

Electronic Supporting Information

Layer-modulated, wafer scale and continuous ultra-thin WS₂ films grown by RF sputtering via post deposition annealing

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KEYWORDS: WS₂, monolayer, RF sputtering, CVD, field effect transistor

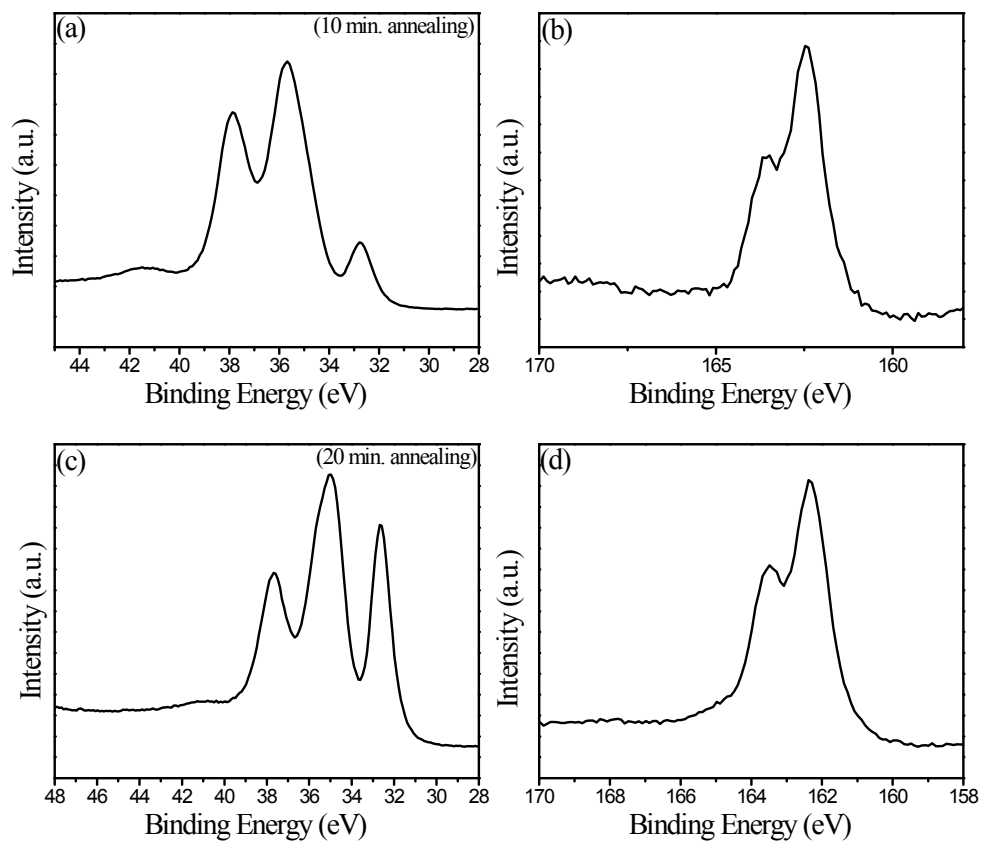


Figure S1 XPS spectra for W and S binding energy peaks of WS₂ films sulfurized at 10 and 20 minutes in sulfur and Ar environment at 650°C.

