Supporting Information

2D MXene Electrochemical Transistors

Jyoti Shakya [a†], Min-A Kang[a,b,†], , Jian Li[a], Armin VahidMohammadi[c], Weiqian Tian[a,d*], Erica Zeglio[e,f*] Mahiar Max Hamedi[a*]

[a] Department of Fibre and Polymer Technology, KTH Royal Institute of Technology, Teknikringen 56, 10044 Stockholm, Sweden
[b]Department of Materials Science and Engineering, Northwestern University, Evanston, IL 60208, USA
[c]A. J. Drexel Nanomaterials Institute and Department of Materials Science and Engineering, Drexel University, Philadelphia, PA 19104, USA
[d]School of Materials Science and Engineering, Ocean University of China, Qingdao, Shandong 266100, China; orcid.org/0000-0003-3497-2054
[e]Division of Nanobiotechnology, Department of Protein Science, Science for Life Laboratory, School of Engineering Sciences in Chemistry, Biotechnology and Health, KTH Royal Institute of Technology and Digital Futures, Solna, Sweden.
[f]Center for the Advancement of Integrated Medical and Engineering Sciences (AIMES), Karolinska Institutet and KTH Royal Institute of Technology, 171 77, Stockholm, Sweden

[†] Equal contribution

E-mail: mahiar@kth.se, zeglio@kth.se, tianweiqian@ouc.edu.cn

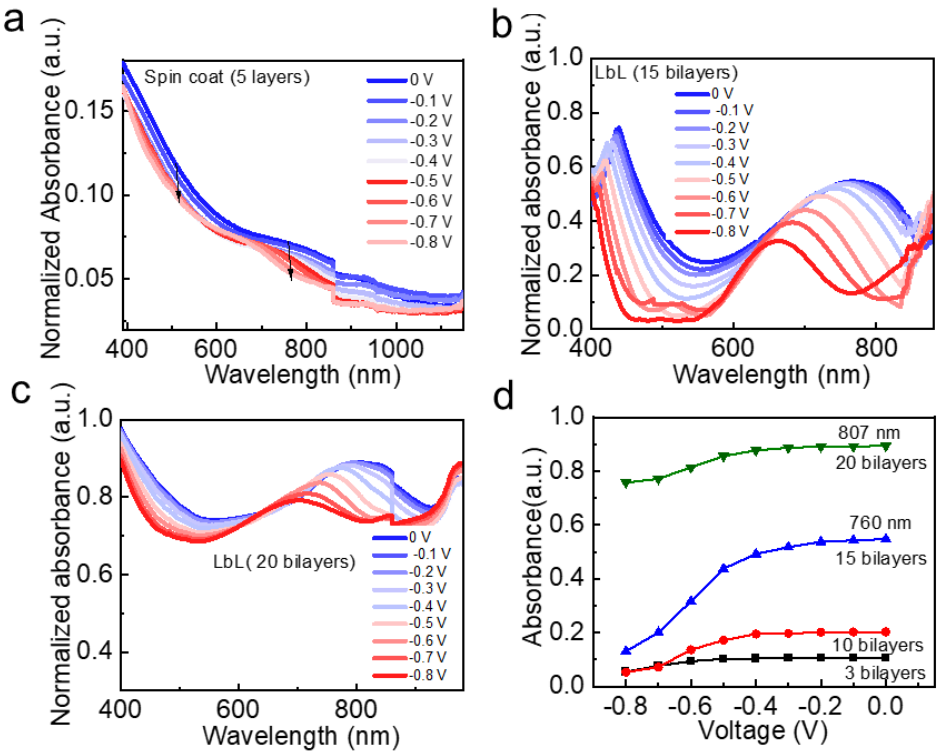

Figure S1. UV-vis spectroelectrochemical measurements of (a) spin-coated MXene (5 layers). (b) LbL-assembled 15 bilayers , (c) LbL-assembled 20 bilayers (d) A comparison of changes in absorption maxima for LbL-assembled films. The absorption maxima were 760 nm for all the films except for the film with 20 bilayers, for which it was 807 nm.

