Electronic supplementary information

for

High-Performance Solution-Processed $Ti_3C_2T_x$ MXenes Doped ZnSnO Thin-Film Transistors via the Formation of a Two-Dimensional Electron Gas

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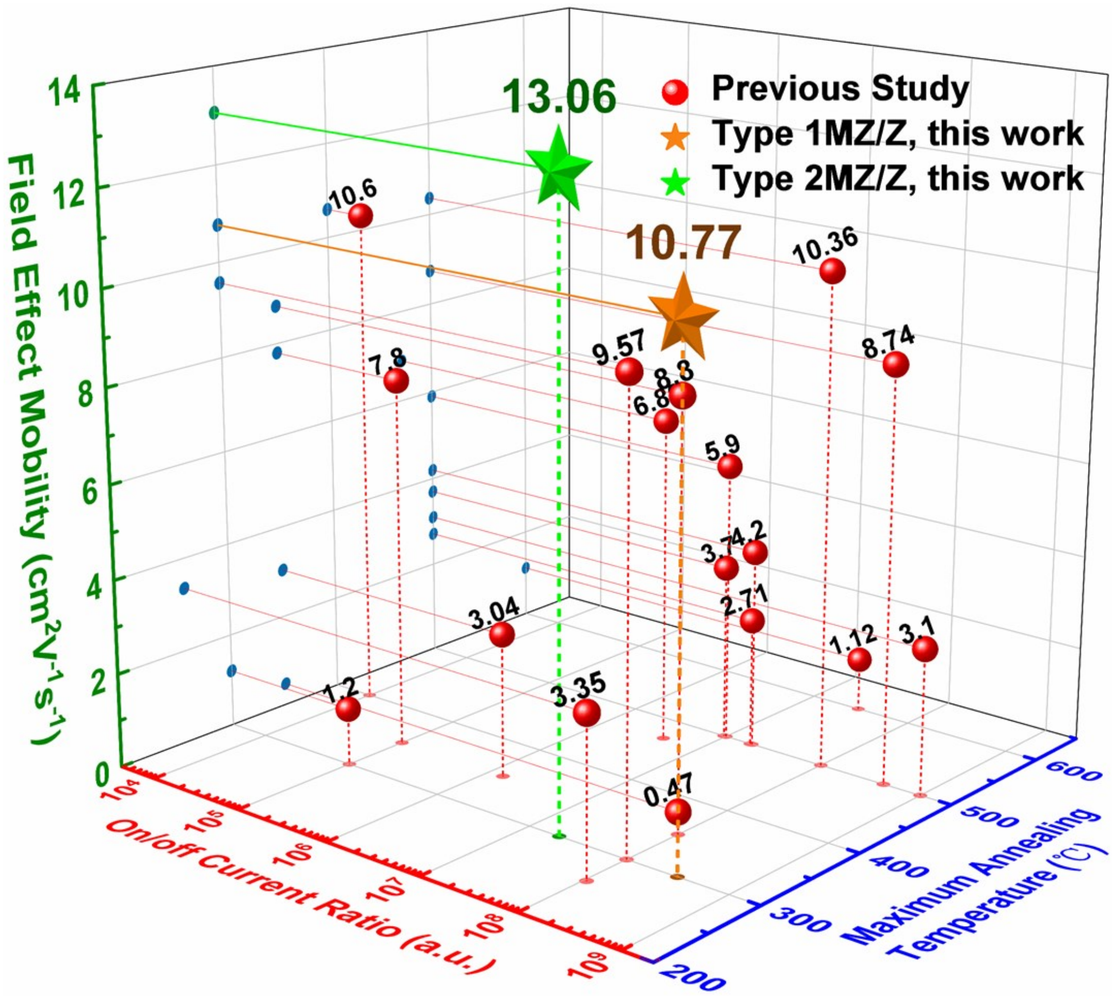

Fig. S1 Recent studies of ZTO-based semiconductor/SiO_2 TFTs device electrical performance and maximum annealing temperature [1-11].