10 min	74.17	25.83
20 min	43.86	56.14
30 min	31.99	68.01

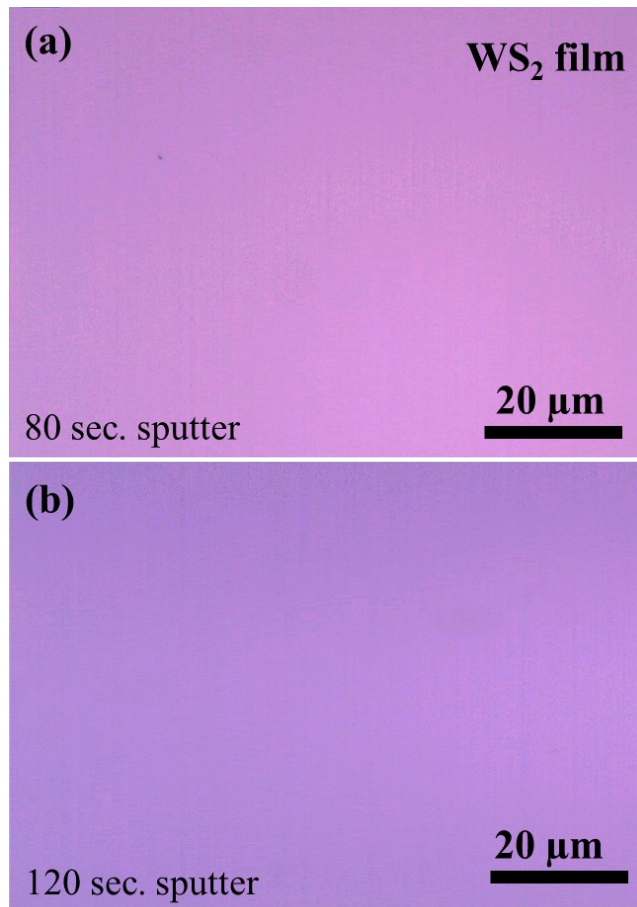


Figure S2. Low magnification optical images of WS₂ films deposited at RF sputtering time (a) 80 sec and (b) 120 sec.

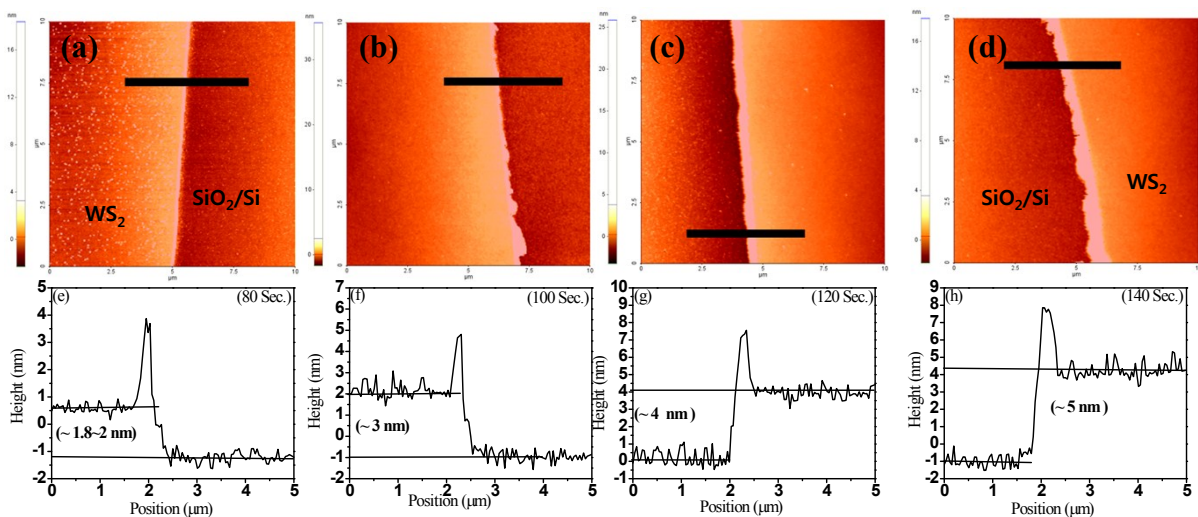


Figure S3 (a-d) AFM topographical images of WS₂ films prepared at different sputtering time such as 80, 100, 120 and 140 sec (few-layer); (e-h) step height profile variations of the corresponding WS₂ films.

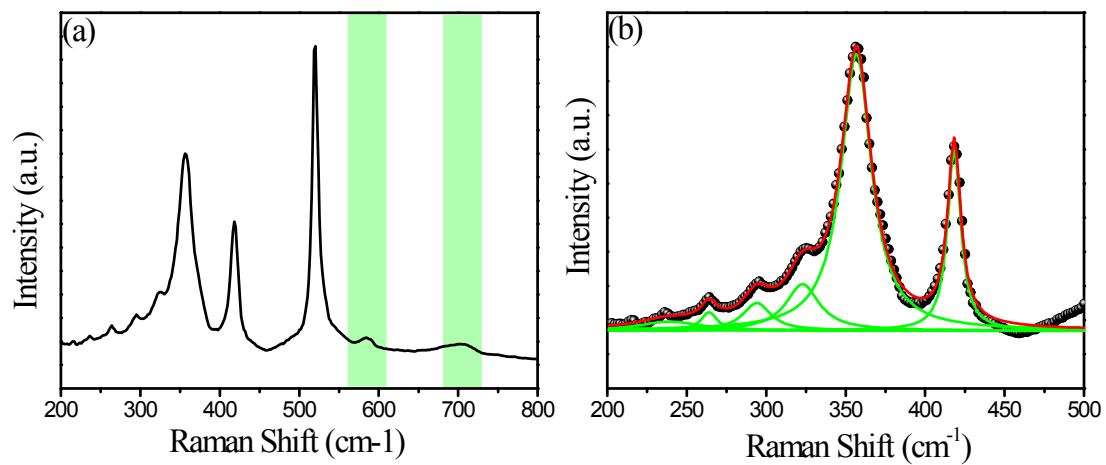


Figure S4 (a) Raman spectrum of WS₂ (80 sec-sputter) at room temperature; (b) Magnified spectra of fifteen Raman modes.

