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Supplementary Information

A study of the doping process in $Li_4Ti_5O_{12}$ and TiO_2 battery electrode materials studied in ion-gated transistor configuration

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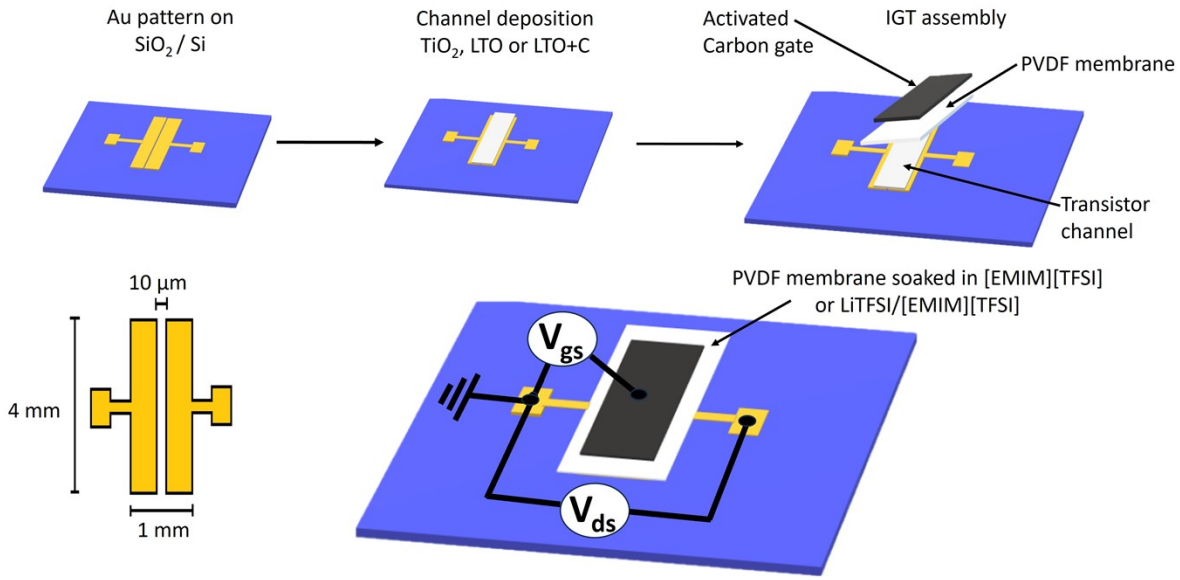

Fig. S1 LTO, LTO+C, and TiO_2 based IGTs gated with [EMIM][TFSI] and LiTFSI/[EMIM][TFSI]. Steps for the device fabrication and assembly, and electrical circuit.