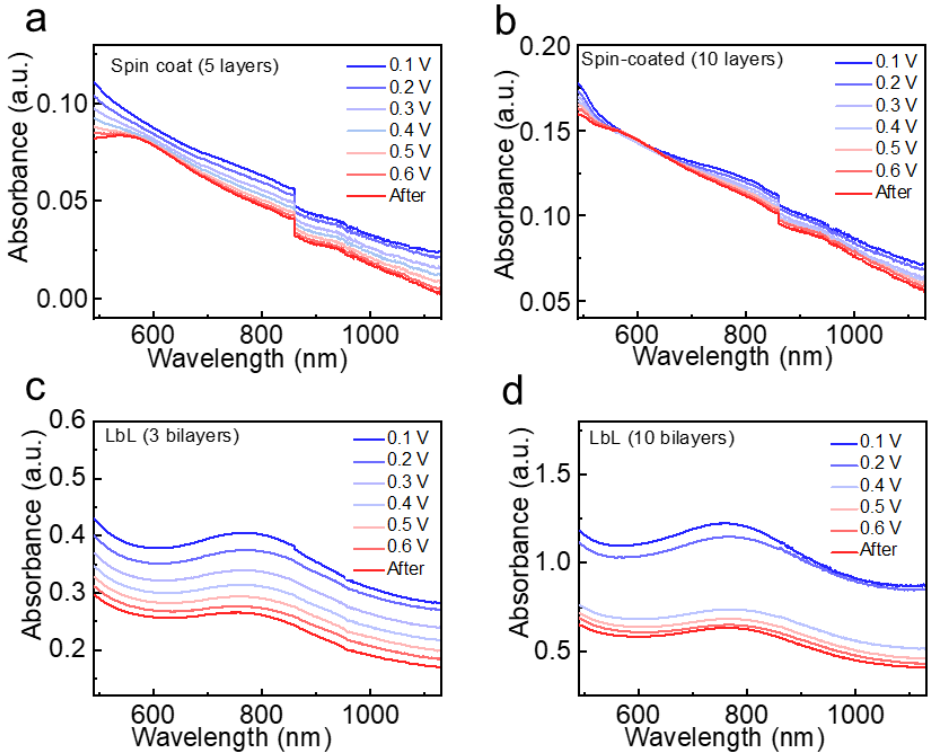

Figure S2. UV-vis spectral absorbance for oxidation of (a) Spin coated (5 layers) (b) Spin coated (10 layers) (c) LbL (3 bilayers) (d) LbL (10 bilayers).

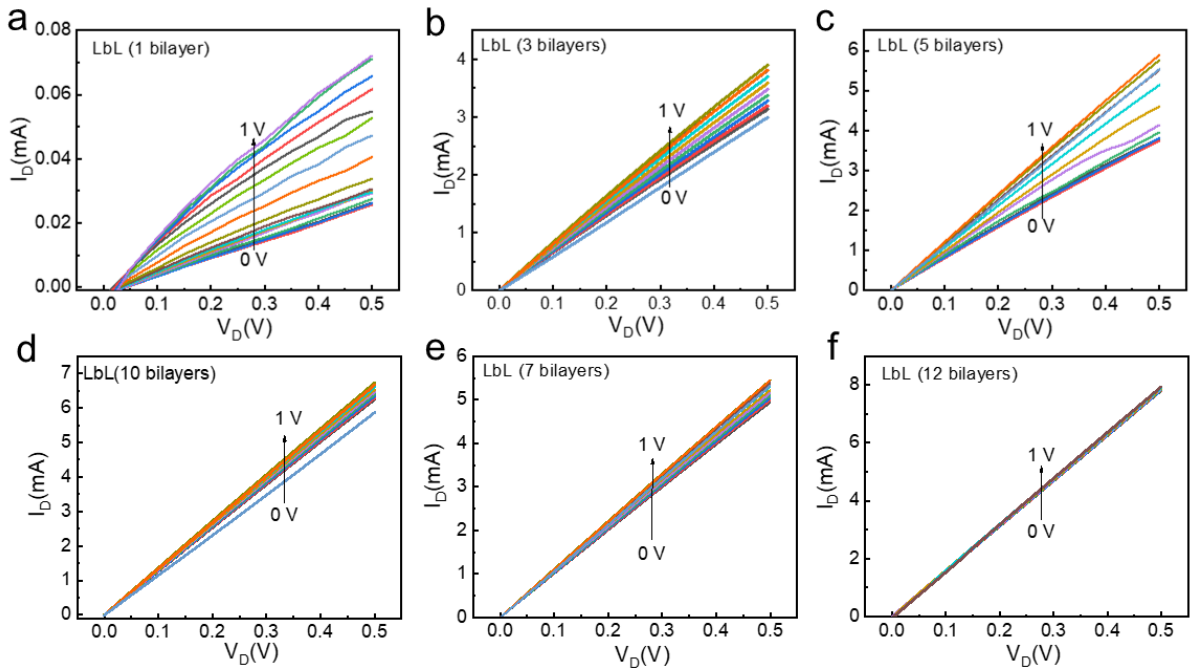

Figure S3. Output curves of MXene ECTs having LbL assembled MXene films as channels (a) 1 bilayer (b) 3 bilayers (c) 5 bilayers (d) 7 bilayers (e) 10 bilayers and (f) 12 bilayers measured for gate voltages ranging from 0 to 1 V.