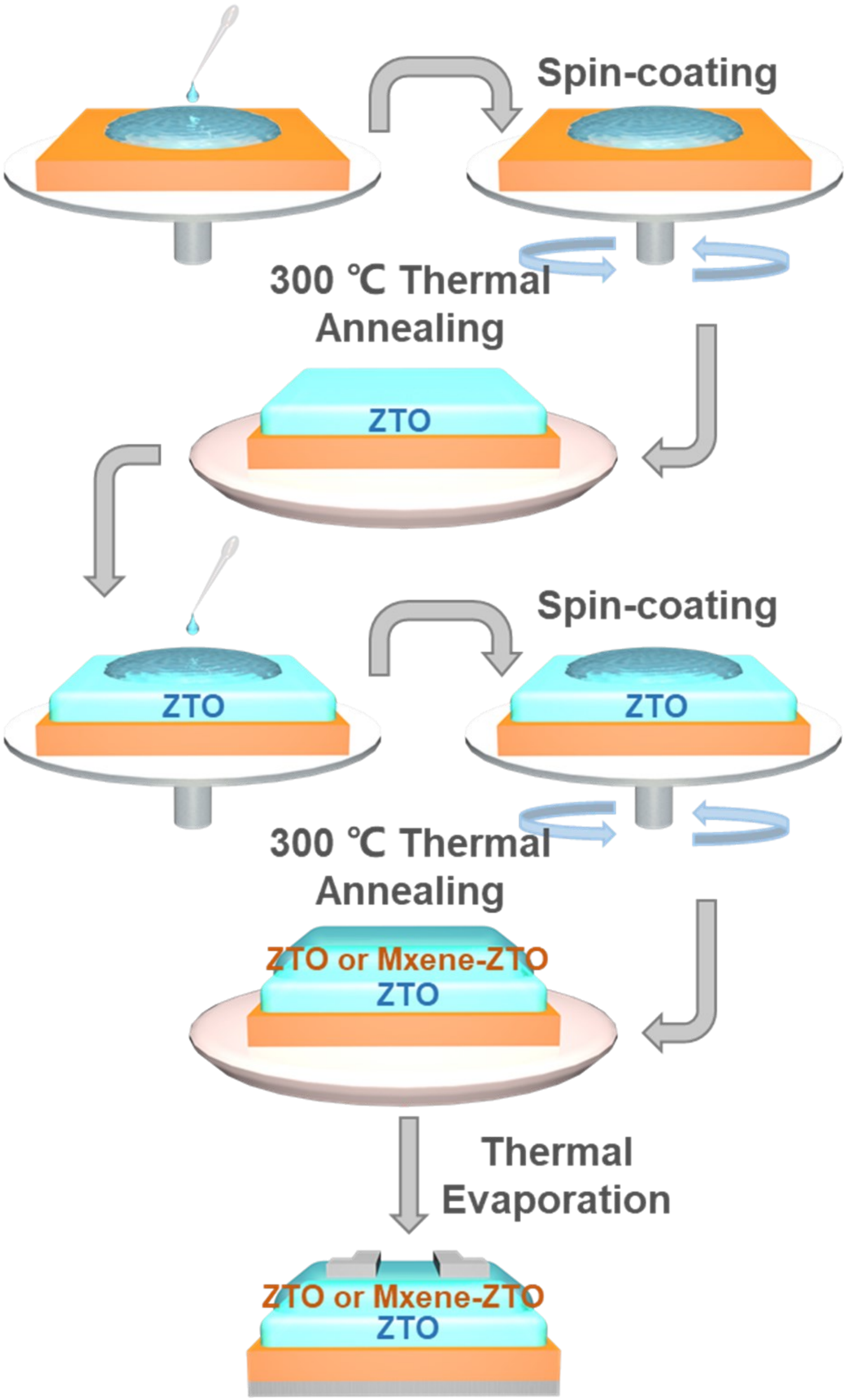

Fig. S2 Process flow chart of solution-processed TFTs fabrication in this work.

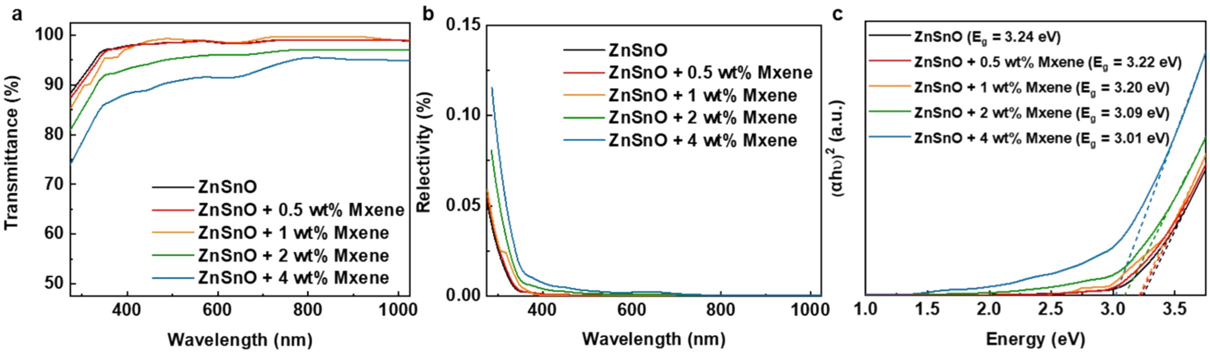

Fig. S3 (a) UV-Vis transmittance and (b) reflectivity results of ZTO and MXene-ZTO thin films with different doping concentrations. (c) The energy bandgap width (E_g) extracted from the UV-Vis curves.