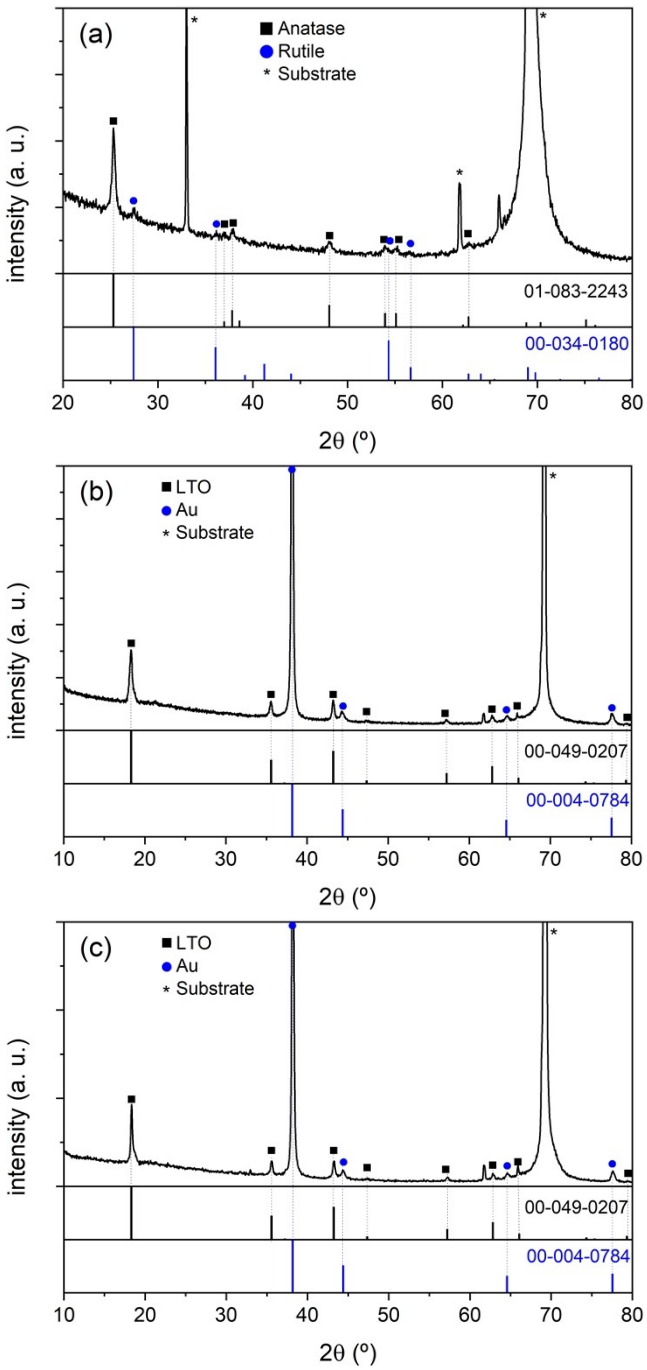

Fig. S2 X-ray diffraction pattern for (a) TiO_2 P25, (b) LTO, and (c) LTO+C on Au patterned SiO_2/Si substrate. Insertion: reference number for the identified phases according to the Joint Committee on Powder Diffraction Standards (JCPDS) database.

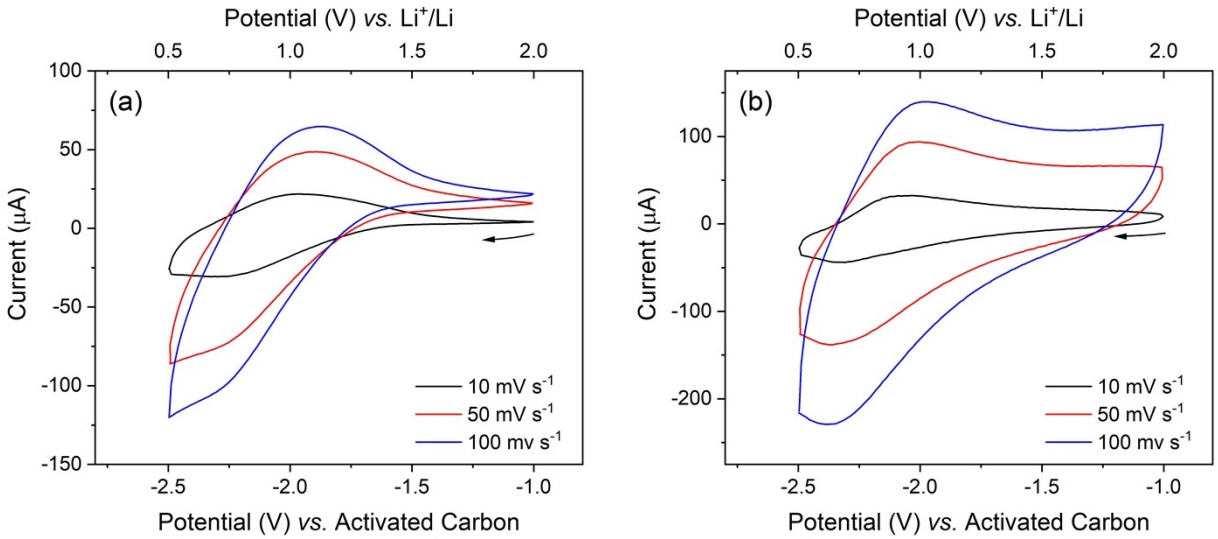

Fig. S3 Cyclic voltammograms at three sweeping rates of (a) LTO, (b) LTO+C in IGT configuration. 0.1 mol L^{-1} LiTFSI in [EMIM][TFSI] as gating medium.

