Supporting Information

Optimization of Two-Dimensional Channel Thickness in Nanometer-Thick SnO_2-Based Top-Gated Thin-Film Transistors using Electric Field Thermopower Modulation: Implications for Flat-Panel Displays

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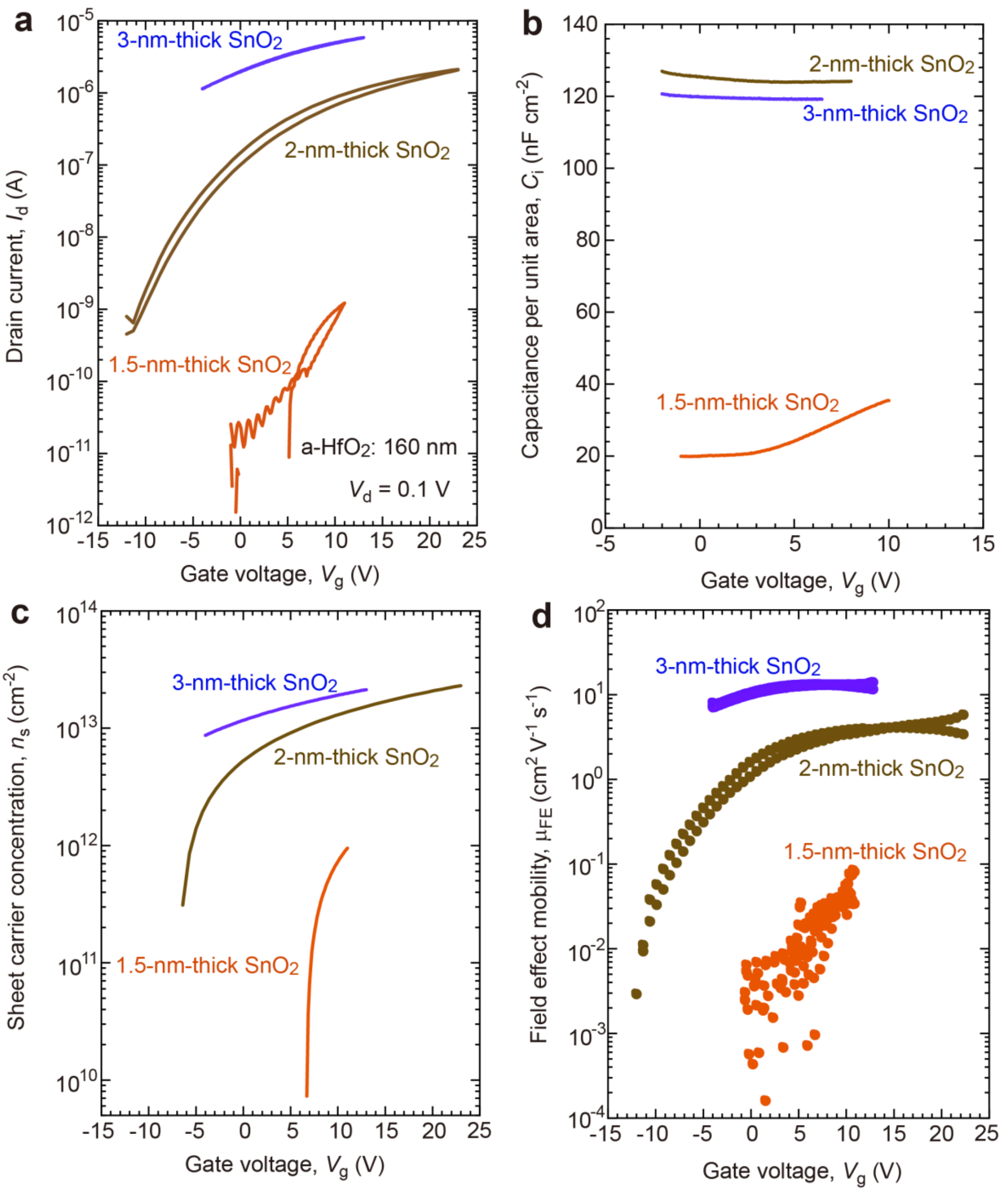

Figure S1. Transistor characteristic of the 1.5-nm-, 2-nm-, and 3-nm-thick a-SnO_2 TFTs with 160-nm-thick HfO_2 gate insulators. Changes in (a) the I_d (V_d = +0.1 V), (b) C_i (20 Hz), (c) the n_s, and the μ_{FE} as function of V_g. Note that the 2-nm-thick a-SnO_2 TFT shows the best transistor characteristics among three samples.