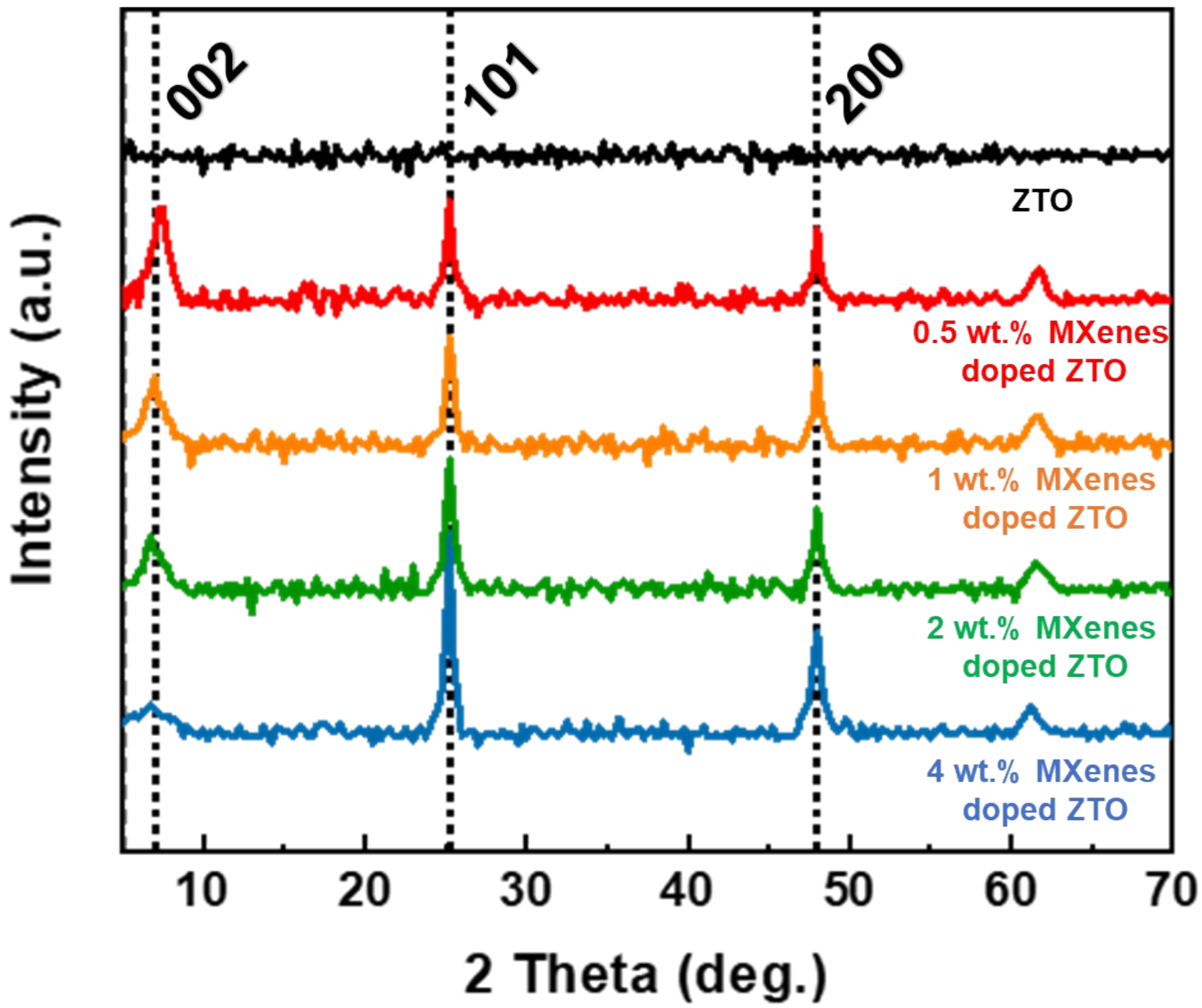

Fig. S4 XRD results for the thin-film samples without or with different MXenes doping concentration.