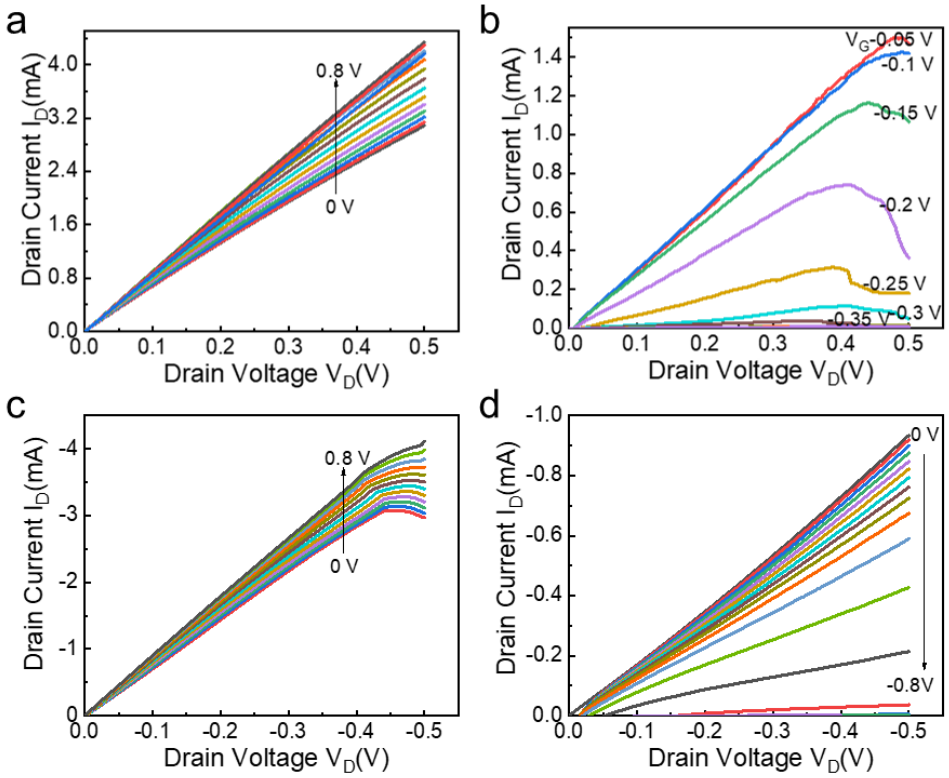

Figure S4. Output characteristics of MXene ECTs at positive drain voltages and gate voltages from (a) 0 to 0.8 V and (b) 0 to -0.35 V and negative drain voltages and gate voltages from (c) 0 V to 0.8 V and (d) 0V to -0.8 V.

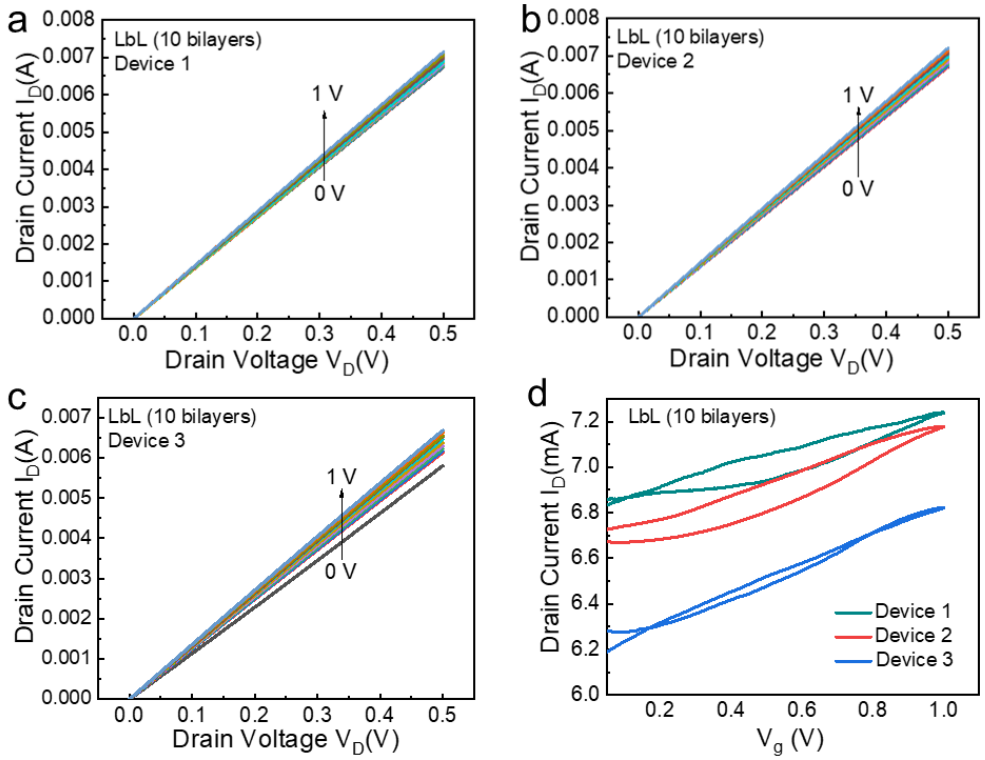

Figure S5. Device variability: Electrical characteristics of MXene ECT devices having LbL (10 Layers) assembled MXene films as channels. (a, b, c) Output curves for various ECT devices measured for gate voltages ranging from 0 to 1 V. (d) A comparison of corresponding transfer curves for devices 1, 2 and 3.

