Electronic Supplementary Material (ESI) for Nanoscale.
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Supporting Information

for

Thickness-Dependent Mobility in Two-Dimensional MoS_2 Transistors

D. Lembke, A. Allain, A. Kis*

Electrical Engineering Institute, Ecole Polytechnique Federale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland

**Correspondence should be addressed to: Andras Kis, andras.kis@epfl.ch*

1. Device Characteristics

In the table below, the following device characteristics are specified: device label, number (#) of layers, SiO_2 substrate unpolished or polished, length (L), voltage probe spacing (L_{xx}), width (W), aspect ratio (L_{xx}/W) as well as MoS_2 area ($L_{xx}\cdot W$) exposed to ambient.

Label	#	Polished?	L [μm]	L_{xx} [μm]	W [μm]	L_{xx}/W	$L_{xx}\cdot W$ [μm^2]
130805 03 V	1	no	7.0	4.0	2.4	1.66	16.8
130807 26 II	1	yes	3.2	1.4	1.3	1.08	4.2
130808 28 VI	1	yes	6.1	3.7	2.4	1.54	14.6
130807 21 III	2	yes	2.9	1.0	2.4	0.42	7.0
130818 17 I	2	no	5.4	3.4	2.4	1.42	13.0
130819 31 II	2	no	3.8	1.4	2.4	0.58	9.1
130807 20 I	3	yes	4.2	1.8	1.3	1.38	5.5
130819 31 II	3	no	7.0	4.0	2.4	1.67	16.8

2. Conductance of All Devices

The evolution of four-probe conductance during the process of cleaning and exposing to ambient for all characterized devices as listed in Section 1.