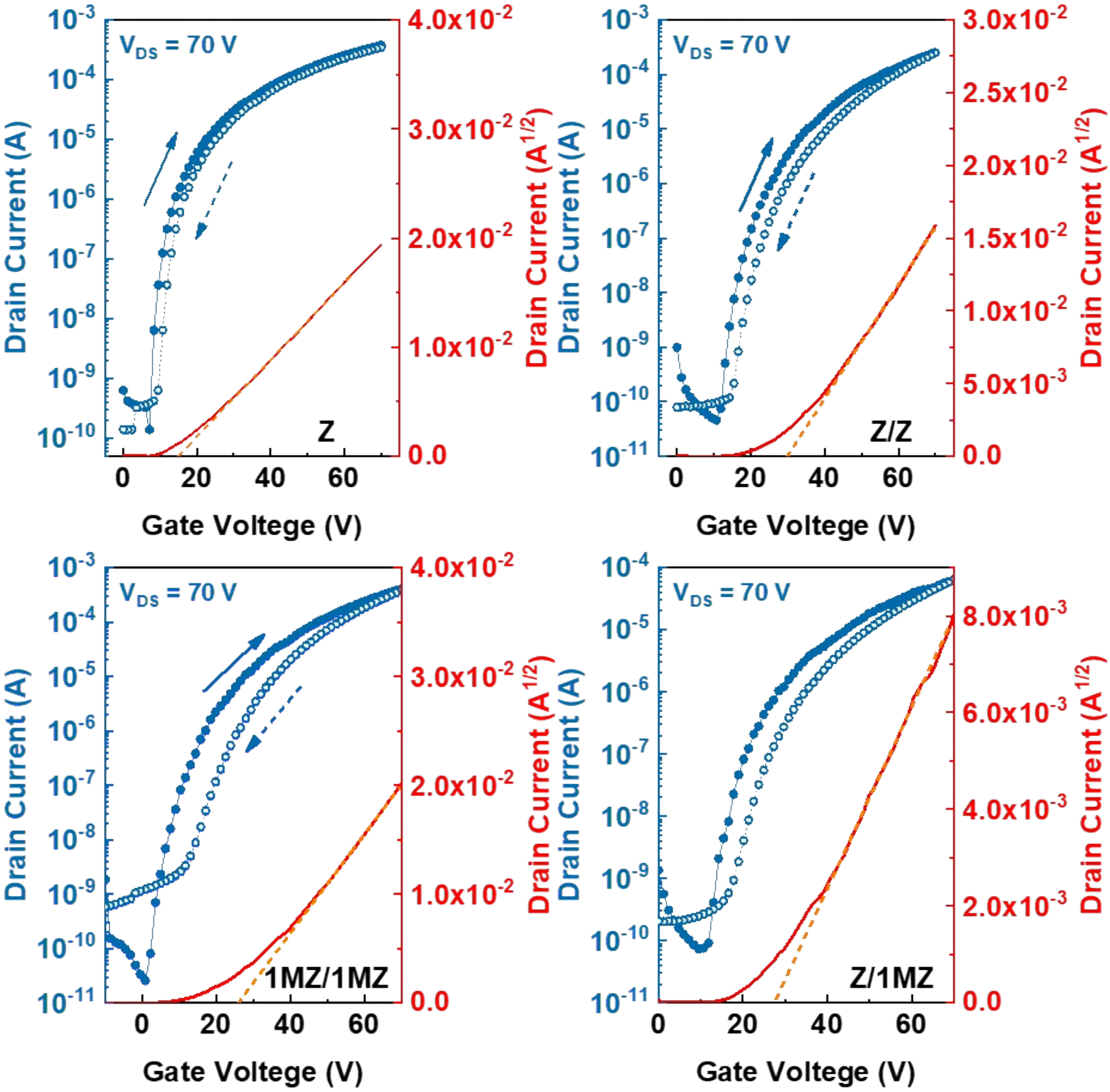

Fig. S5 Transfer curves for (a)Z, (b)Z/Z, (c)1MZ/1MZ, and (d)Z/1MZ TFTs under V_{DS} of 70 V.

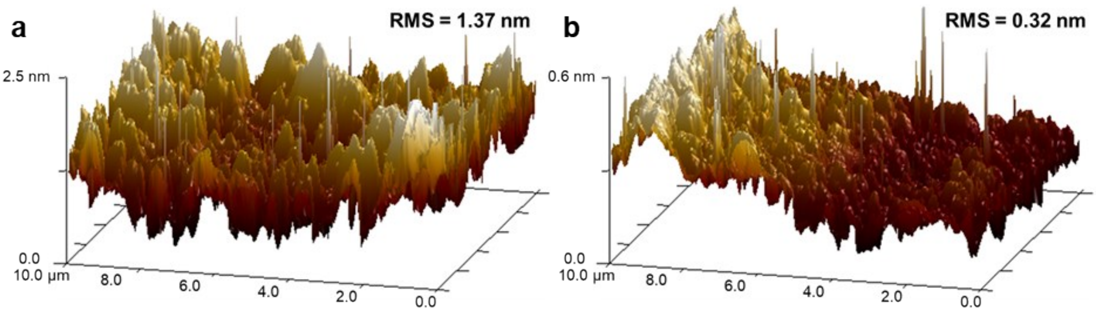

Fig. S6 AFM results for the surfaces of (a) 1 wt.% MXenes doped ZTO and (b) ZTO thin films.