Table S1. Summary of MXene ECTs parameters. We have measured 3 devices (Channel dimensions, L = 20 µm, W = 1000 µm for each 1, 3, 5, 7, 10 and 12 bilayers

LbL bilayers	Thickness [nm][a)]	V_{TH} [V][b)]	Average maximum Transconductance $g_{m,max}$[mS][c)]	Areal Capacitance [mF][d)]	µ [$cm^2V^{-1}s^{-1}$][e)]
1	08.79	0.20	0.07 ± 0.06	-	0.008
3	26.38	0.20	2.19 ± 1.20	1.8 ± 0.09	0.030
5	43.97	0.20	2.76 ± 2.01	5.0 ± 0.25	0.036
7	61.55	0.27	1.82 ± 0.41	8.1 ± 0.40	0.014
10	87.94	0.35	0.79 ± 0.08	11.4 ± 0.57	0.008
12	105.5	0.28	0.32 ± 0.11	-	0.002

a) Extracted from Field Emission Scanning Electron Microscope (FESEM)[17]

b) Determined using extrapolation in the linear region method

c) Extracted from transfer curves

d) Areal capacitance extracted from cyclic voltammetry using equation (2)

e) Estimated using equation (1)

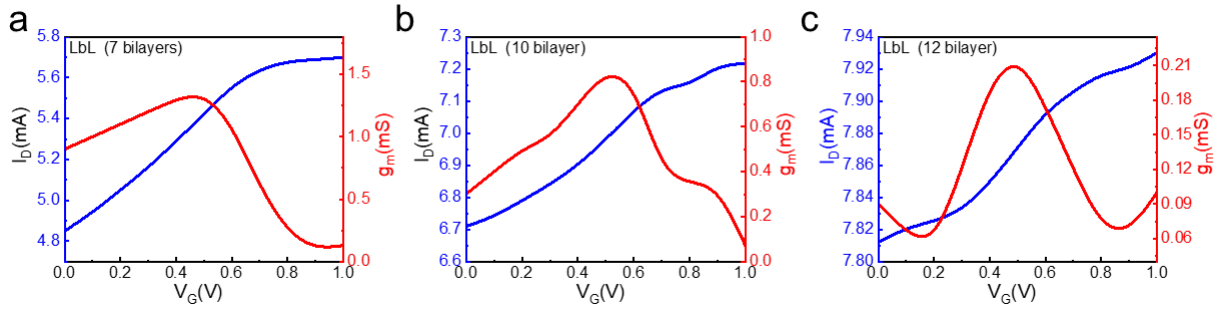

Figure S6. Transfer curves and the corresponding normalized transconductance plotted with respect to the gate voltages at V_D = 0.5 V, for LbL-assembled different layers of MXene (a) 7 bilayers, (b) 10 bilayers and (c) 12 bilayers.

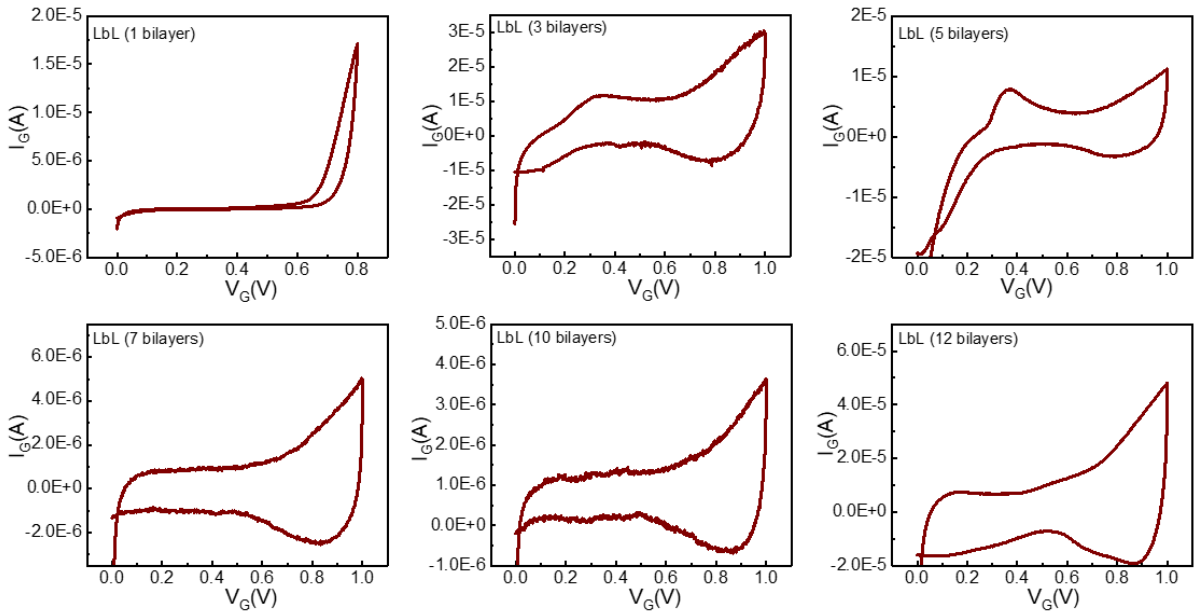

Figure S7. Gate currents for MXene ECTs with 1, 3, 5, 7, 10 and 12 bilayers at fix V_D= 0.5 V and V_G from 0 to 0.8 V.

