Chemical vapor deposition merges MoS_2 grains into high-quality and centimeter-scale films on Si/SiO_2

Mukesh Singh[a], Rapti Ghosh[b,c,d], Yu-Siang Chen[c], Zhi-Long Yen[a], Mario Hofmann[a], Yang-Fang Chen[a] and Ya-Ping Hsieh[c,d†]

[a]Department of Physics, National Taiwan University, Taipei 106, Taiwan

[b]Department of Physics, National Central University, Chung Li 320, Taiwan

[c]Institute of Atomic and Molecular Sciences, Academia Sinica, Taipei 115, Taiwan

[d]Molecular Science and Technology, Taiwan International Graduate Program, Academia Sinica, Taipei 115, Taiwan

[†]Correspondence to: yphsieh@gate.sinica.edu.tw (Ya-Ping Hsieh)

Supplementary data S1: Uniformity of the in-situ O_2-processed continuous MoS_2 films

Uniformity of the MoS_2 films was measured using AFM and it showed ~1 – 2 nm thickness. Figure 1 represents the AFM images of different oxygen-assisted MoS_2 samples and its surface height profile, which confirms about the reproducibility as well as large area uniformity. To confirm the large area uniformity of the film thickness, we have measured the thickness at several locations (~ 10 places) using AFM and all measurements show the same result of ~ 1 – 2 nm. (Here, we have shown the AFM image and corresponding surface height profile of a few places.) These results show that films are quite uniform in large area.

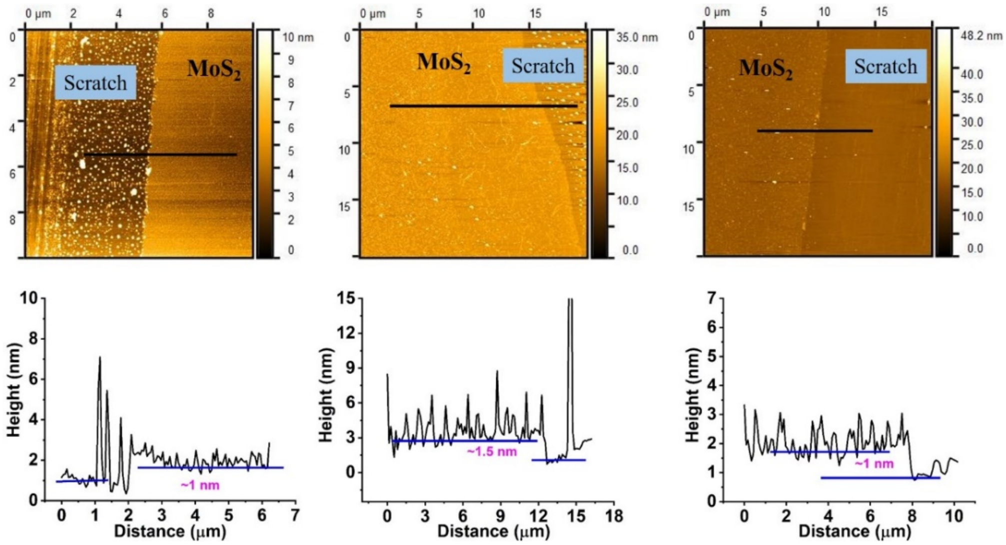

Figure 1: AFM images of different oxygen-assisted MoS_2 films and its surface height profile, which confirms about the reproducibility as well as large area uniformity.

Supplementary data S2: Transistor device fabrication on Si/SiO_2

Field effect transistor devices were fabricated on Si/SiO_2 (90 nm) using photolithography followed by thermal evaporation of Ti (3 nm) / Au (80 nm) for source and drain electrodes on top of MoS_2. Thermally grown 90 nm SiO_2 acts as gate dielectric and Si acts as gate electrode. The channel length of the device was 6 and 25 μm for the films processed without oxygen and in-situ oxygen samples respectively. After completion of lift-off process, devices were annealed in Ar environment at 200 ^{o}C for 2h, for removing the organic residue. All the measurements were performed in ambient condition.

Supplementary data S3: Responsivity data comparison for the two terminal co-planar geometry (in ambient condition)

Responsivity (A/W)	Wavelength and laser power	Area of devices (L/W)* (in μm)	Materials	References
1 at V_{ds} = 1.5 V	532 nm, 200 μW	A few micron / tens to 100 micron	CVD MoS_2	[1]
$1x10^{-3}$ at V_{ds} = 1V	405 nm, 100 μW	2 / 20	CVD MoS_2	[2]
59 at V_{ds} = 1.2 V	532 nm, $1.69x10^{-3}$ W/cm^2	5 / ~30	Exfoliated MoS_2	[3]
**780 at V_{ds} = 1V	532 nm, $1.3x10^{-4}$ W/cm^2	---	CVD MoS_2	[4]
$1.1x10^{6}$ at V_{ds} = 0.15V	460 nm, 0.33 pW	---	Exfoliated MoS_2	[5]
$1.1x10^{-3}$ at V_{ds}=1.5V	514.5 nm, 1 μW	0.8 / 5	CVD MoS_2	[6]
$0.42x10^{-3}$ at V_{ds}=1V	550 nm, 80 W/cm^2	2.1 / 2.6	Exfoliated MoS_2	[7]
7 at V_{ds}=1V	488 nm, 1 μW	---	CVD MoS_2	[8]
420 at V_{ds}=15V	532 nm, 10^{-5} W/cm^2	125 / 480	CVD MoS_2	**This work**

* L is channel length; W is channel width. ** V_g-V_{th} = 100V

CVD (Chemical Vapor Deposition)

Supplementary data S4: I-T curve of oxygen assisted MoS_2 thin films

For the stability of photosensor, I-T measurement were performed for 10 cycles with a laser power of $9.5x10^{-3}$ W/cm^2. A uniform sustainable of photocurrent for longer duration indicate that defect density in oxygen-assisted MoS_2 is decreased, as shown in figure 2. Due to decrease in trap states, a fast recovery time of the order of millisecond is observed. The rise and fall time are 350 ms and 310 ms respectively.