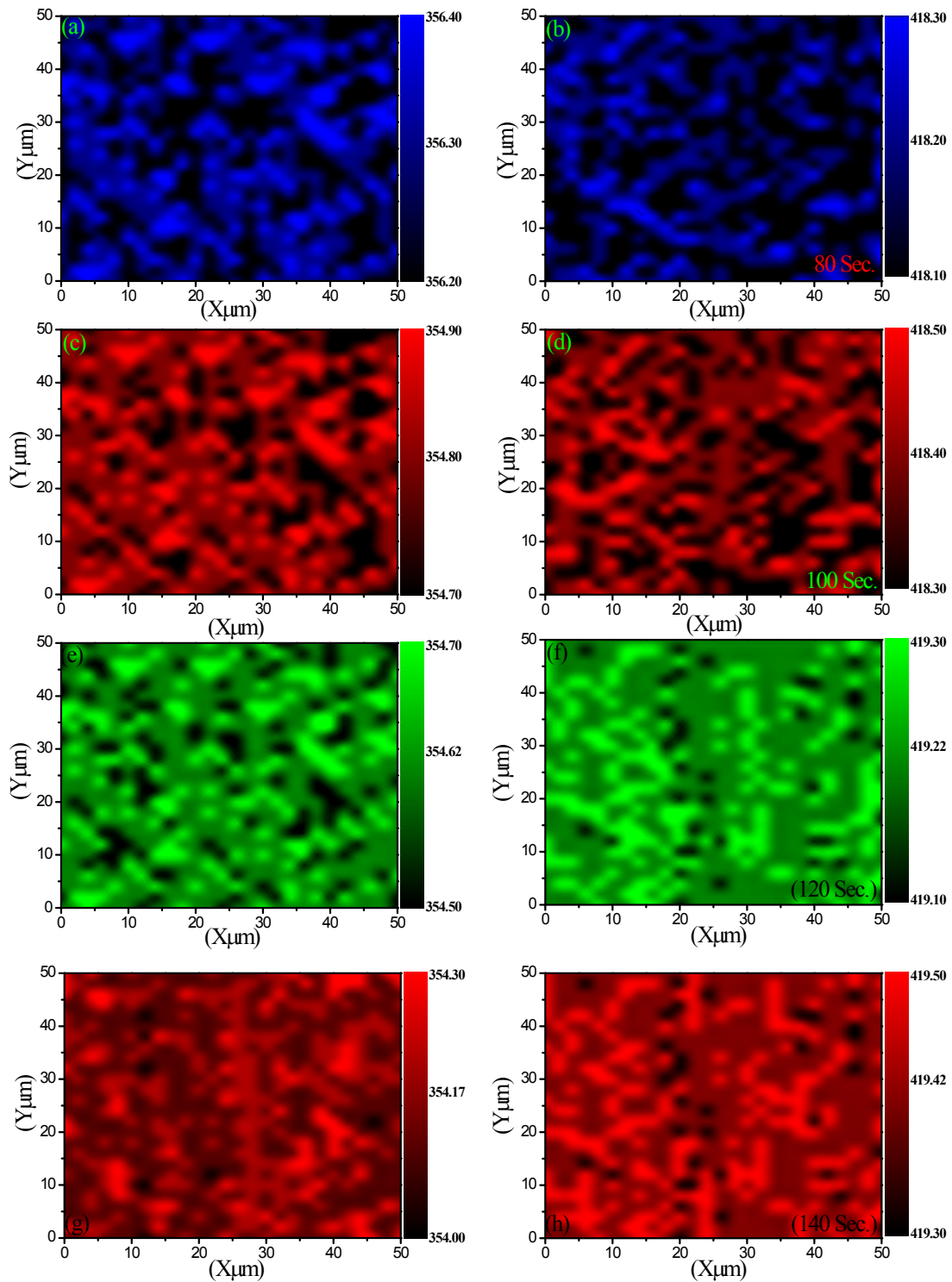


Figure S5. Raman mapping of E_{12g} and A_{1g} peak E_{12g} and A_{1g} peak (a,b) 80 sec (c,d) 100 sec. (e,f) 120sec, (g,h) 140 sec-sample