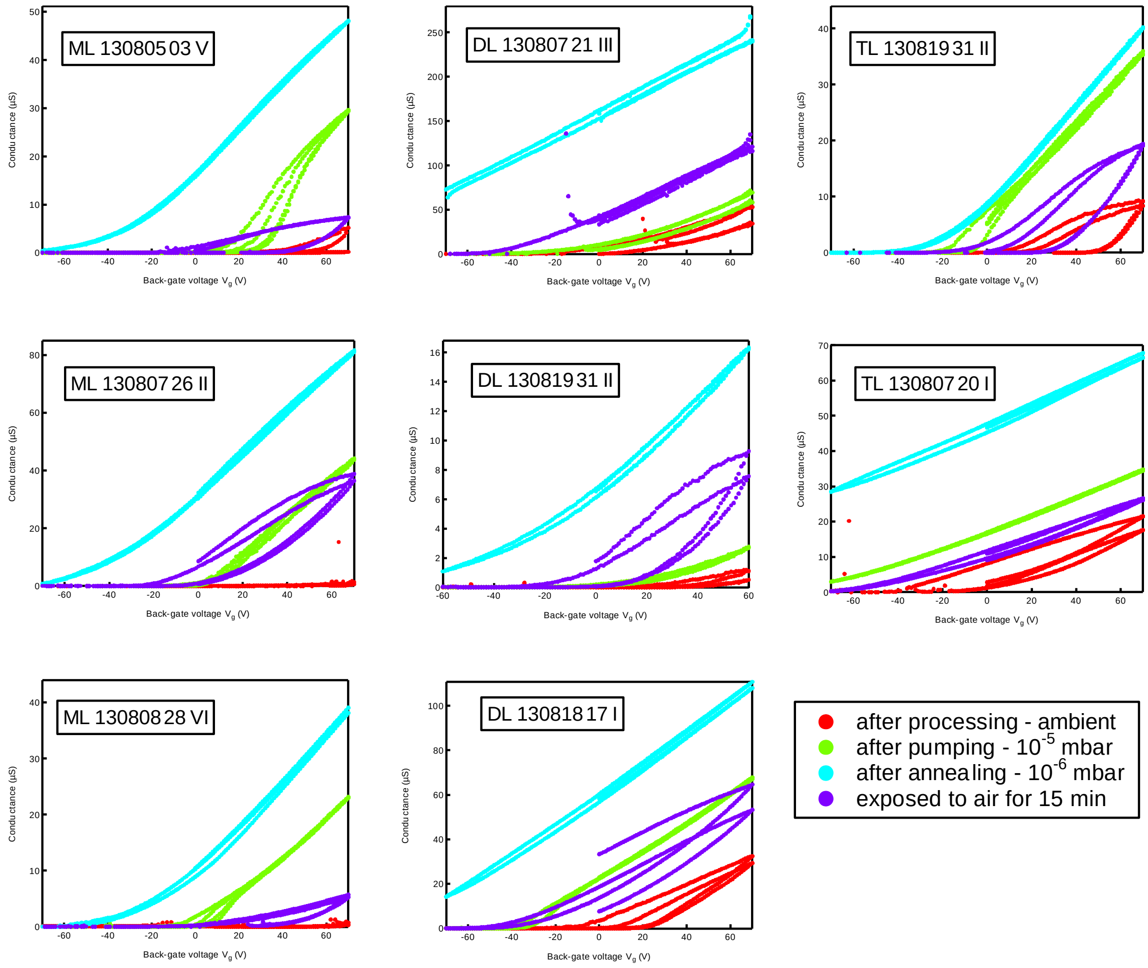

Figure SI 1. Evolution of four-probe conductance during the process of cleaning and exposing to ambient. The four shown steps are: right after fabrication in ambient (red), in vacuum (~ 1 x 10^{-5} mbar) before overnight annealing (green), in vacuum (~ 1 x 10^{-6} mbar) after overnight annealing (blue) at 120 °C and after ~ 15 minutes of exposure to ambient (purple).

3. Mobility of All Devices

The evolution of mobility during the process of cleaning and exposing to ambient for all characterized devices as listed in Section 1.