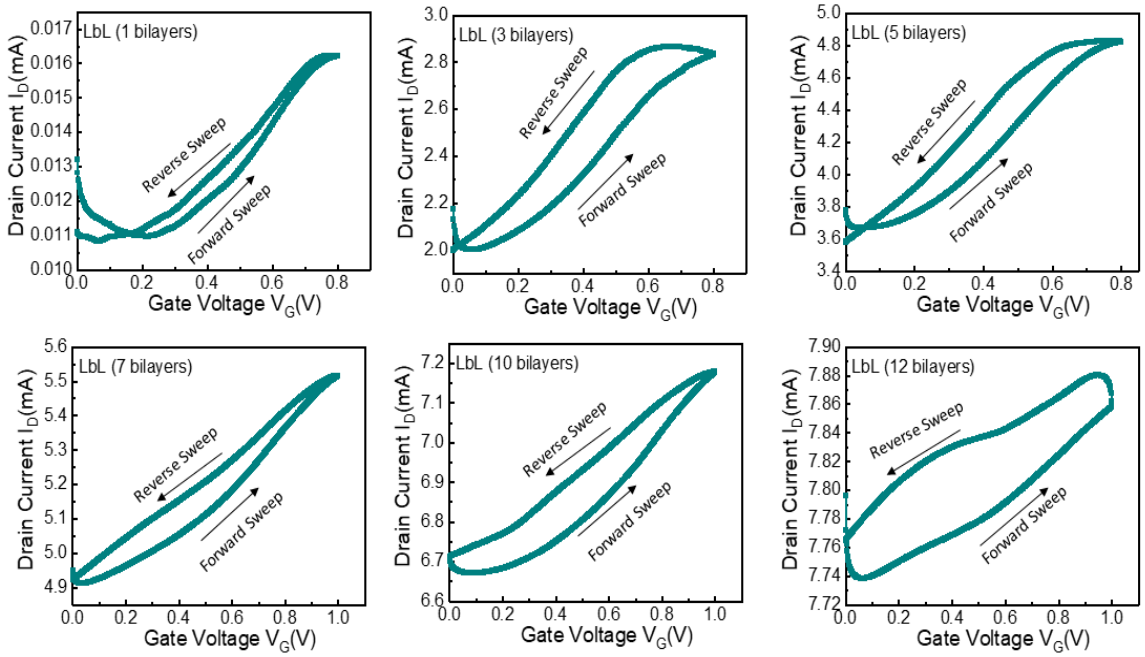

Figure S8. Transfer curves for MXene ECT (a) 1, (b) 3, (c) 5, (d) 7, (e) 10 and (f) 12 bilayers at V_D = 0.5V and V_G from 0 to 0.8V.

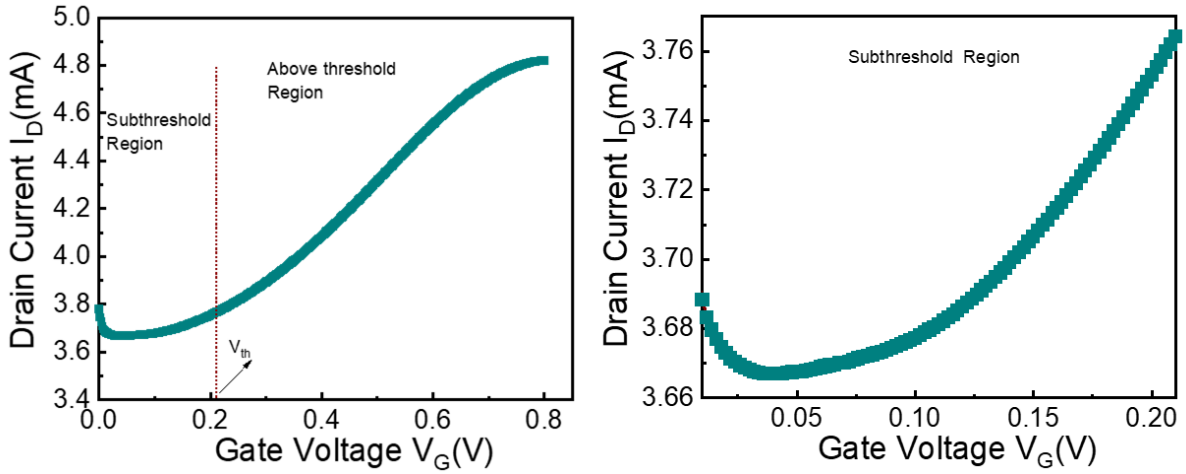

Figure S9. Subthreshold region of MXene LbL (5 bilayers device) bilayers at V_D = 0.5V and V_G from 0 to 0.8V.