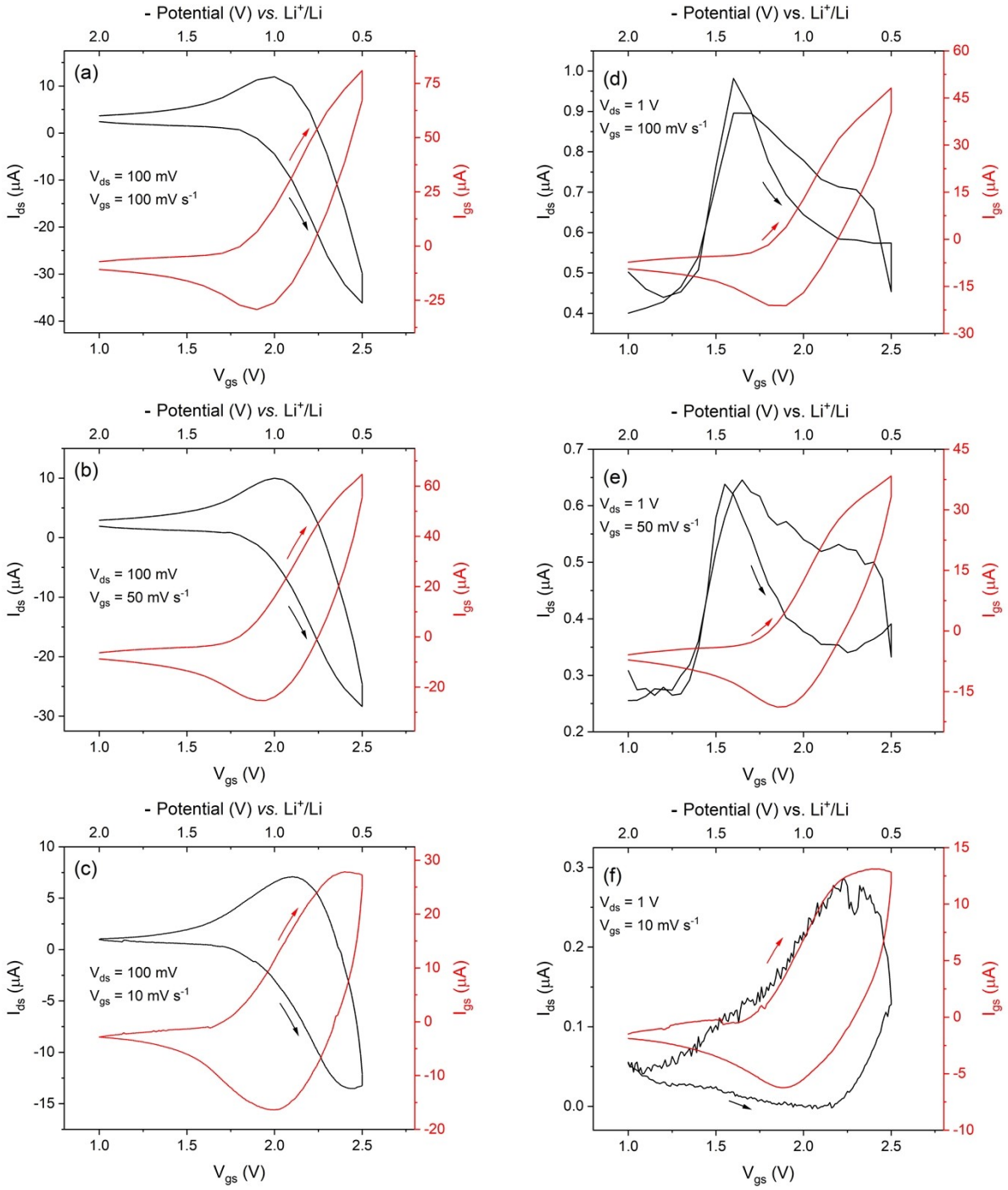

Fig. S4 Transfer characteristics of LTO with V_{ds} = 0.1 V at three V_{gs} sweeping rates, (a) 100, (b) 50, and (c) 10 mV s^{-1}. Additionally, with V_{ds}=1V and three V_{gs} sweeping rates (d) 100 mV s^{-1}, (e) 50 mV s^{-1}, (f) 10 mV s^{-1}. 0.1 mol L^{-1} LiTFSI in [EMIM][TFSI] as gating medium.

For the V_{gs} sweeping rates investigated here, there is no clear transistor effect for LTO IGTs, most likely for kinetic reasons: at 10, 50, 100 mV s^{-1}, ions do not have the time needed to suitably redistribute to cause effective doping.

