



A Morphological Study of Solvothermally Grown SnO₂ Nanostructures for Application in Perovskite Solar Cells

Zhuldyz Yelzhanova ^{1,†}, Gaukhar Nigmatova ^{2,†}, Damir Aidarkhanov ¹, Bayan Daniyar ¹, Bakhytzhan Baptayev ³, Mannix P. Balanay ⁴, Askhat N. Jumabekov ⁵ and Annie Ng ^{1,*}

¹ Department of Electrical and Computer Engineering, School of Engineering and Digital Sciences, Nazarbayev University, Kabanbay Batyr Ave. 53, Nur-Sultan 010000, Kazakhstan; zhuldyz.yelzhanova@nu.edu.kz (Z.Y.); aidarkhanov@nu.edu.kz (D.A.); bayan.daniyar@nu.edu.kz (B.D.)

² Department of Chemical and Materials Engineering, School of Engineering and Digital Sciences, Nazarbayev University, Kabanbay Batyr Ave. 53, Nur-Sultan 010000, Kazakhstan; gaukhar.nigmatova@nu.edu.kz

³ National Laboratory Astana, Kabanbay Batyr Ave. 53, Nur-Sultan 010000, Kazakhstan; bbaptayev@nu.edu.kz

⁴ Department of Chemistry, School of Sciences and Humanities, Nazarbayev University, Kabanbay Batyr Ave. 53, Nur-Sultan 010000, Kazakhstan; mannix.balanay@nu.edu.kz

⁵ Department of Physics, School of Sciences and Humanities, Nazarbayev University, Kabanbay Batyr Ave. 53, Nur-Sultan 010000, Kazakhstan; askhat.jumabekov@nu.edu.kz

* Correspondence: annie.ng@nu.edu.kz

† These authors contributed equally to this work.

Table S1. The dimensions of SnO₂ nanostructures grown in different pressure by using different sizes of autoclave reactors.

Condition	Length (nm)			Diameter of SnO ₂ Bundle (nm)		
	Min (nm)	Max (nm)	Mean ± SD (nm)	Min (nm)	Max (nm)	Mean ± SD (nm)
-						
25 mL, 130 psi	383	478	425±21	1092	1484	1220±140
50 mL, 87 psi	278	349	319±19	244	572	389±82
100 mL, 72.5 psi	108	156	131±12	40	112	60±21

Table S2. The dimensions of SnO₂ nanostructures grown on substrates mounted at different orientations.

Condition	Length (nm)			Diameter of SnO ₂ Bundle (nm)		
	Min (nm)	Max (nm)	Mean ± SD (nm)	Min (nm)	Max (nm)	Mean ± SD (nm)
-						
45°	87	178	135±30	42	156	69±28
90°	86	154	116±21	42	185	91±41
0°	105	152	132±13	46	91	64±14

Table S3. The dimensions of SnO₂ nanostructures grown in a ternary solvent system with different DI water to ethanol ratios.

Condition	Length (nm)			Diameter of SnO ₂ Bundle (nm)		
	<i>Min</i> (nm)	<i>Max</i> (nm)	<i>Mean ± SD</i> (nm)	<i>Min</i> (nm)	<i>Max</i> (nm)	<i>Mean ± SD</i> (nm)
-						
1:9	79	186	139±26	47	215	81±42
3:7	103	178	136±18	50	98	73±15
1:1	102	154	131±16	45	83	61±11
7:3	69	129	100±19	26	70	41±12
9:1	30	77	48±14	NA	NA	NA

Table S4. The dimensions of SnO₂ nanostructures grown on different types of seed layers.

Condition	Length (nm)		
	<i>Min</i> (nm)	<i>Max</i> (nm)	<i>Mean ± SD</i> (nm)
-			
Magnetron Sputtering	104	155	128±14
NP	102	200	164±26
QD	72	136	109±16

Table S5. The dimensions of SnO₂ nanostructures grown in different acetic acid concentrations.

Condition	Length (nm)		
	<i>Min</i> (nm)	<i>Max</i> (nm)	<i>Mean ± SD</i> (nm)
-			
6 mL	91	151	119±16
6.5 mL	105	153	128±13
9.75 mL	55	119	80±17

Table S6. The dimensions of SnO₂ nanostructures grown with different growth durations.

Condition	Length (nm)			Diameter of SnO ₂ Bundle (nm)		
	<i>Min</i> (nm)	<i>Max</i> (nm)	<i>Mean±SD</i> (nm)	<i>Min</i> (nm)	<i>Max</i> (nm)	<i>Mean ± SD</i> (nm)
-						
6 hrs	83	138	119±14	37	109	62±22
12 hrs	101	153	129±16	45	91	65±11
24 hrs	97	154	130±15	39	146	79±33
12+12 hrs	131	312	219±49	56	202	109±40

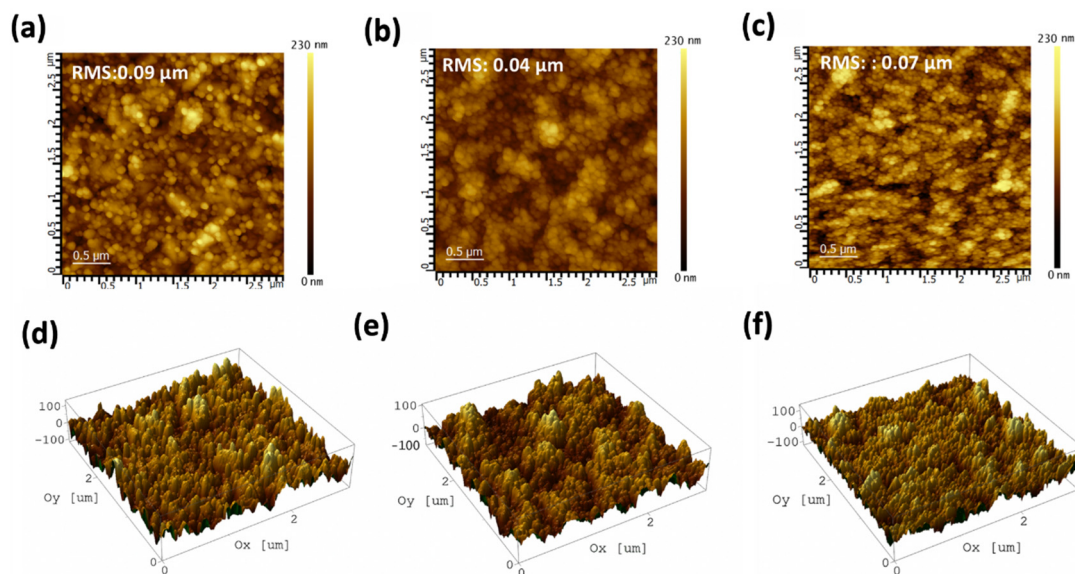


Figure S1. The topography of SnO_2 nanorods obtained by the atomic force microscopy for the samples mounted in various orientations during solvothermal growth: (a,d) 45° ; (b,e) 90° ; (c,f) 0° .