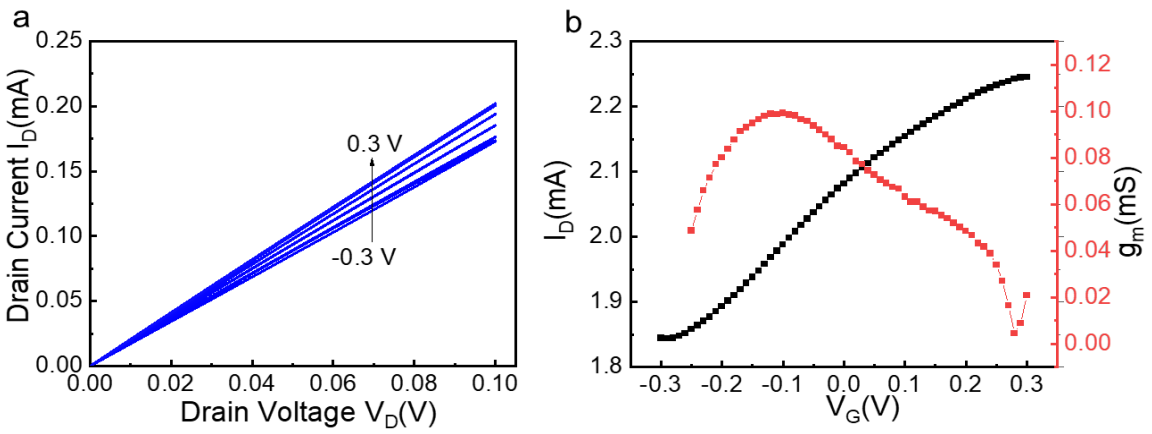

Figure S10. Output curve (a) for spin coated MXene ECTs, measured for gate voltages ranging from -0.3V to 0.3V. Corresponding transfer curves and calculated transconductance values (b) measured at V_D = 0.5 V.

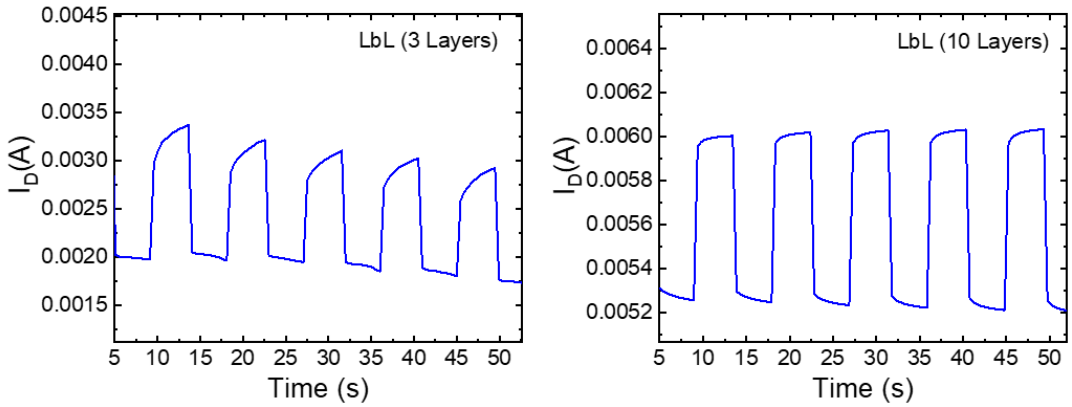

Figure S11. The transient response of the channel current (V_D = 0.5V, V_G= 1V) of LbL (3 bilayers) and LbL (10 bilayers)

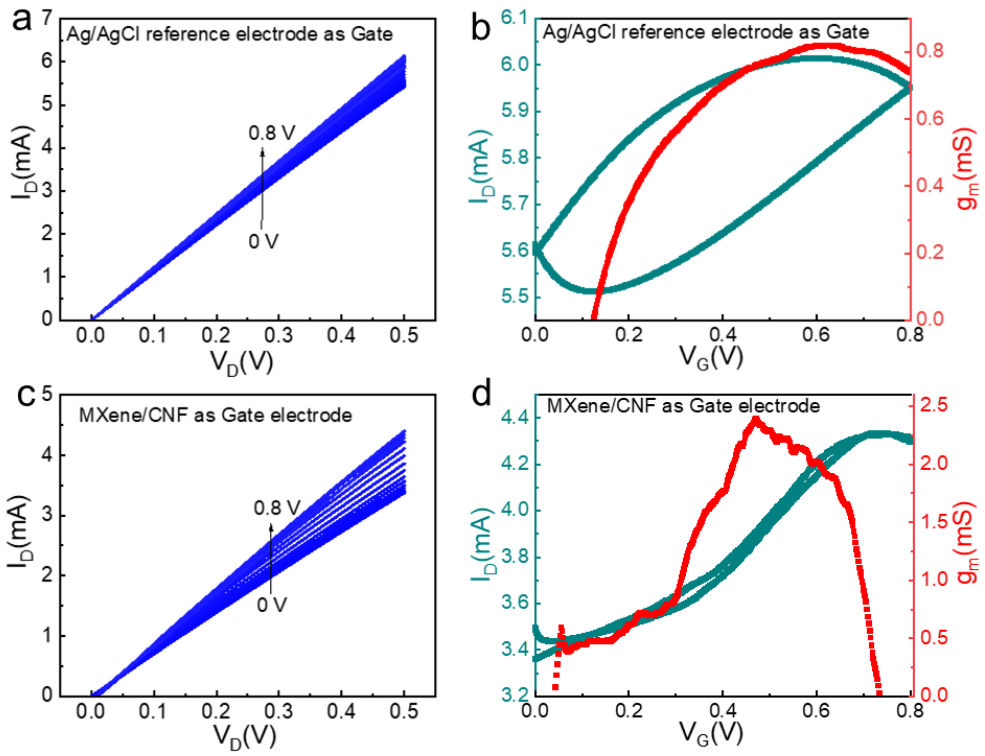

Figure S12. Channel gating with different gate electrode: Output and transfer characteristics of 5 bilayers of MXene using (a, b) Ag/AgCl reference electrode (3 M KCl aqueous solution), and (c, d) MXene-CNF membrane at V_D = 0.5 V and V_G from 0 to 0.8 V