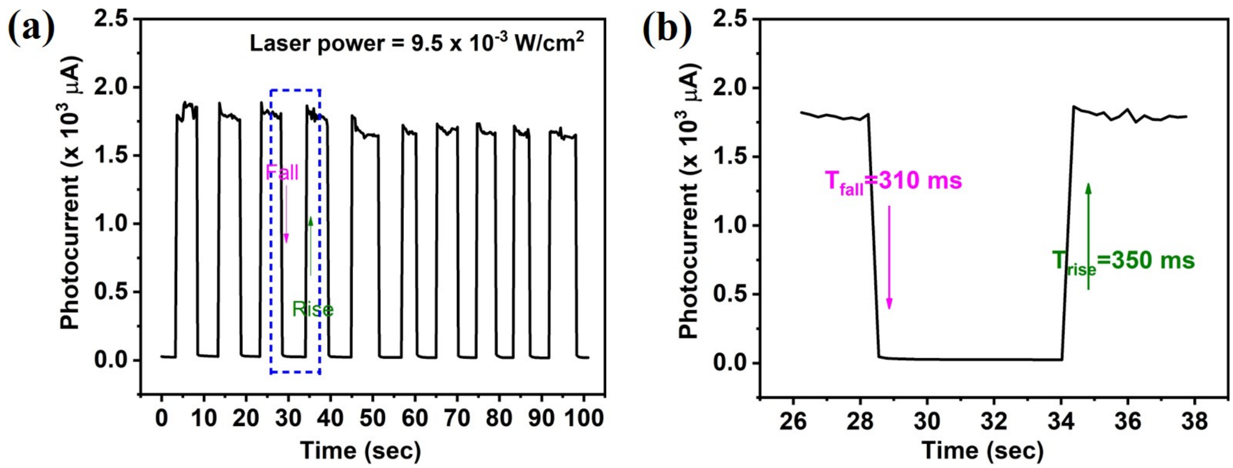

Figure 2: (a) I-T curve of oxygen assisted MoS2 thin films for 10 cycles at a fixed biasing of V_{ds} 15V and (b) is corresponding fall and rise time 310 ms and 350 ms respectively.

Supplementary data S5: Uniform wafer scale photosensitivity of MoS_2

Wafer scale continuous MoS_2 films were grown on Si/SiO_2 using 3-inch CVD system. Figure 3 represents the large scale growth of MoS_2 in centimetre dimensions and its photoluminescence histogram around the whole wafer. Photoluminescence of the sample were measured randomly in one direction from one end to another end with a step of 2 mm. The histogram of photoluminescence intensity shows almost uniform single layer MoS_2 films over the entire substrate. However, a small decrease in photoluminescence intensity is observed at the other end of the samples. This may be due to the bilayer MoS_2, which could be possible due to the concentration gradient of MoO_3 vapor in large area i.e. higher towards MoO_3 source and lower far away from the source.

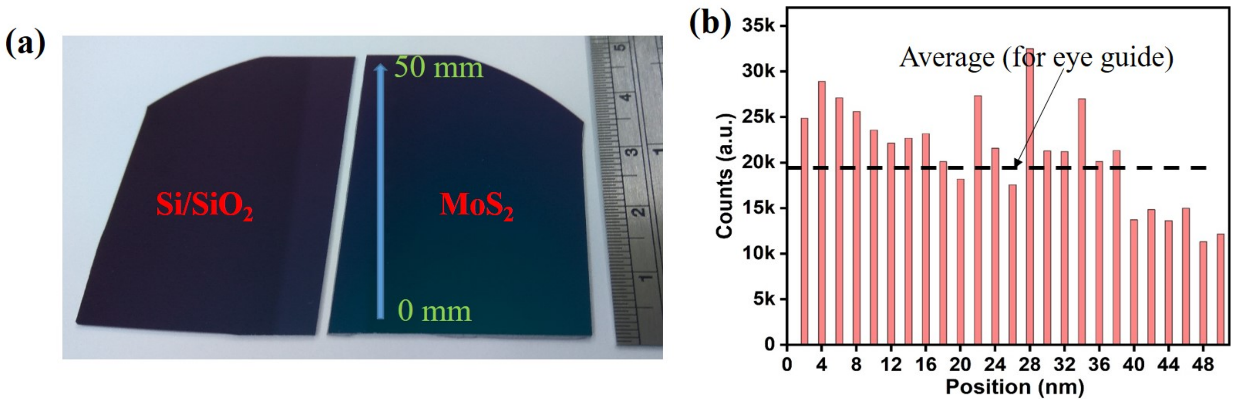

Figure 3: (a) Wafer scale continuous MoS_2 growth on Si/SiO_2 substrate (right side). A blank Si/SiO_2 substrate (left side) is shown here for the reference of contrast image. (b) Histogram of photoluminescence intensity measured on the wafer scale samples from one end to another end in one direction with 2 mm step. (Black dashed line is represented for eye guide only).

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