Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Supplementary Information

Electronic influence of ultrathin aluminum oxide on the transistor device performance of binary indium/tin oxide films.

M. Isabelle Büschges,[a] Vanessa Trouillet,[b] Jörg J. Schneider*[a]

Table S1 Binding energies of the core levels Al 2*p*, Sn 3*d*, In 3*d* and O 1*s* for the thin-films ITAO 1-3.

	ITAO 1	**ITAO 2**	**ITAO 3**
	BE [eV]	BE [eV]	BE [eV]
Al $2p_{3/2}$	73.8	73.9	74.0
Al $2p_{1/2}$	74.4	74.5	74.6
Sn $3d_{5/2}$	486.6	486.6	486.8
In $3d_{5/2}$	444.5	444.5	444.5
O 1*s* M_x-O_y In_2O_3/SnO_2	530.1	530.1	530.1
O 1*s* M_x-O_y Al_2O_3	531.7	531.5	531.2
O 1*s* M-OH	532.7	532.6	532.5

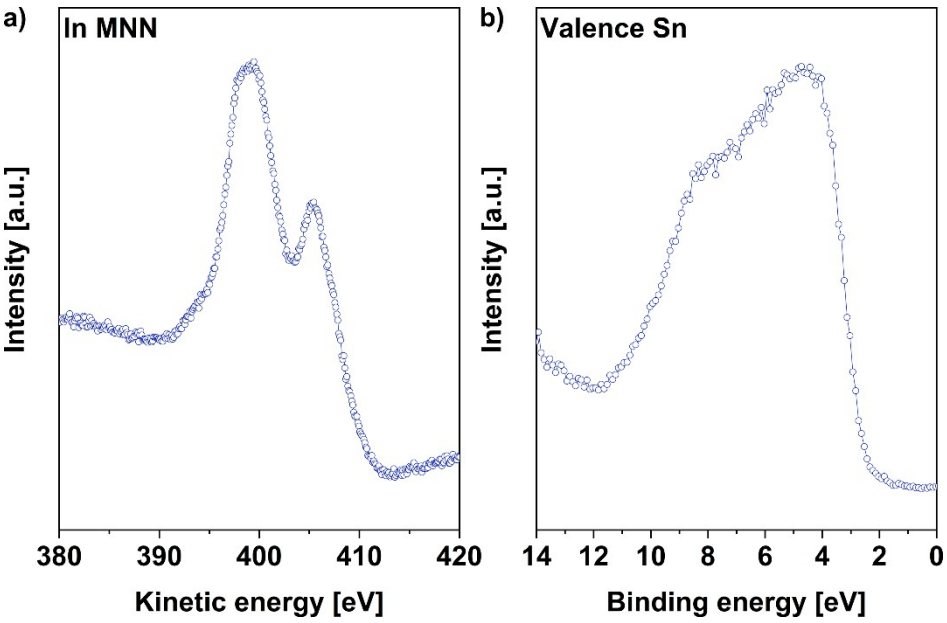

Fig. S1 Auger lines of In and valence band of Sn for the heterostructure ITAO 2.

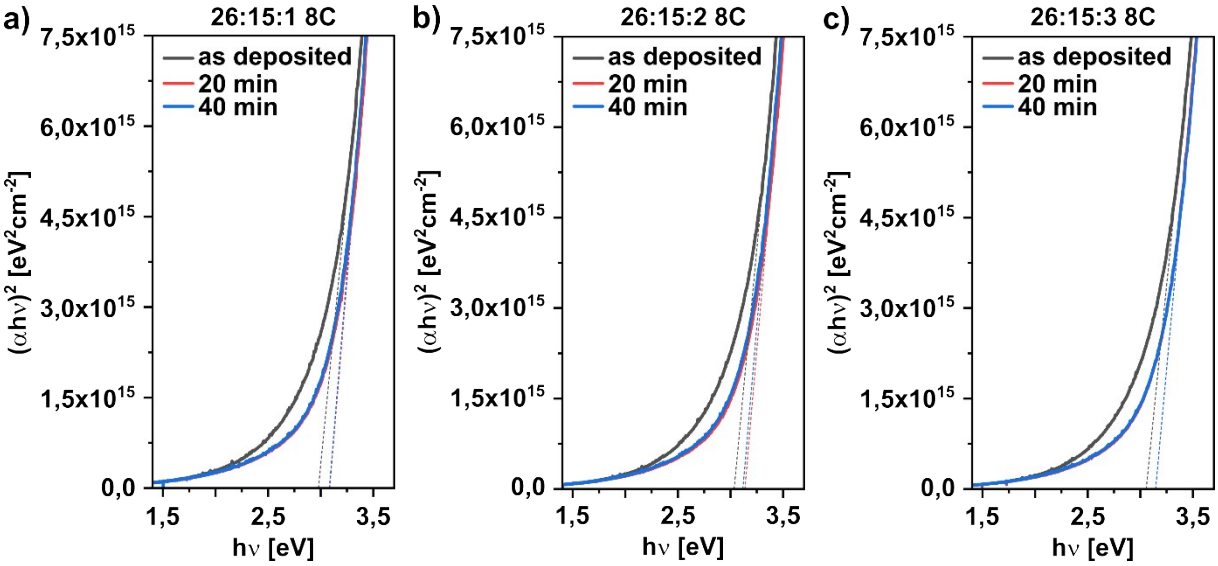

Fig. S2 Tauc plots for the thin-films a) 26:15:1, b) 26:15:2, and c) 26:15:3 as-deposited, annealed for 20 min and 40 min at 400°C.

