Bifunctional electrocatalyst of low-symmetry mesoporous titanium dioxide modified with cobalt oxide for oxygen evolution and reduction reactions

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__Supporting materials__

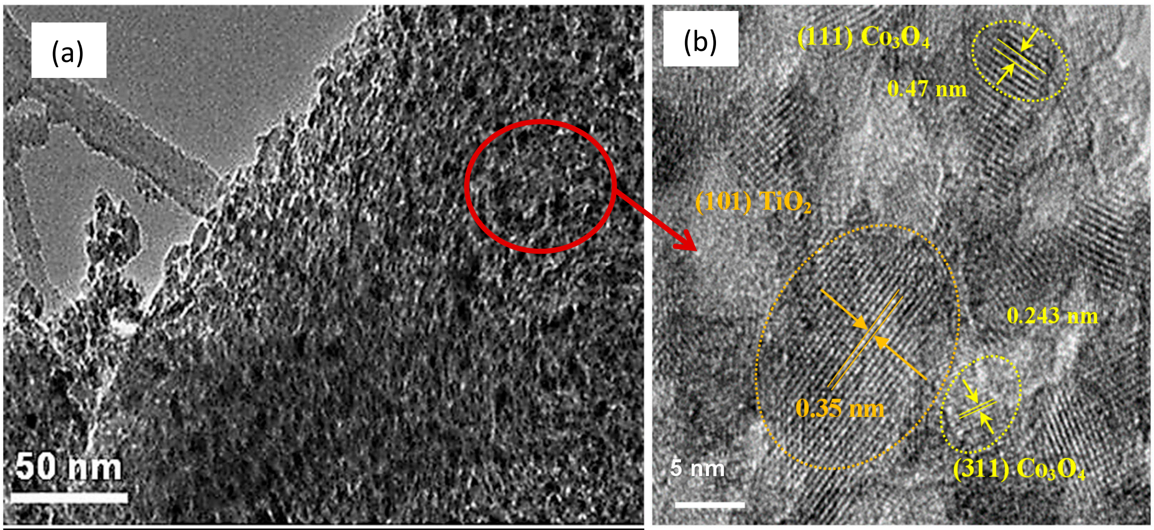

Figure S1 (a) TEM image for Co_3O_4(7)/*lsm*-TiO_2 with cobalt oxide nanoparticles, and (b) High magnification TEM showing the crystal fringes of the TiO_2 and Co_3O_4 nanoparticles.

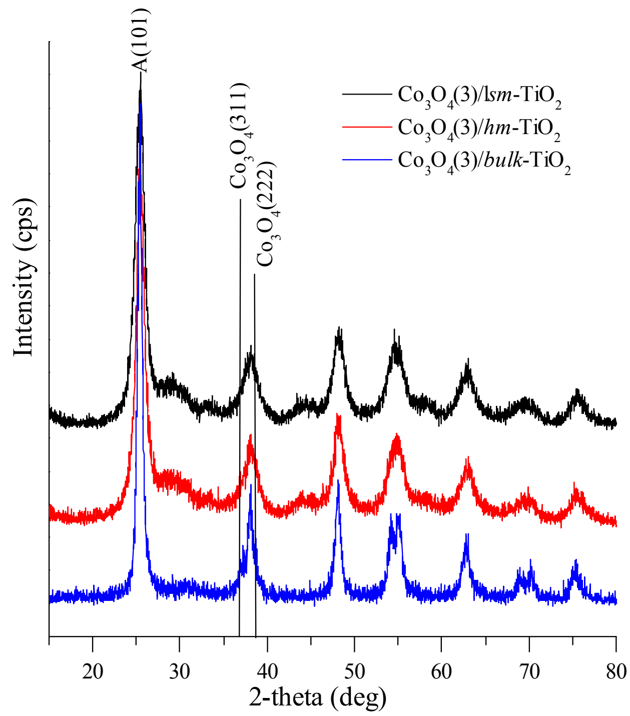

Figure S2 XRD spectra of Co_3O_4(3)/*lsm*-TiO_2 , Co_3O_4(3)/*hm*-TiO_2 and Co_3O_4(3)/*bulk*-TiO_2.

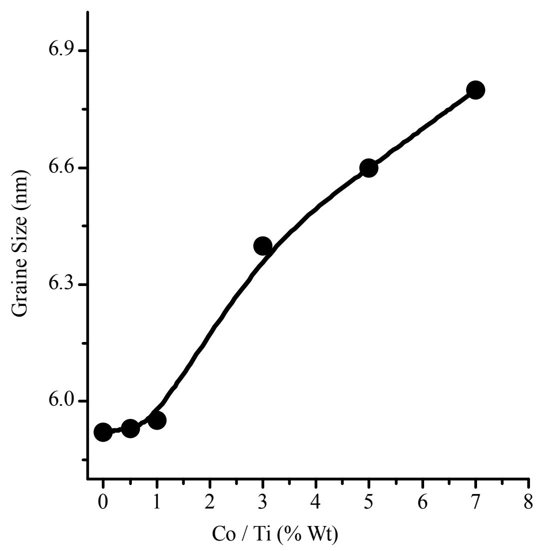

Figure S3 plot for the effect of varying cobalt content on the average crystallite size of the Co_3O_4(x)/*lsm*-TiO_2 catalysts.