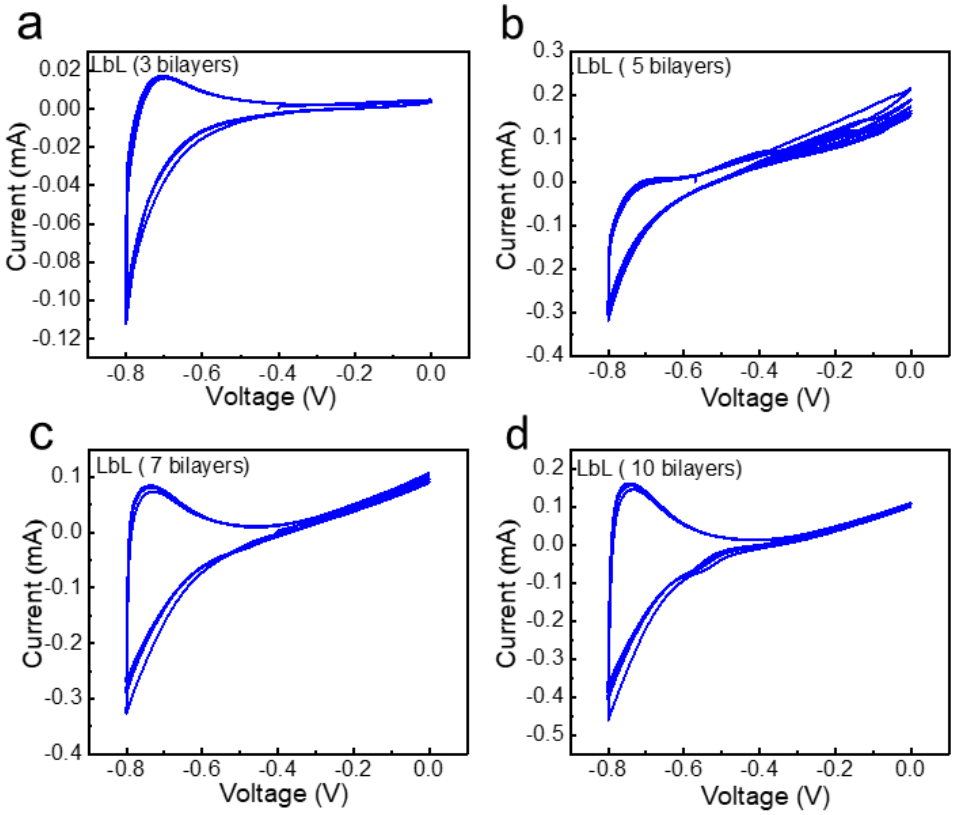

Figure S13. Cyclic voltammograms of (a) 3 (b) 5, (c) 7 and (d) 10 bilayers of LbL assembled MXene. All measurements were performed using a three-electrode setup with an Ag/AgCl pellet acting as a pseudo-reference electrode.

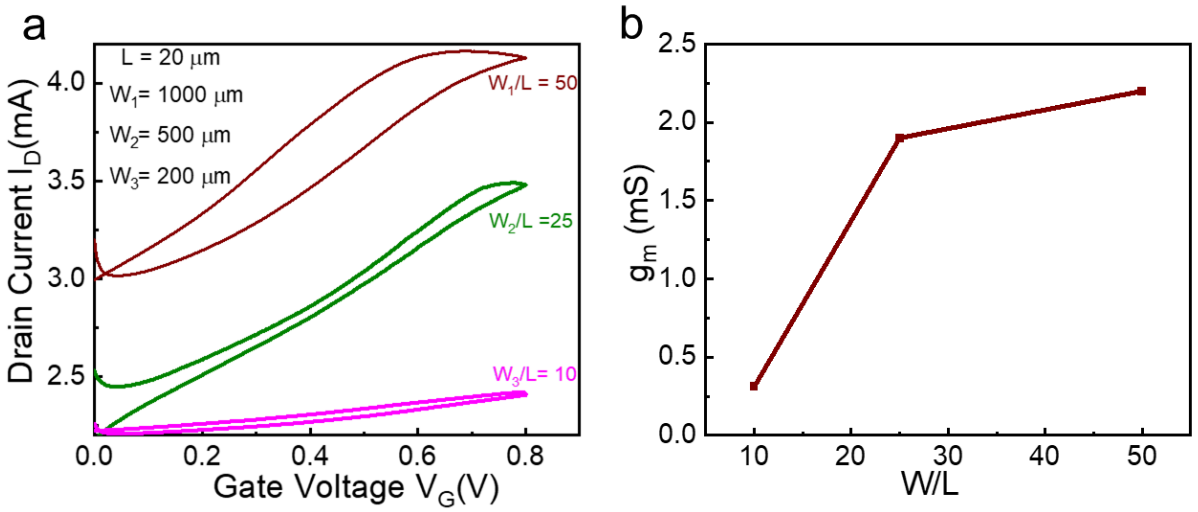

Figure S14. (a) Transfer characteristics of 5 bilayers MXene coated on the channel with width 1000 μm, 500 μm and 200 μm at V_D = 0.5V and V_G = 0 to 0.8 V. (b) Corresponding transconductance.

