangle length.

4. Etching of MoS_2 flakes on mica substrate

Fig. S4a and S4b are microscopic images of MoS_2 flakes on mica before and after thermal annealing. After annealed at 270°C, many etched triangular pitches appeared on the monolayer MoS_2, while the bilayer and multilayers MoS_2 remained less changed. Fig. S4c shows an AFM image of Fig. S4b, emphasizing the different etching behaviors between monolayer MoS_2 and multilayer MoS_2.

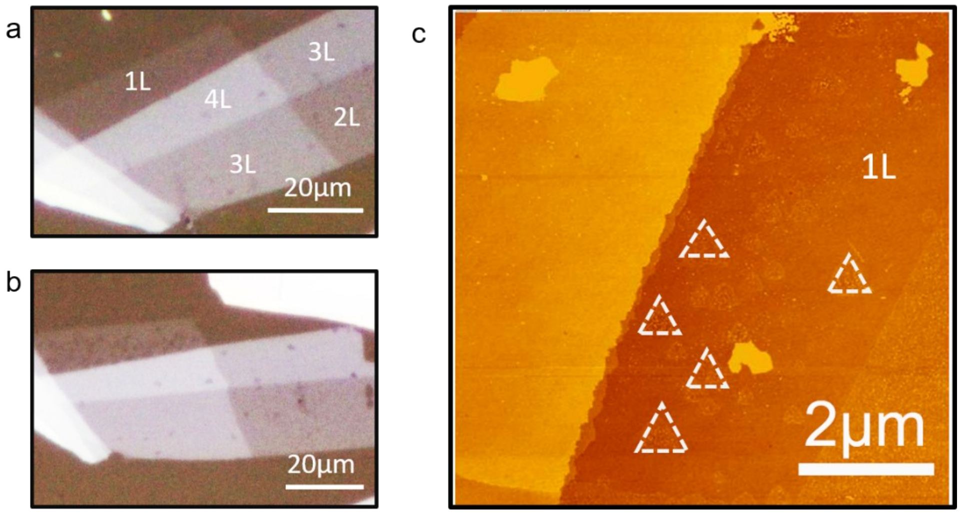

Fig. S4 Opical images of MoS_2 on mica before **(a)** and after **(b)** annealed at 270 °C at 10 kPa pressure. **(c)** AFM topography image of MoS_2 on mica after annealed at 270 °C at 10 kPa pressure.

5. Thicknesses of monolayer MoS_2 on different substrates

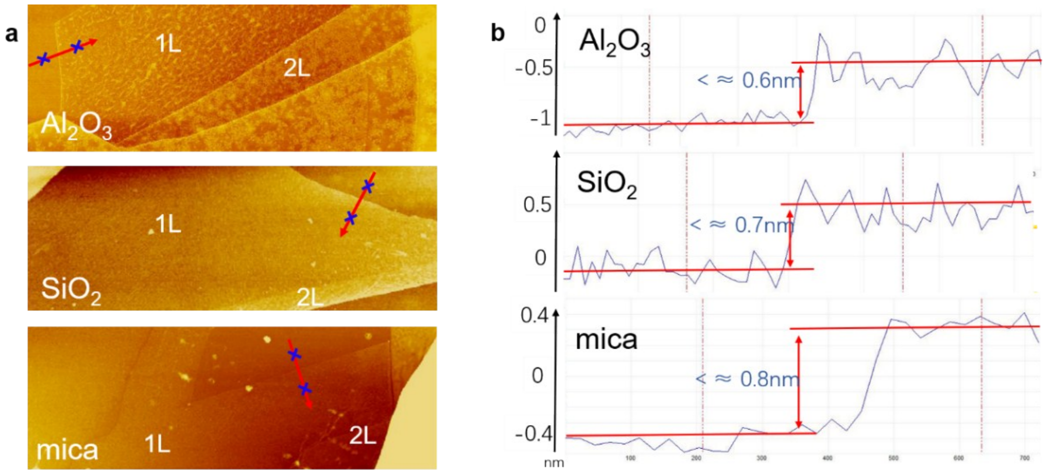

Fig. S5 (a) AFM images and **(b)** height scanning curves of the monolayer MoS_2 on Al_2O_3, SiO_2 and mica substrates.

6. Determination of mica surface crystal orientation and composition

Referring to Fig. S6a, after comparison with the standard card, the mica we used was found to have a monoclinic crystalline structure, and the normal crystalline orientation is along the <001> direction. Fig. S6c shows the XPS spectra of mica, with a detailed analysis of each peak; the content of each element in mica can be semi-quantitatively determined. Its chemical formula can be written as KAl_2 $[AlSi_3O_{10}]$ $[OH]_2$.