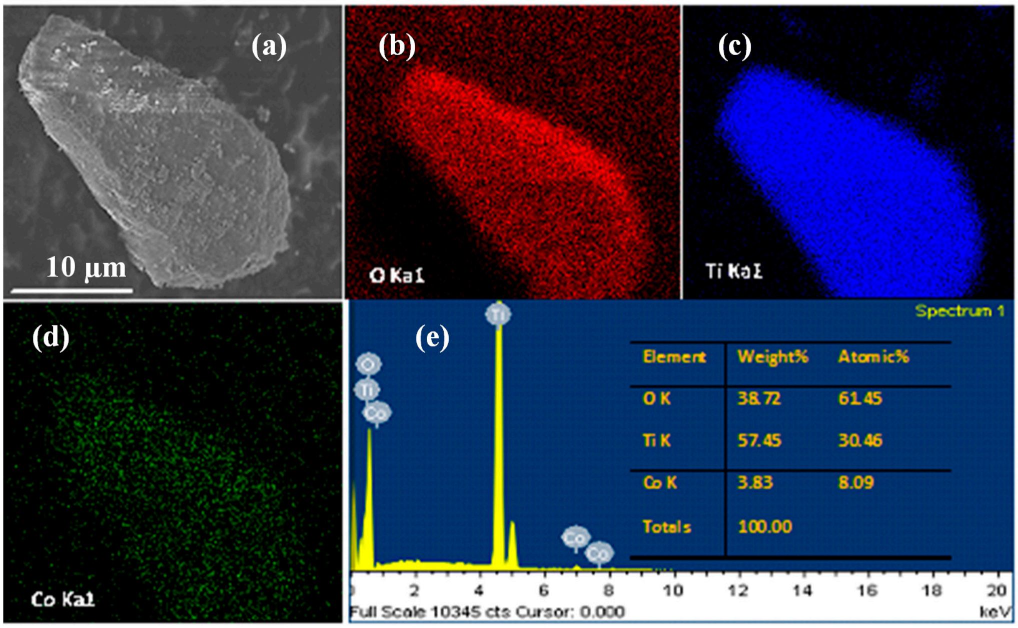

Figure S4 SEM-EDX elements mapping of Co(3)/hm-TiO_2.

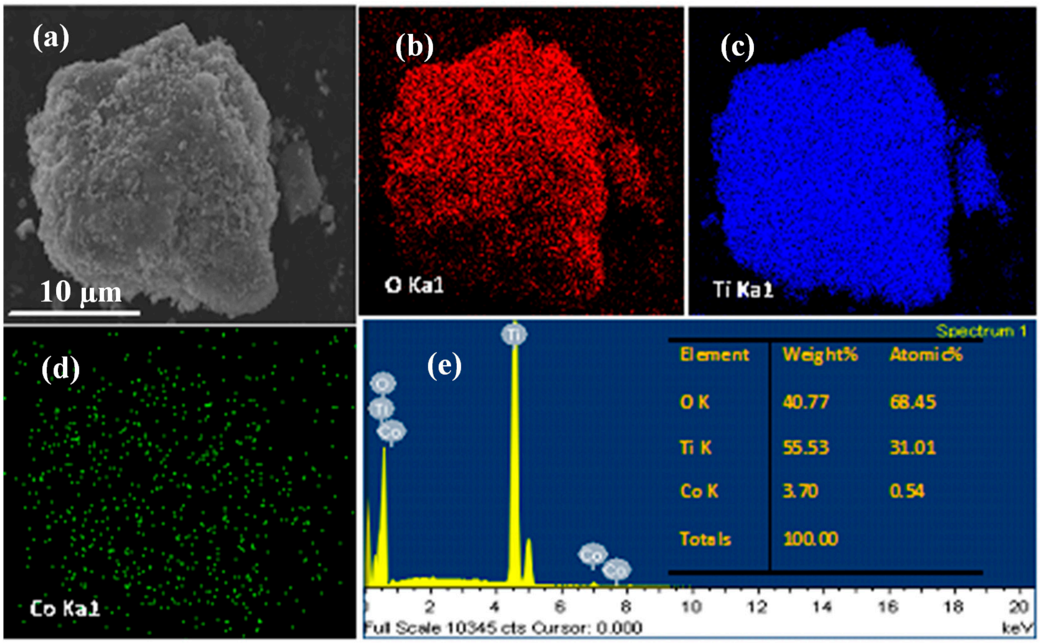

Figure S5 SEM-EDX elements mapping of Co(3)/*lsm*-TiO_2 catalyst.