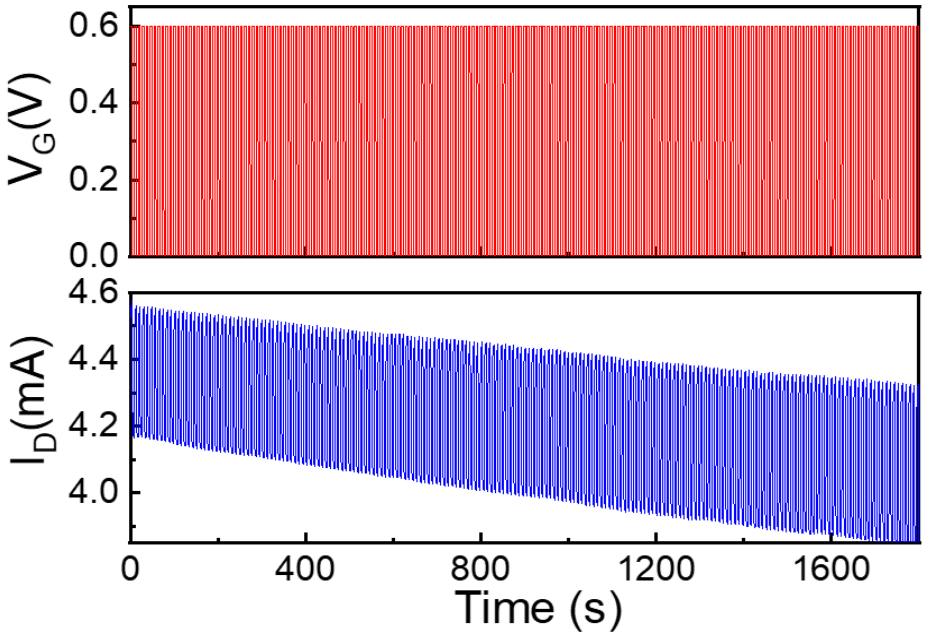

Figure S15. Stability test for 5 bilayer MXene ECTs under sequential square wave gate voltage pulse for 30 min, at V_D= 0.5 V, and V_G from 0 to 0.6 V.

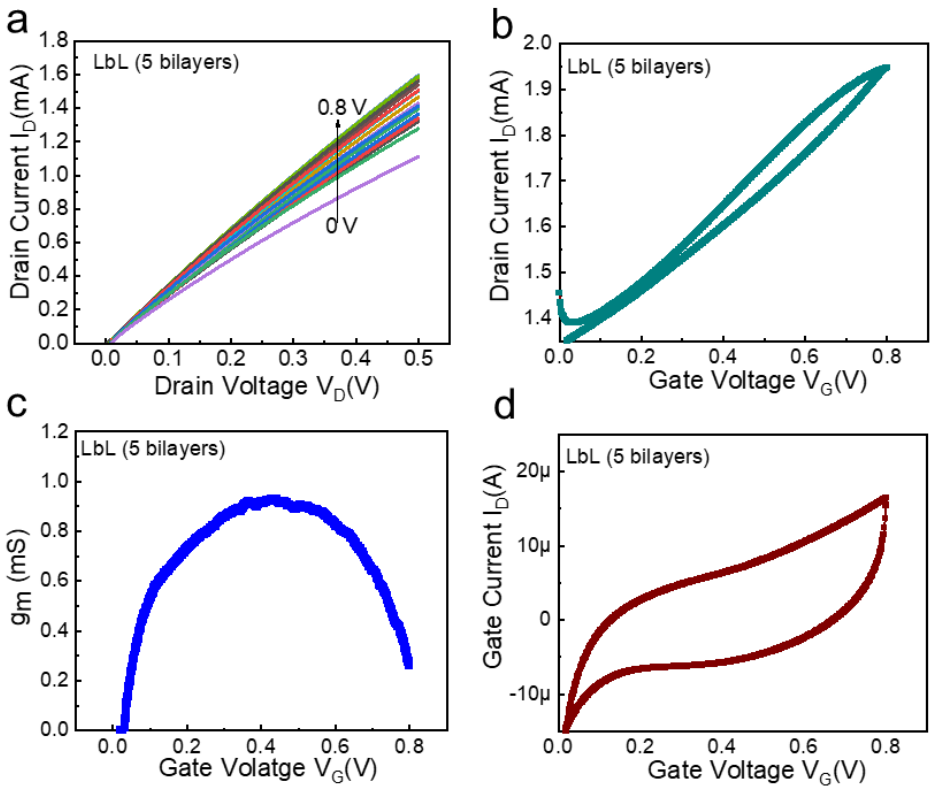

Figure S16. (a) Output curves at V_D from 0 to 0.5 V and V_G from 0 to 0.8 V. (b) Transfer curves at V_D = 0.5 V and V_G from 0 to 0.8 V. (c) Transconductance plot and (d) gate current for MXene ECTs devices having LbL assembled 5 bilayers as channel in 0.1 M NaCl aqueous electrolyte at V_D = 0.5 V and V_G from 0 to 0.8 V.