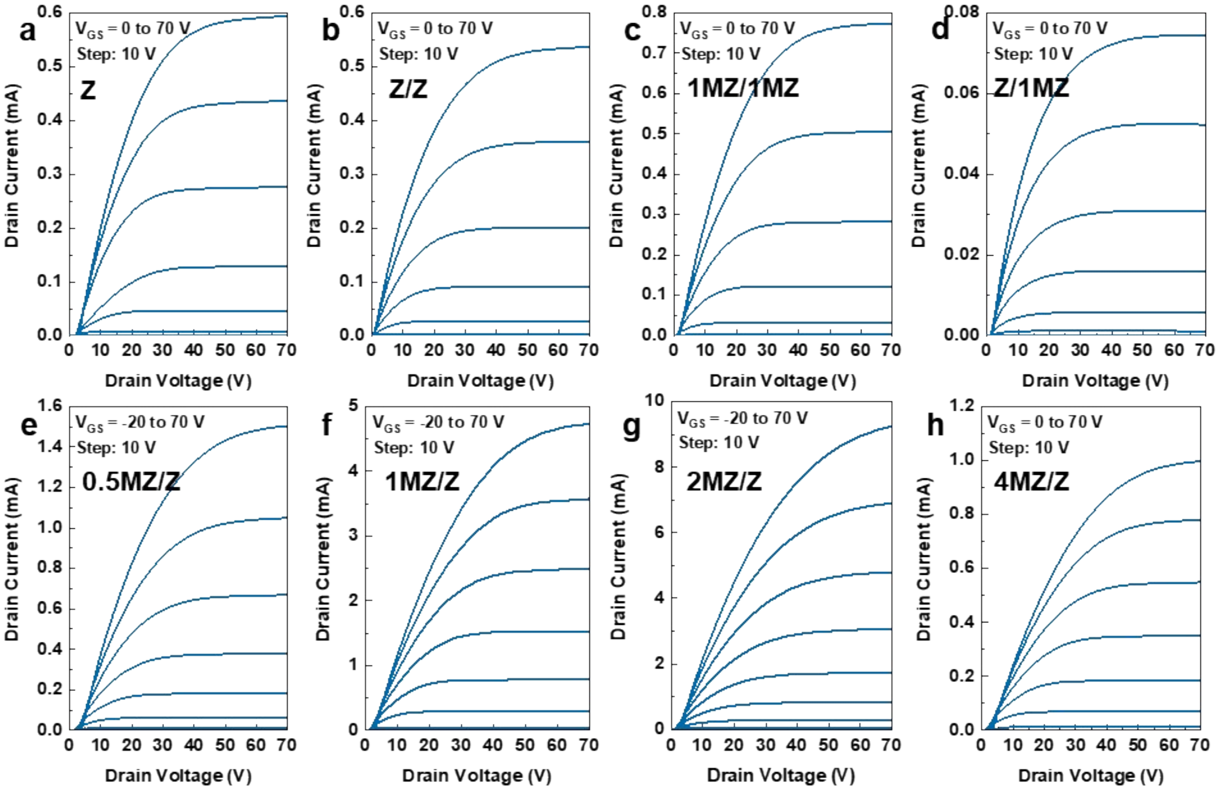

Fig. S7 Transfer curves for (a)Z, (b)Z/Z, (c)1MZ/1MZ, (d)Z/1MZ, (e)0.5MZ/Z, (f)1MZ/Z, (g)2MZ/Z, and (h)4MZ/Z TFTs.

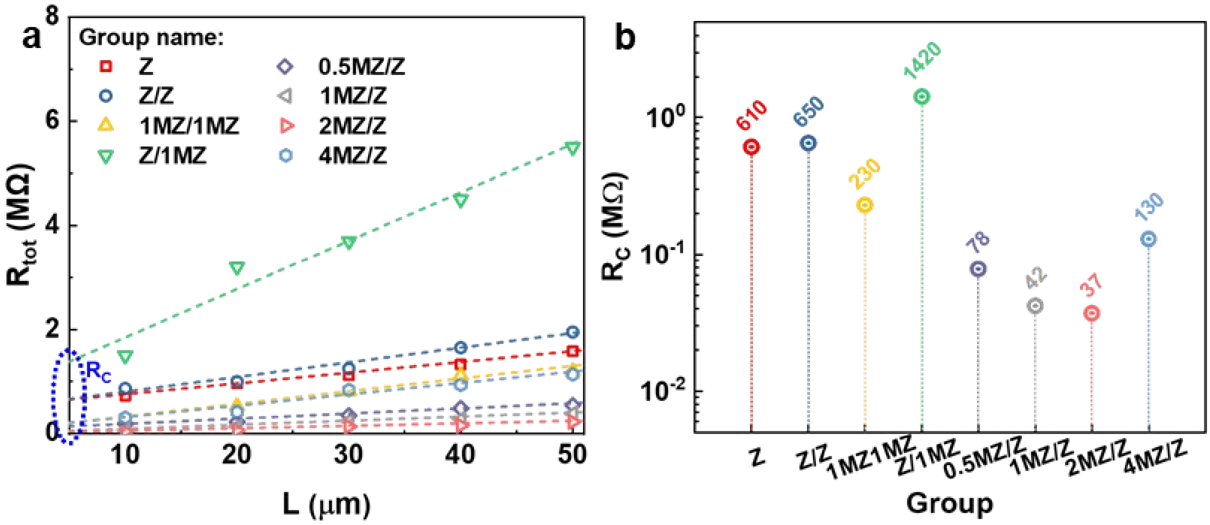

Fig. S8 (a)Total channel resistance under various channel length calculated for TFTs belong to each group. (b)The contact resistance extracted from the R_{tot}-L results.