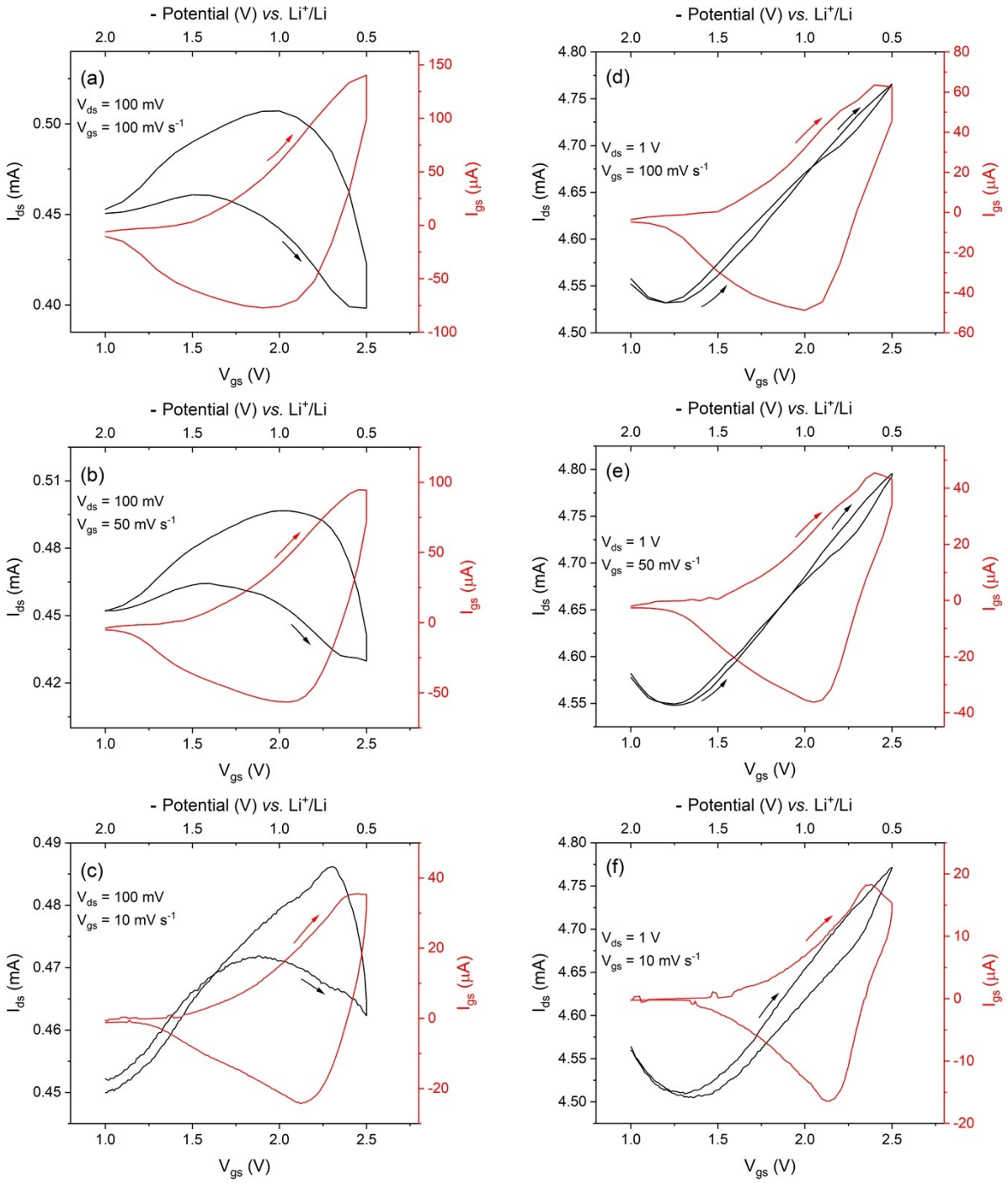

Fig. S5 Transfer characteristics of LTO+C with V_{ds} = 0.1 V at three V_{gs} sweeping rates, (a) 100 mV s^{-1}, (b) 50 mV s^{-1} and (c) 10 mV s^{-1}. Additionally, with V_{ds}=1V and three V_{gs} sweeping rates (d) 100 mV s^{-1}, (e) 50 mV s^{-1}, (f) 10 mV s^{-1}. 0.1 mol L^{-1} LiTFSI in [EMIM][TFSI] as gating medium.

The results show that at V_{ds}=0.1 V the doping of the LTO+C channel transistor is not clear; higher V_{ds} values have to be applied to observe a significant doping.