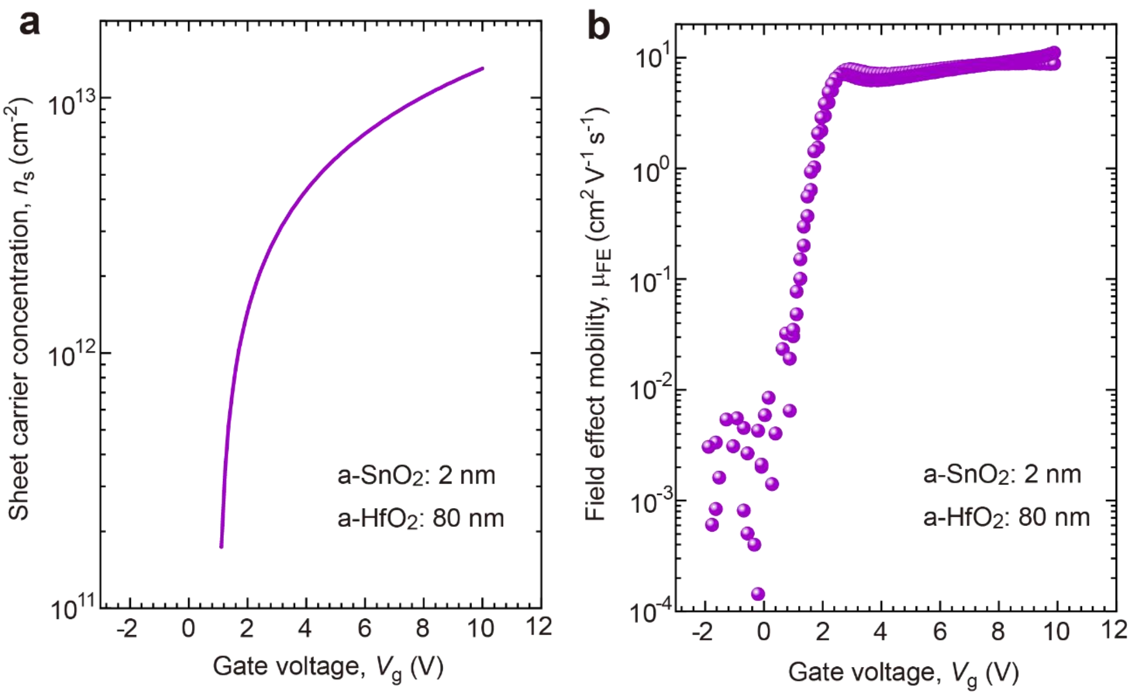

Figure S2. Transistor characteristics of the 2-nm-thick a-SnO_2 TFT with 80-nm-thick a-HfO_2 gate insulator. Changes in (a) the n_s and (b) the μ_{FE} as function of V_g. The μ_{FE} reaches ~10 cm^2 V^{-1} s^{-1}.

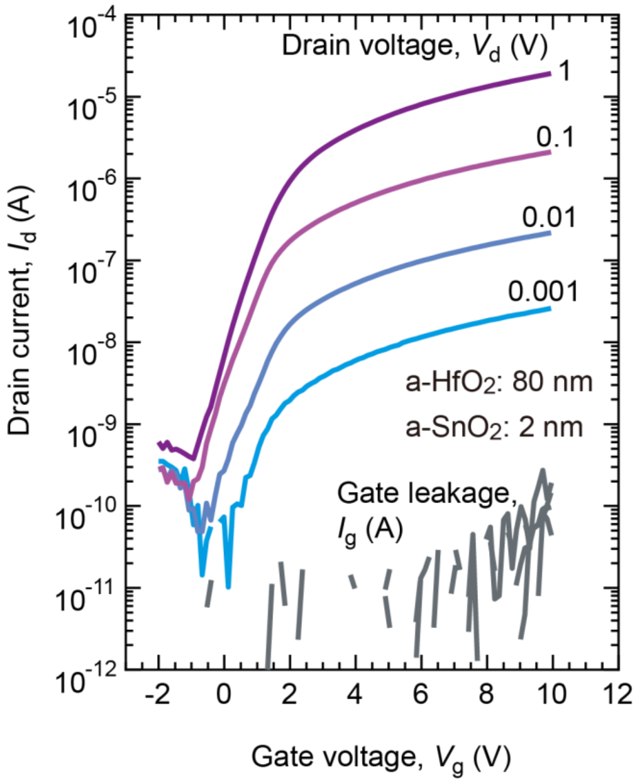

Figure S3. Transfer characteristics curves of the 2-nm-thick a-SnO_2 TFT with 80-nm-thick a-HfO_2 gate insulator with various V_d. The measurements were performed in air.