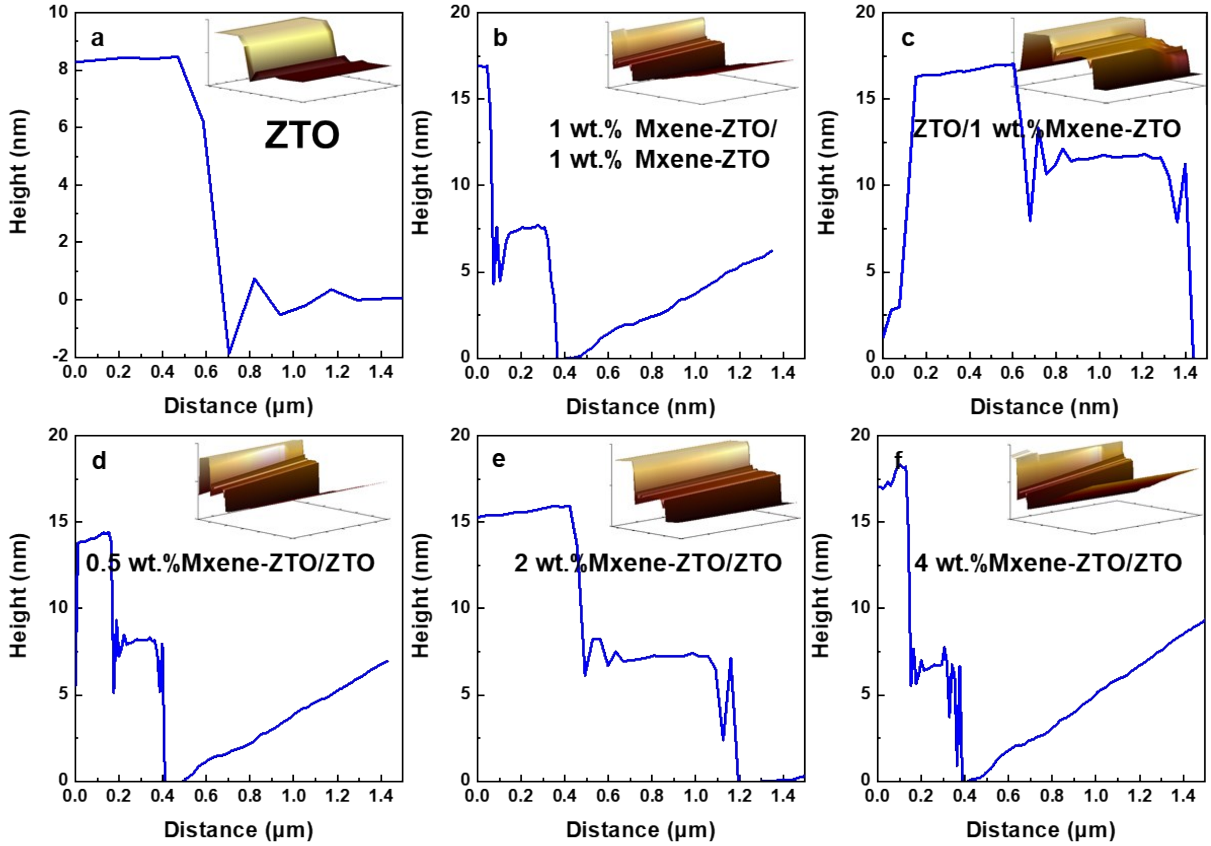

Fig. S9 The thickness of (a) ZTO single layer, (b) 1 wt.% MXenes doped ZTO double layer, (c) ZTO/1 wt.% MXenes doped ZTO bilayer, (d) 0.5 wt.% MXenes doped ZTO/ZTO bilayer, (e) 2 wt.% MXenes doped ZTO/ZTO bilayer, and (f) 4 wt.% MXenes doped ZTO/ZTO bilayer measured by AFM (refers to Z, 1MZ/1MZ, 0.5MZ/Z, 2MZ/Z, and 4MZ/Z TFTs, respectively.).