Table S2 Calculated band gaps depending on post-deposition annealing time and corresponding film thickness.

	Eg [eV]			Film thickness [nm]		
Composition $In_2O_3/SnO_2/Al_2O_3$	**As deposited**	**20 Min @400°C**	**40 Min @400°C**	**As deposited**	**20 Min @400°C**	**40 Min @400°C**
26:15:1	2.98	3.09	3.08	12.91	12.53	12.52
26:15:2	3.04	3.14	3.12	14.56	14.06	14.06
26:15:3	3.06	3.15	3.15	15.80	15.33	15.30

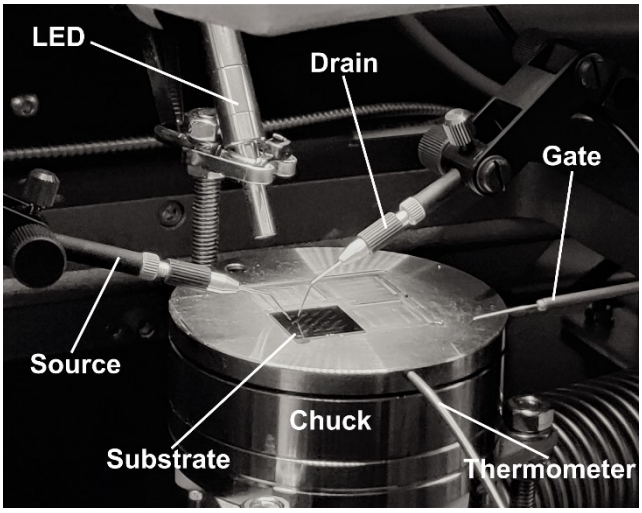

Fig. S3 Measuring setup consisting of a temperature controllable chuck, equipped with thermometer. Source, drain, and gate probes, as well as the LED fixture for the illumination experiments is shown.

Table S3 Dependence of the transistor parameters V_{on} and I_{off} on the illumination energies ranging from 2.0 to 3.7 eV.

	26:15:1		**26:15:2**		**26:15:3**	
Energy [eV]	**V_{on} [V]**	**I_{off} [A]**	**V_{on} [V]**	**I_{off} [A]**	**V_{on} [V]**	**I_{off} [A]**
Dark	-5.4	$1.14 \cdot 10^{-6}$	-1.7	$5.48 \cdot 10^{-8}$	-1.1	$3.27 \cdot 10^{-9}$
2.0	-5.7	$1.18 \cdot 10^{-6}$	-1.8	$5.63 \cdot 10^{-8}$	-1.1	$3.49 \cdot 10^{-9}$
2.3	-6.0	$1.21 \cdot 10^{-6}$	-2.0	$5.76 \cdot 10^{-8}$	-1.1	$3.56 \cdot 10^{-9}$
2.6	-6.0	$1.24 \cdot 10^{-6}$	-2.2	$5.92 \cdot 10^{-8}$	-1.2	$3.68 \cdot 10^{-9}$
3.1	-6.6	$1.29 \cdot 10^{-6}$	-2.5	$6.19 \cdot 10^{-8}$	-1.6	$3.89 \cdot 10^{-9}$
3.2	-7.1	$1.34 \cdot 10^{-6}$	-3.0	$6.55 \cdot 10^{-8}$	-1.9	$4.18 \cdot 10^{-9}$
3.4	-7.2	$1.41 \cdot 10^{-6}$	-3.4	$7.07 \cdot 10^{-8}$	-2.4	$4.60 \cdot 10^{-9}$
3.7	-7.6	$1.47 \cdot 10^{-6}$	-4.0	$7.58 \cdot 10^{-8}$	-2.4	$5.00 \cdot 10^{-9}$

For calculating the charge carrier density the following ε-values were used:

Table S4 Values used and obtained for the calculation of the charge carrier densities.

	ε	n_{free} ITAO 1	n_{free} ITAO2	n_{free} ITAO3
In_2O_3	8.9[1]	$2.95 \cdot 10^{16}$	$2.24 \cdot 10^{16}$	$2.01 \cdot 10^{16}$
SnO_2	7.031[2]	$3.74 \cdot 10^{16}$	$2.84 \cdot 10^{16}$	$2.54 \cdot 10^{16}$

With $C_{ox} = 3.64 \cdot 10^{-8}$ F·cm^{-2} and T = 298 K.

1 I. Hamberg and C. G. Granqvist, Evaporated Sn-doped In2O3 films: Basic optical properties and applications to energy-efficient windows, *J. Appl. Phys.*, 1986, **60**, R123-R160.

2 M. A. Yıldırım, S. T. Yıldırım, E. F. Sakar and A. Ateş, Synthesis, characterization and dielectric properties of SnO2 thin films, *Spectrochim. Acta - A: Mol. Biomol. Spectrosc.*, 2014, **133**, 60–65.