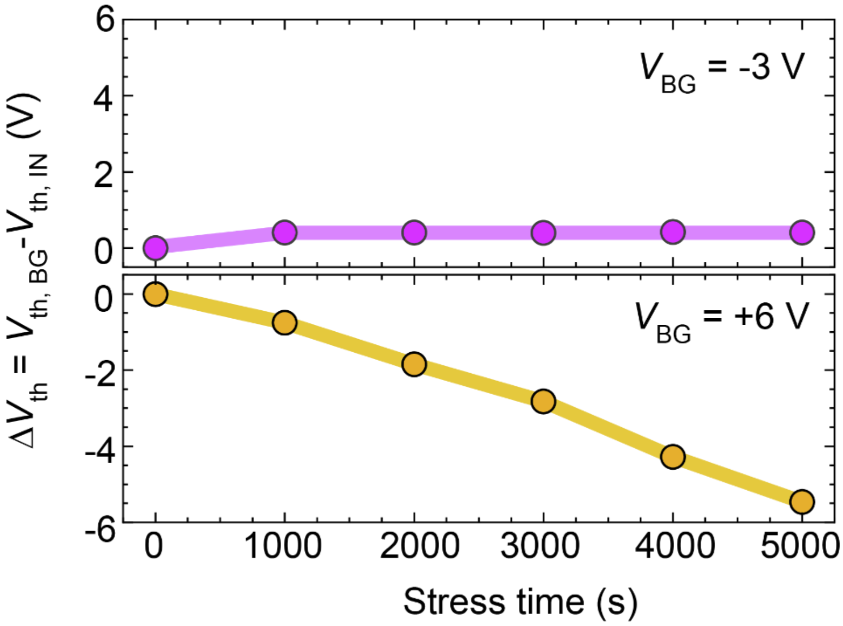

Figure S4. Threshold voltage shift ($\Delta V_{th} = V_{th,\ BG} - V_{th,\ IN}$) of the 2-nm-thick top gated a-SnO_2 TFT with 80-nm-thick a-HfO_2 gate insulator under V_{BG} = –3 V (NGBS) and V_{BG} = +6 V (PGBS) as a function of stress time. The measurements were performed in air.

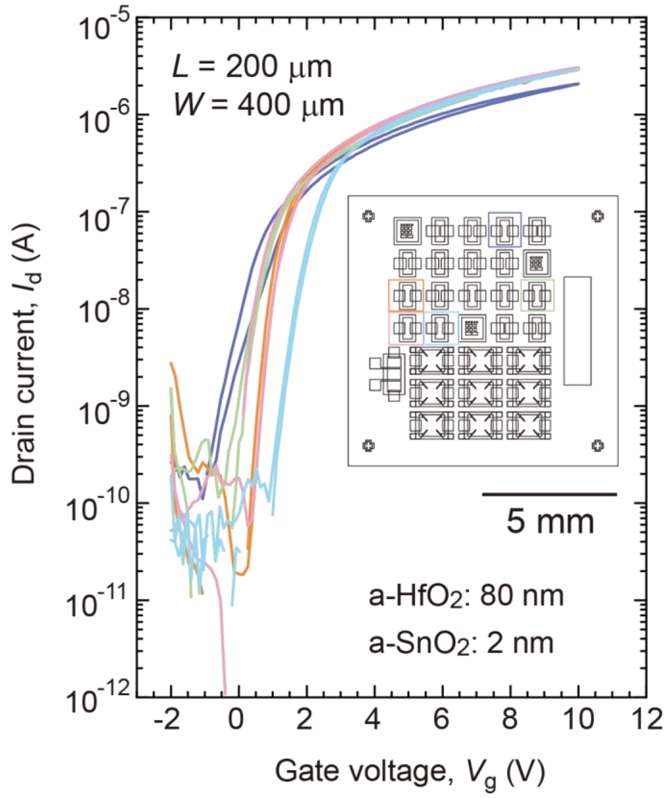

Figure S5. Transfer characteristics curves of several 2-nm-thick a-SnO_2 TFTs with 80-nm-thick a-HfO_2 gate insulator on the same substrate. The measurements were performed in air.

TABLE S1. Structure, on-off current ratio, threshold gate voltage (V_{th}), subthreshold swing factor (*S.S.*), field effect mobility (μ_{FE}), fabrication method for SnO_2 TFTs.

Sample	Structure	On/off ratio	V_{th} (V)	*S.S.* (mV/decade)	μ_{FE} ($cm^2V^{-1}s^{-1}$)	Fabrication method	year
Ta-doped SnO_2 nanowires	Bottom-gate	10^5	−9	312	179	Catalyst-mediated vapor-liquid solid (VLS)	2007[1]
Sb-doped SnO_2 nanocrystal	Bottom-gate	3×10^4	−1	200	158	radio frequency (RF) magnetron sputtering	2009[2]
Undoped SnO_2 polycrystal film	Bottom-gate	2.2×10^6	1.72	260	96.4	ALD	2014[3]
Undoped SnO_2 film	Bottom-gate	4.5×10^7	−20	623	35.4	radio frequency (RF) magnetron sputtering	2015[4]
Undoped SnO_2 film	Bottom-gate	2.3×10^7	+0.27	110	147	Physical vapor deposition	2016[5]
Undoped SnO_2 film	Bottom-gate	10^7	−45	-	12	ALD	2019[6]
Undoped amorphous SnO_2 film	Bottom-gate	10^8	−0.38	114	99.2	Sputtering	2019[7]
Undoped amorphous SnO_2 film	Bottom-gate	10^5	−14	650	20	PLD	2020[8]
Undoped amorphous SnO_2 film	Top-gate	10^5	+0.65	230	10	PLD	This work

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