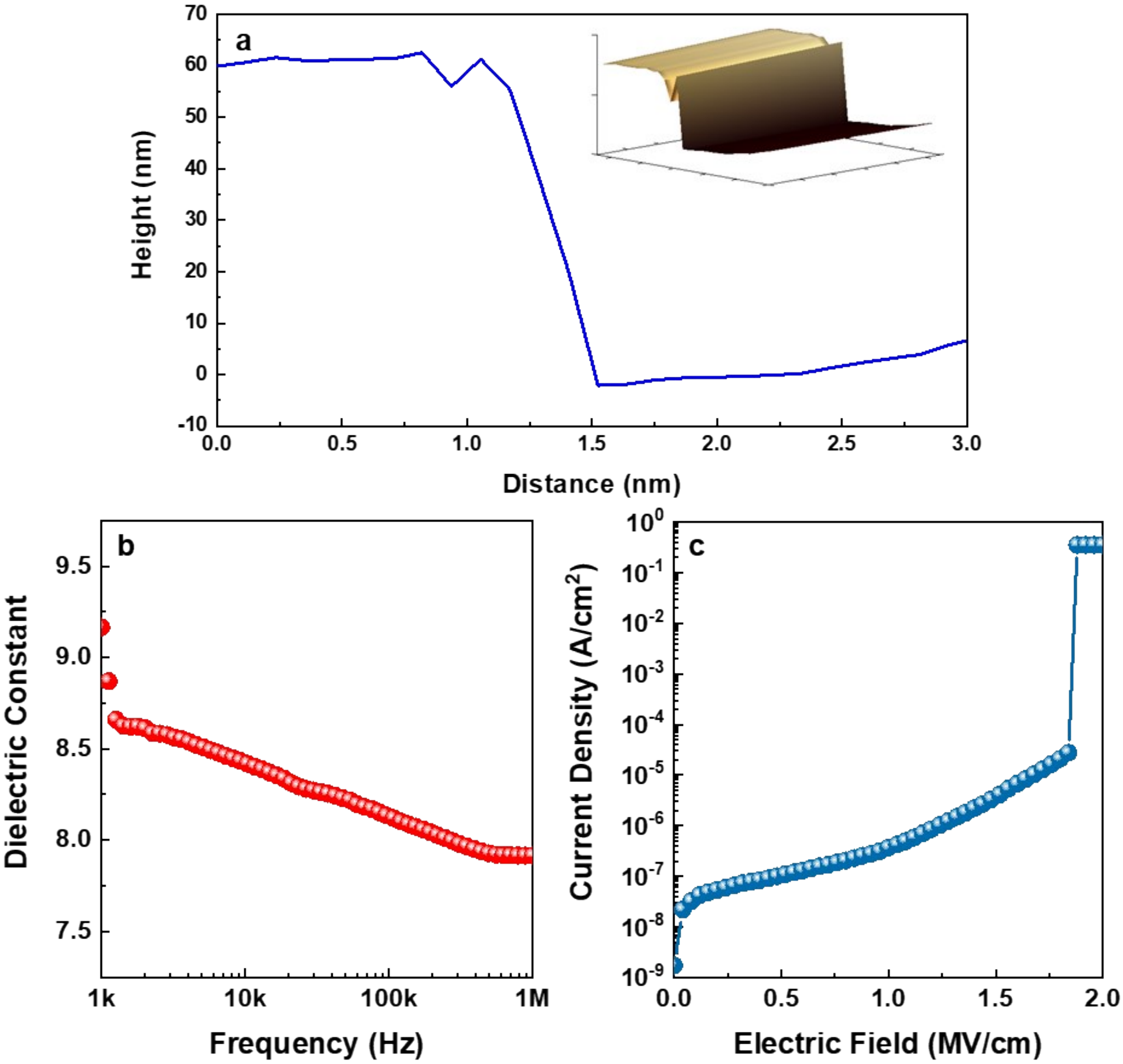

Fig. S10 (a) The thickness of the solution-processed AlO_X dielectric layer. (b) The dielectric constant-frequency behavior of the solution-processed AlO_X dielectric layer. (c) The current density-electric field curve of the solution-processed AlO_X dielectric layer.

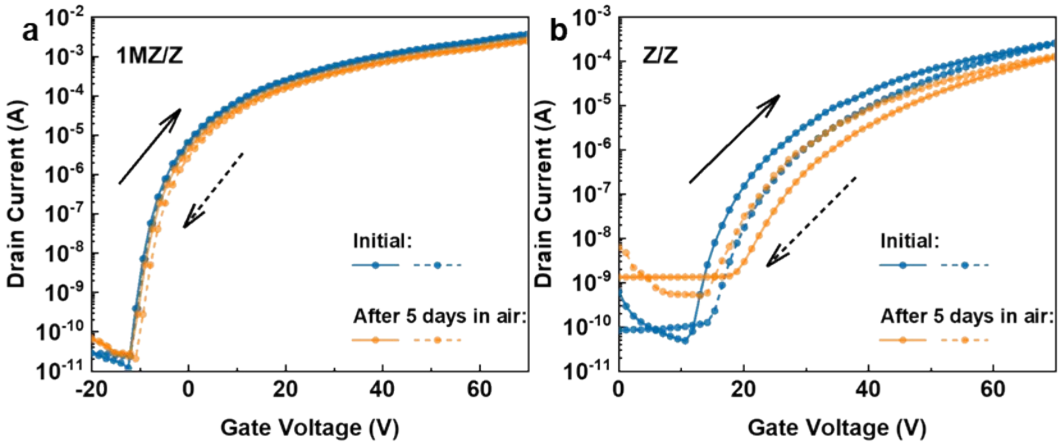

Fig. S11 The transfer curves of (a) 1MZ/Z and (b) Z/Z TFTs before and after exposure to air for 5 days.