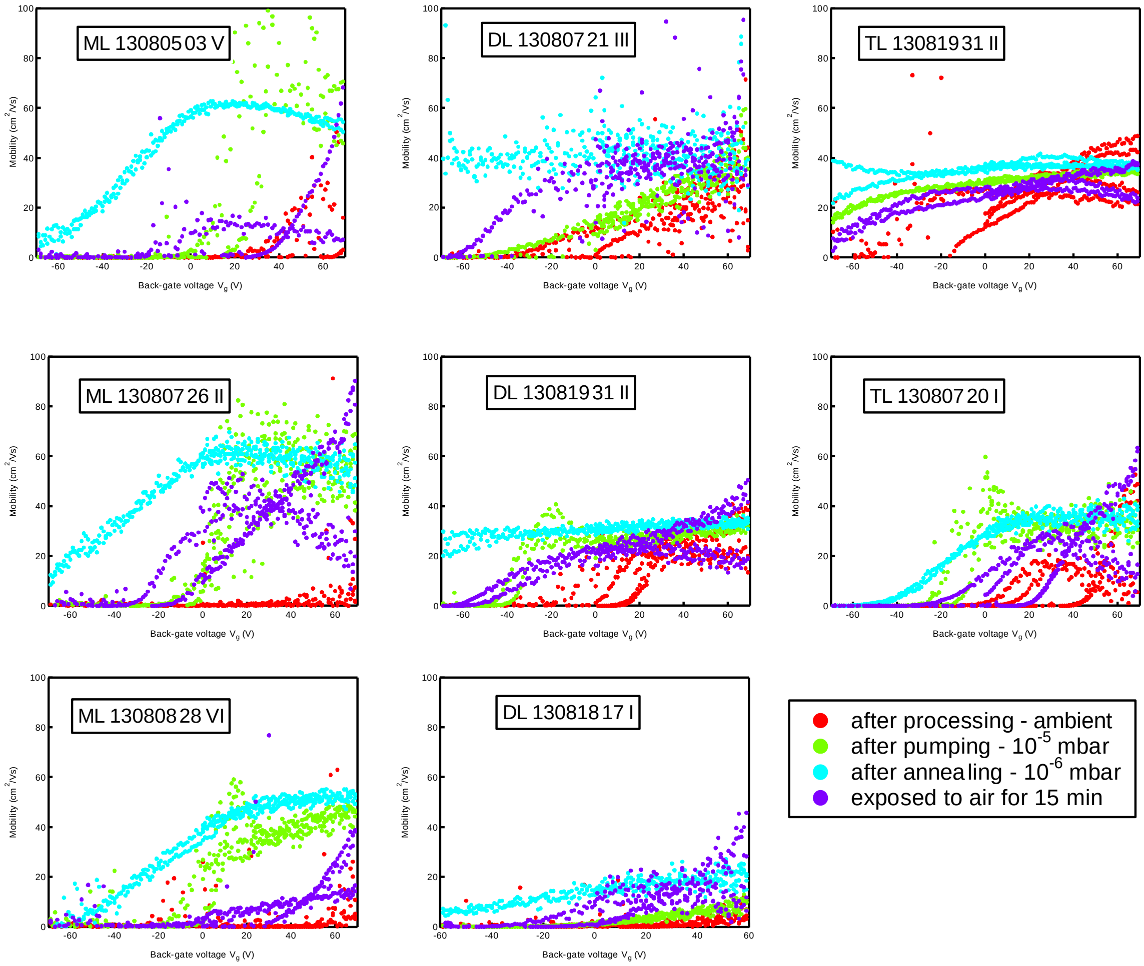

Figure SI 2. Evolution of mobility during the process of cleaning and exposing to ambient. The four shown steps are: right after fabrication in ambient (red), in vacuum (~ 1 x 10^{-5} mbar) before overnight annealing (green), in vacuum (~ 1 x 10^{-6} mbar) after overnight annealing (blue) at 120 °C and after ~ 15 minutes of exposure to ambient (purple).

4. Student t-Test

We perform a statistical t-test and formulate our null-hypothesis as: “The band mobility in monolayer devices is lower than in devices based on two and three layer thick MoS_2“. The test is based on the following statistics:

Label	#	μ_{band} [$cm^2 \cdot V^{-1}s^{-1}$]
130805 03 V	1	62.7
130807 26 II	1	61.2
130808 28 VI	1	52.8
130807 21 III	2	43.5
130818 17 I	2	19.6
130819 31 II	2	32.1
130807 20 I	3	35.4
130819 31 II	3	36.9

We deduce a mean value $\bar{x}_1$ of 58.9 $cm^2 \cdot V^{-1}s^{-1}$ for the monolayer FETs and $\bar{x}_2$ of 33.5 $cm^2 \cdot V^{-1}s^{-1}$ for FETs based on thicker layers. The standard deviations of our sample sets are $\bar{s}_1$ = 5.4 $cm^2 \cdot V^{-1}s^{-1}$ and $\bar{s}_2$ = 8.8 $cm^2 \cdot V^{-1}s^{-1}$, respectively. The t-value is given by

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}}}$$

The degree of freedom d.f. of this test is given by the Welch–Satterthwaite equation

$$d.f. = \frac{\left(\frac{s_1^2}{N_1} + \frac{s_2^2}{N_2}\right)^2}{\frac{\left(\frac{s_1^2}{N_1}\right)^2}{N_1 - 1} + \frac{\left(\frac{s_2^2}{N_2}\right)^2}{N_2 - 1}}$$

With this, we calculate a t-value of 5.1 and a d.f. of 5.9. By comparing these values with the theoretical z-score we can reject our initial hypothesis that the monolayer device has a lower mobility than thicker ones with a probability of error of less than 0.5%. In other words, we can say that the mobility of our monolayer MoS_2 devices is higher than the other devices with a confidence of at least 99.5%.

5. Ultra-flat SiO_2 Substrate

The SiO_2 substrate of ~half of the devices was intentionally chemically and mechanically polished by using a commercial CMP machine (Alpsitec E460) to establish an ultra-flat substrate prior to exfoliation. The polishing of SiO_2 results in an ultra-smooth substrate and the RMS value of the surface height can be reduced from a value of 230 pm in the unpolished SiO_2 to 119 pm in the polished surface.