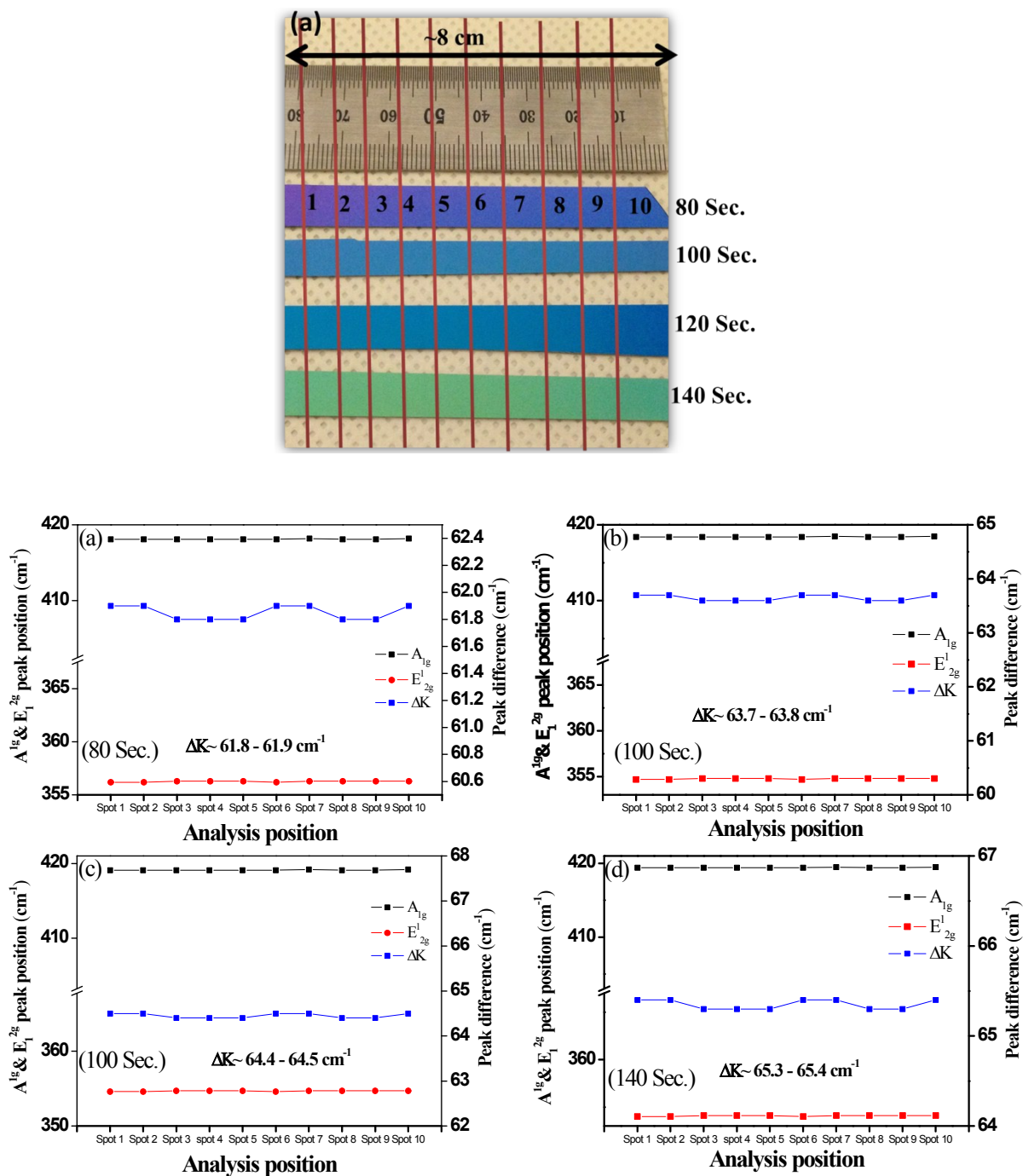


Figure S6 (a) Large-area (approximately 8 cm) 80, 100, 120, and 140 sec-sample, (b-e) relative Raman peak position of E_{12g}^1 and A_{1g} bands and the peak differences (ΔK) plotted as a function of numbered spot at ten measurement points.