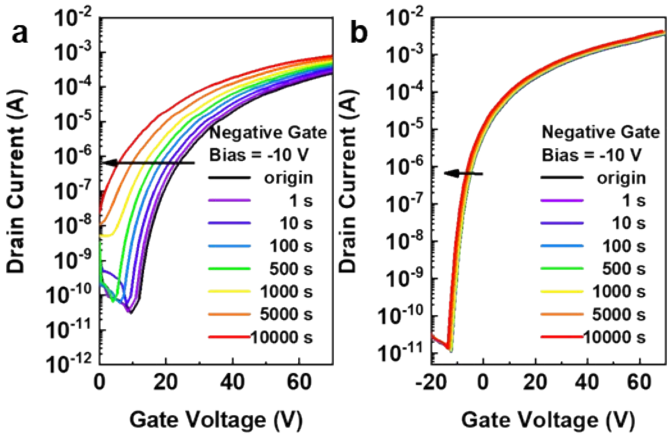

Fig. S12 Transfer curves of (a) Z/Z and (b) 1MZ/Z devices under -10 V negative gate bias with a duration of 10000 s.

Table S1. Recent studies of ZTO-based semiconductor/SiO_2 TFTs device electrical performance and maximum annealing temperature.

Maximum Annealing Temperature (°C)	On/off Current ratio	Field Effect Mobility ($cm^2V^{-1}s^{-1}$)	Year	Reference
300	$\sim 1\times10^5$	1.2	2015	[8]
350	$\sim 1\times10^5$	7.8	2015	[8]
500	$\sim 1.9\times10^7$	4.2	2016	[1]
300	$\sim 1\times10^8$	9.57	2016	[12]
500	$\sim 1\times10^8$	10.36	2016	[12]
350	$\sim 1\times10^8$	8.8	2017	[9]
400	$\sim 1\times10^5$	10.6	2017	[9]
260	$\sim 1.06\times10^8$	3.35	2018	[4]
500	$\sim 4.32\times10^8$	8.74	2018	[4]
500	$\sim 9.50\times10^6$	3.7	2018	[7]
500	$\sim 1\times10^9$	3.1	2018	[10]
500	$\sim 1\times10^7$	5.9	2019	[6]
600	$\sim 3\times10^7$	1.12	2019	[11]
350	$\sim 1\times10^8$	0.47	2020	[3]
500	$\sim 1.82\times10^7$	2.71	2020	[2]
350	$\sim 1.41\times10^6$	3.04	2020	[5]
470	$\sim 4.17\times10^6$	6.89	2020	[5]
300	$\sim 1.2\times10^8$	10.77 ± 1.83	Type 1MZ/Z, this work	

300	~1.3×10^7	13.06 ± 3.12	Type 2MZ/Z, this work

Table S2. Recent studies of ZTO-based semiconductor/High-*k* oxides TFTs device electrical performance.

Channel material	Dielectric material	Fabrication method	Mobility ($cm^2V^{-1}s^{-1}$)	S.S. (V/dec)	On/off ratio	Ref.
ZnSnO	ZrO_x	Spin-coating	4.61	0.25	10^8	3
ZnSnO	DyO_x	Spin-coating	0.57	0.1	$7.8*10^4$	13
ZnSnO	AlO_x	Spin-coating	2.6	0.25	$2.4*10^6$	14
ZnSnO	$ZrTiO_x$	Spin-coating	17.9	-	10^5-10^6	6
InZnSnO	ZrO_x	Spin-coating	9.5	0.087	10^8	15
ZnSnO:N	HfO_2	Spin-coating	0.2	0.11	10^6	16
1 wt.% MXenes-ZnSnO/ZnSnO	AlO_x	Spin-coating	28.35	0.23	$2.52*10^5$	This work

Table S3. The thickness of the oxide channels

Thin-film structure	Thickness (nm)
ZTO single layer	~8
ZTO/ZTO	~ 14
1 wt.% MXenes doped ZTO/1 wt.% MXenes doped ZTO	~17
ZTO/1 wt.% MXenes doped ZTO	~16
0.5 wt.% MXenes doped ZTO/ZTO	~15
1 wt.% MXenes doped ZTO/ZTO	~15
2 wt.% MXenes doped ZTO/ZTO	~16
4 wt.% MXenes doped ZTO/ZTO	~18

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