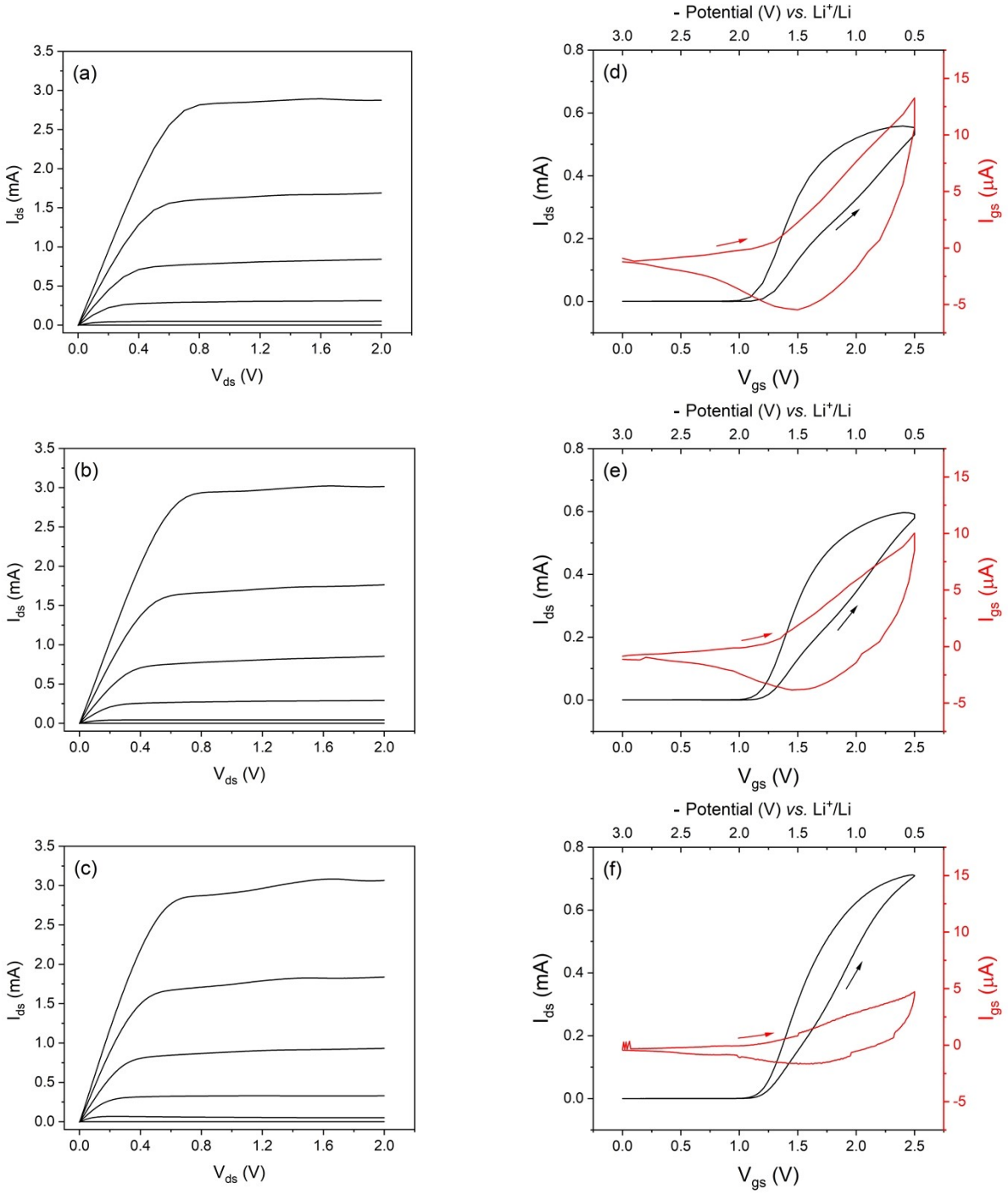

Fig. S6 TiO_2 IGTs without Li^+ in [EMIM][TFSI]. Output characteristics at V_{ds} sweeping rate of (a) 100 mV s^{-1}, (b) 50 mV s^{-1}, (c) 10 mV s^{-1}, V_{gs} from 1 V to 2 V with 200 mV step. Transfer characteristics at 100 mV s^{-1}, 50 mV s^{-1}, 10 mV s^{-1} (d, e, f), V_{ds}=100 mV. Potential range 0 V≤V_{gs}≤ 2.5 V.