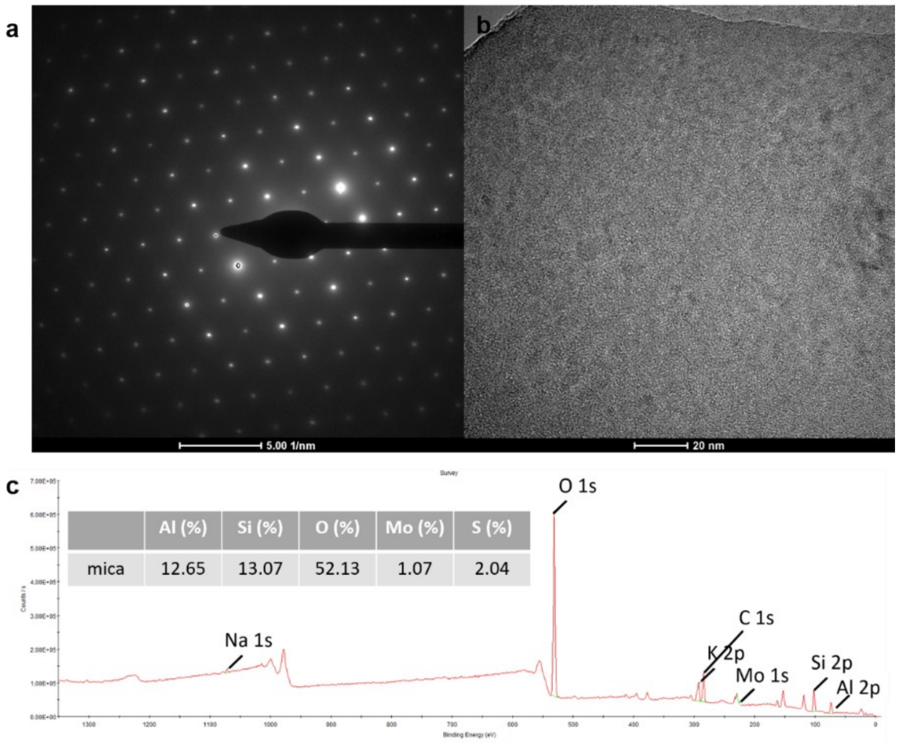

Fig S6 (a) Diffraction image and **(b)** SEM image of mica, demonstrating a monoclinic crystal of space group C2 with a (001) crystal plane, whose orientation is in the <001> direction perpendicular to the crystal plane. **(c)** XPS measurement showed that the chemical formula of the mica used is KAl_2 $[AlSi_3O_{10}]$ $[OH]_2$.

7. Schematic of mica crystal surface

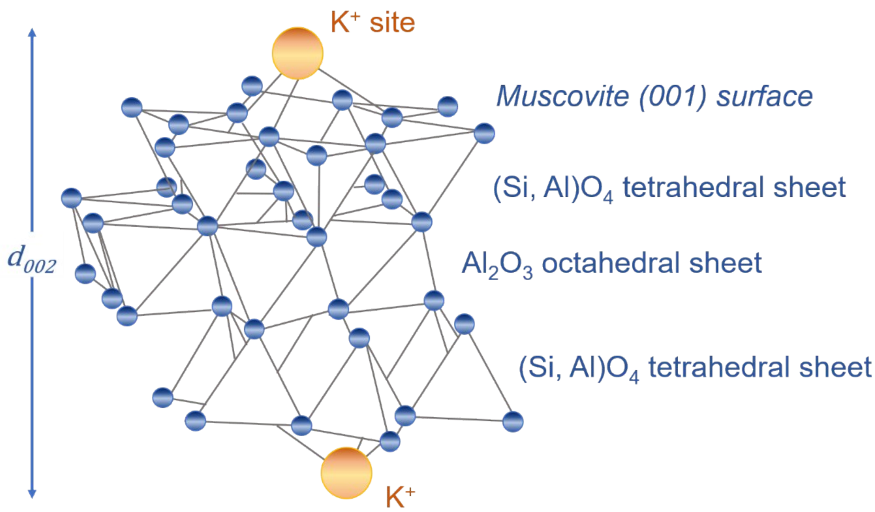

Fig. S7 A schematic showing mica crystal (001) surface structure (referring to Cheng, et.al, Ref. 45 in the maintext).

8. Thermal etching of MoS_2 grown by chemical vapor deposition (CVD)

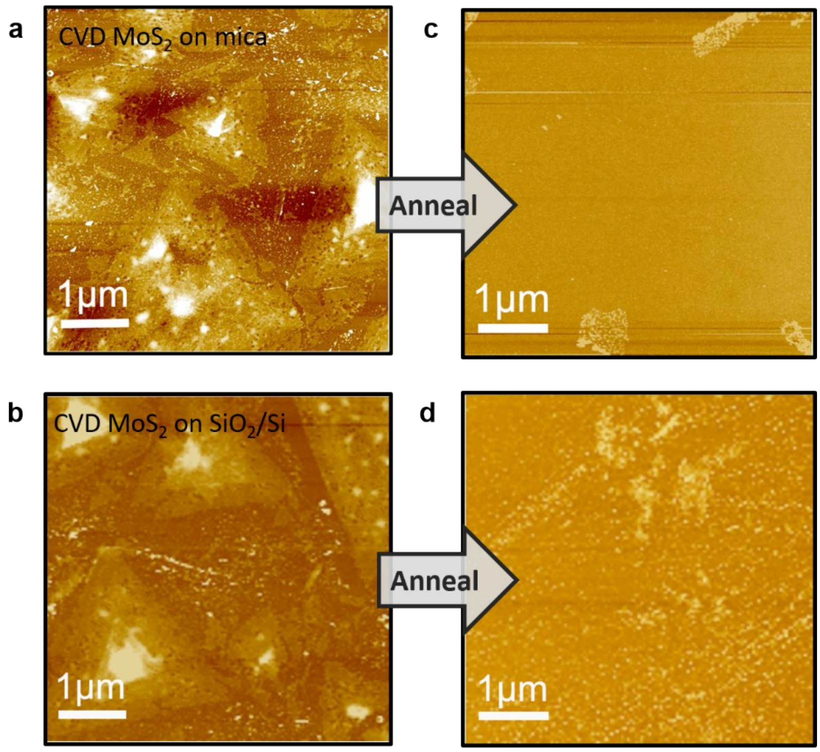

Fig. S8 AFM topography images of CVD monolayer MoS_2, which were originally grown on a SiO_2/Si substrate and then transferred to mica **(a)** and SiO_2/Si **(b)** substrates. After annealed at 240°C for 15min at atmospheric pressure, the monolayer MoS_2 flakes were almost completely etched both on mica **(c)** and on SiO_2/Si **(d)** substrates.