Table S2 Statistical analysis of Raman mapping

		80 Sec.	100 Sec.	120 Sec.	140 Sec.
E_{2g}¹ mode	Average	356.285	354.8055	354.6032	354.1364
	Max.	356.4	354.9	354.7	354.3
	Min.	356.2	354.7	354.5	354
	Standard deviation	0.074613	0.060167	0.062914	0.06441
A_{1g} mode	Average	418.17	418.3905	419.2328	419.4316
	Max.	418.3	418.5	419.3	419.5
	Min.	418.1	418.3	419.1	419.3
	Standard deviation	0.072147	0.072299	0.051088	0.050672
Δ k	Average	61.8852	63.5852	64.6304	65.282
	Max.	62	63.8	64.8	65.4
	Min.	61.7	63.4	64.5	65.1
	Standard deviation	0.082024	0.087702	0.079883	0.085705

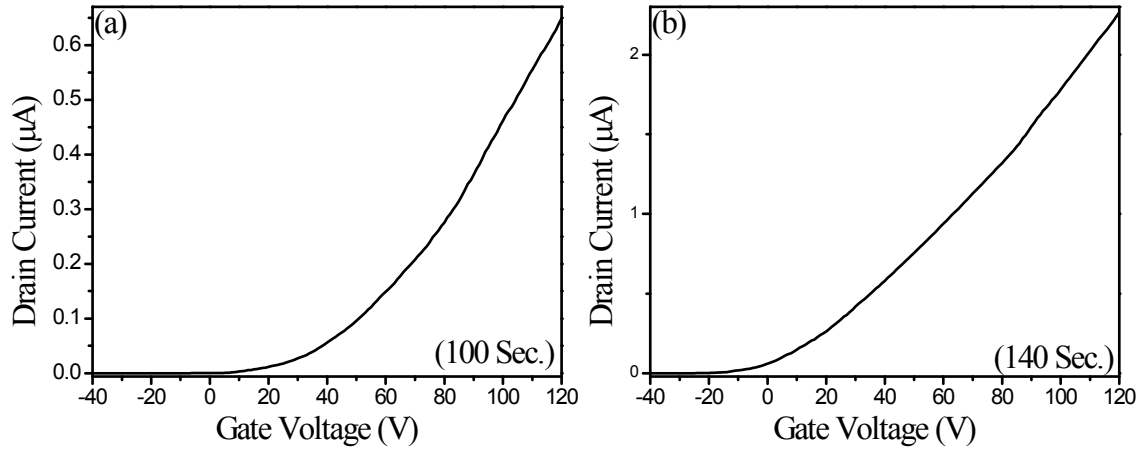


Figure S7. Linear I_{ds} - V_{bg} based FETs ($V_d = 1V$) of WS₂ (100 Sec. sputter) and (140 Sec. sputter) films. The extracted transconductances values of 100 and 140 Sec. sputter samples are 9.35×10^{-9} S and 2.26×10^{-8} S, respectively.

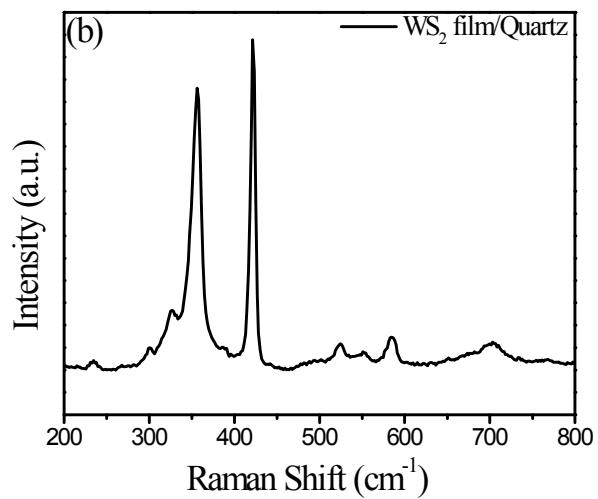
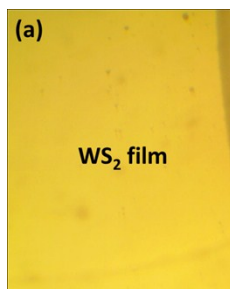


Figure S8 (a) optical image of WS₂ film on quartz substrate. (b) Raman spectrum for few layer WS₂ film. E_{2g}¹ is at ~355.5 cm⁻¹ and A_{1g} at ~421.7 cm⁻¹.