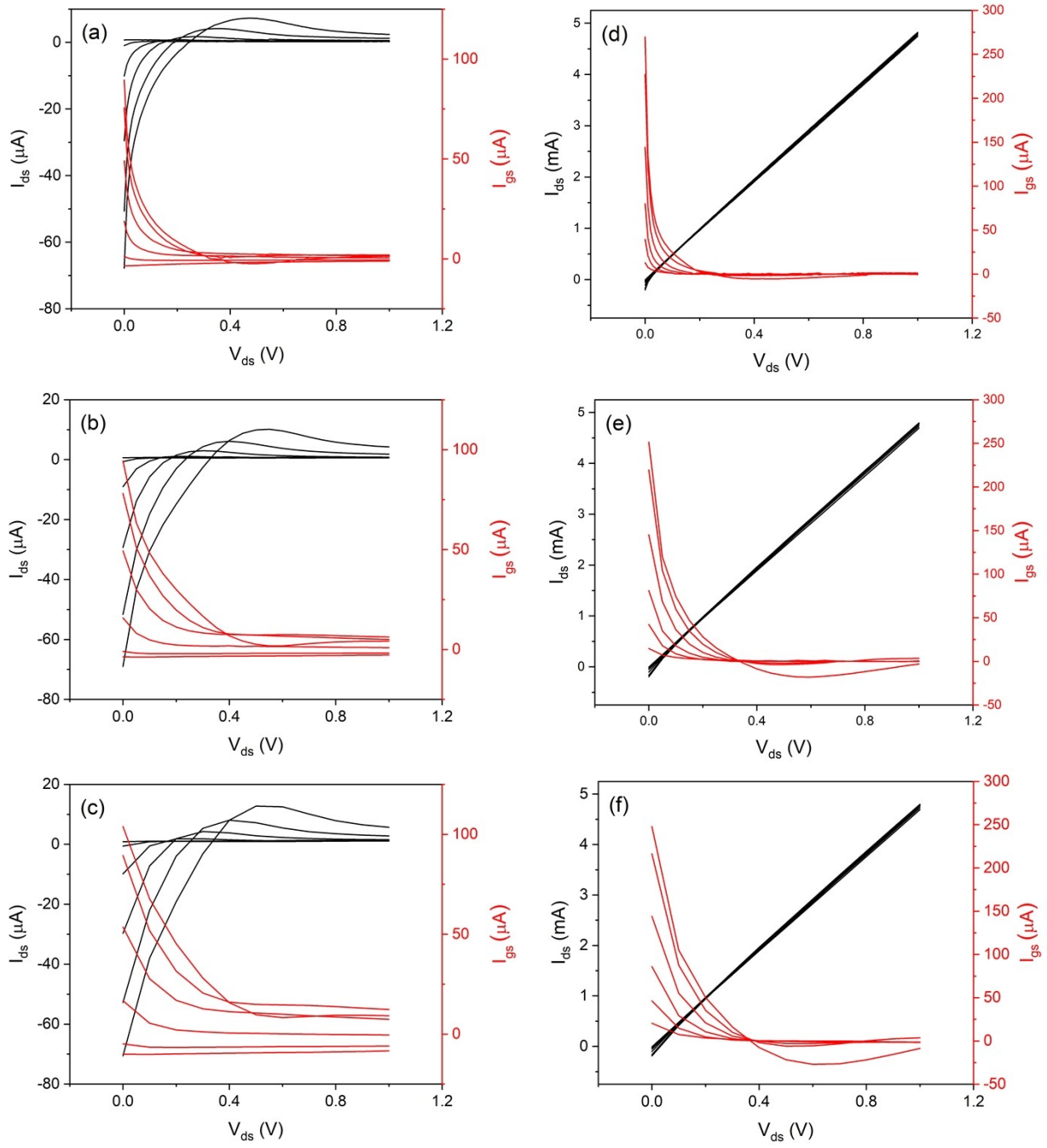

Fig. S7 Output characteristics of LTO at V_{ds} scan rate of 10 mV s^{-1} (a), 50 mV s^{-1} (b), 100 mV s^{-1} (c). Output characteristics of LTO+C at V_{ds} scan rate of 10 mV s^{-1} (d), 50 mV s^{-1} (e), 100 mV s^{-1} (f). V_{gs} from 1.5 V to 2.5 V with 0.2 V increment.

In the absence of carbon conductive additive, capacitive currents dramatically affect the output characteristics in LTO IGTs. In the presence of carbon conductive additive, the additive determines the shapes of the output characteristics of LTO+C transistors (that feature a clear ohmic behavior).

TiO_2
10 mV s^{-1}
without Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2.5 V	7×10^{-4} A	backward	7×10^{4}
off	0.9 V	1×10^{-8} A	forward	

with Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2 V	8×10^{-4} A	forward	ca 10^{4}
off	0.8 V	5×10^{-8} A	forward	

50 mV s^{-1}
without Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2.4 V	6×10^{-4} A	backward	3×10^{4}
off	1 V	2×10^{-8} A	forward	

with Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2 V	8×10^{-4} A	forward	3×10^{3}
off	0.7	3×10^{-7} A	forward	

100 mV s^{-1}
without Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2.4 V	6×10^{-4} A	backward	6×10^{3}
off	0.9 V	1×10^{-7} A	forward	

with Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2.5 V	8×10^{-4} A	forward	2×10^{3}
off	0.9 V	4×10^{-7} A	forward	

LTO
1 mV s^{-1}
with Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2.5 V	7×10^{-7} A	backward	1.7×10^{2}
off	1.8 V	4×10^{-9} A	forward	

LTO with CARBON
1 mV s^{-1}
with Li^+

	V_{gs}	I_{ds}	scan	on/off
on	2.5 V	4.7×10^{-3} A	backward	1.06
off	1.5 V	4.5×10^{-3} A	forward	

Table S1. Highest values of **on/off** for the IGTs investigated in this work calculated from the transfer characteristics in Figure 2 and Figure 4. The values of on/off depend on the specific transistor channel material (TiO_2, LTO, LTO+C), on the sweeping rate of $V_{gs,}$ and the type of loop (clockwise or anticlockwise) featured by the I_{ds} vs. V_{gs} transfer characteristics.