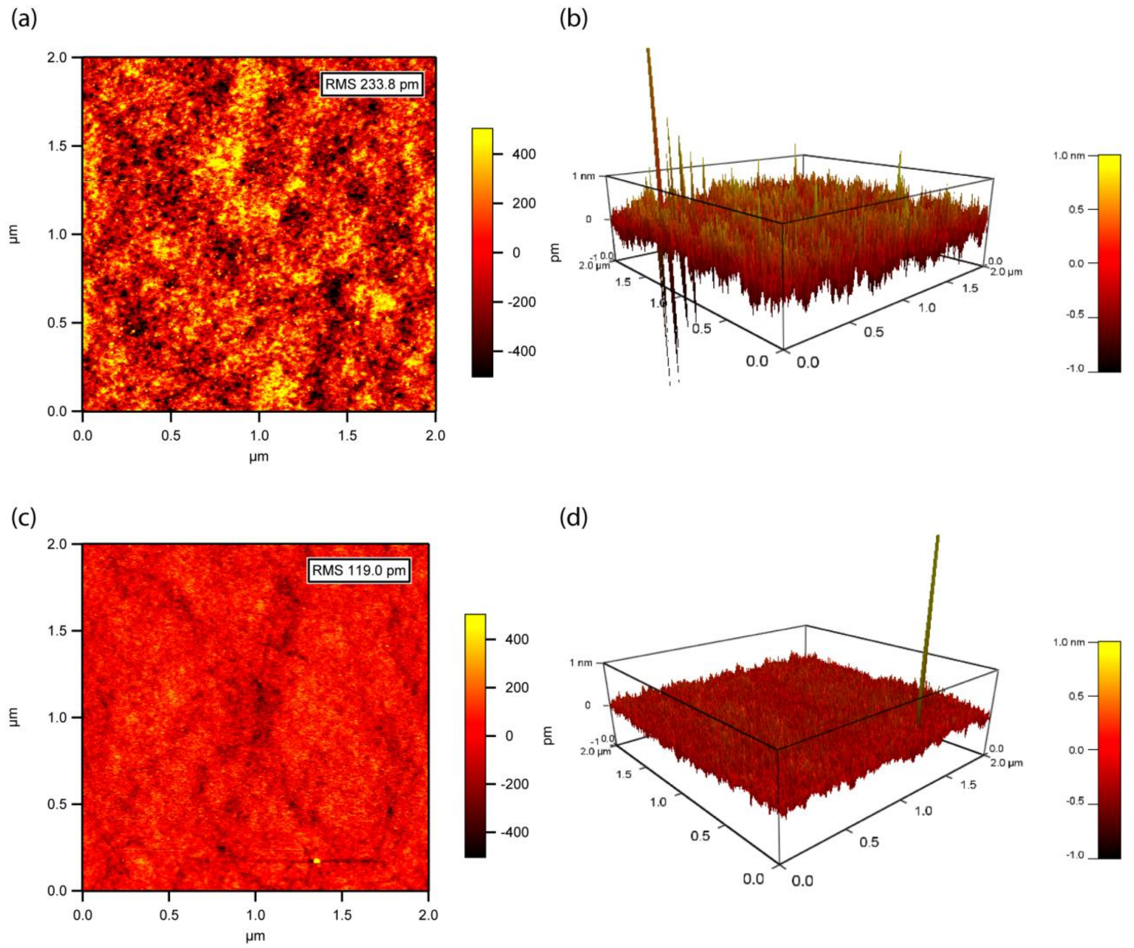

Figure SI 3. Morphology of the SiO_2 substrate. (a) AFM image (2 x 2 µm^2) of the unpolished SiO_2 surface. The RMS of this surface is 233.8 pm. (b) 3D representation of the image in (a). (c) AFM image (2 x 2 µm^2) of the polished SiO_2 surface after CMP treatment, exhibiting a RMS of 119.0 pm. (d) 3D representation of the image in (c).