Table S1. The atomic contents of Co, Ti, O in *lsm*-TiO_2 and $Co_{3.0}$/*lsm*-TiO_2 according to the XPS reports.

Catalyst	O /atom %	Ti /atom %	Co /atom %	Co/(Co+Ti) %
lsm-TiO_2	64.57	35.43	0	0
Co_3O_4(3)/*lsm*-TiO_2	70.90	28.25	0.85	2.92

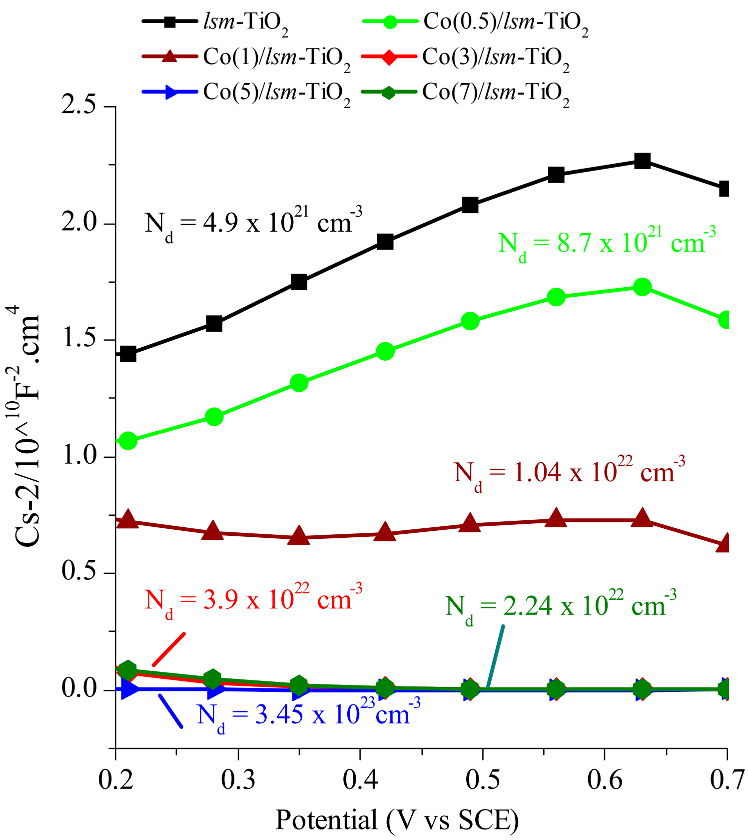

Figure S6 Mott–Schottky plot of pure *lsm*-TiO_2 and Co_3O_4 modified *lsm*-TiO_2 electrodes measured at 500 Hz.

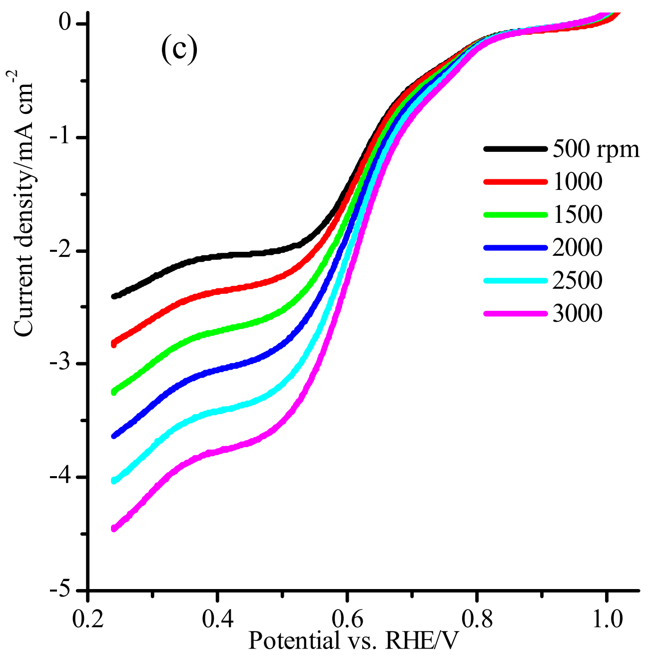

Figure S7 LSV curves of Co_3O_4(3)/*lsm*-TiO_2 at a scan rate of 10 mV s^{-1} and a rotation speed of 500, 1000, 1500, 2000, 2500, and 3000 rpm in O_2-saturated 1.0 M KOH,

Turnover frequency (TOF) calculation method

The calculation of mass activity, specific activity, and turnover frequency (TOF) in this work is based on literature published by Gao *et al.* [52], and the details are shown below.

The values of mass activity (A g^{-1}) were calculated from the catalyst loading m (0.8 mg cm_{geo}^{-2}) and the measured current density j (mA cm_{geo}^{-2}) at η = 0.370 V:

$$\text{mass activity} = \frac{j}{m}$$

The values of specific activity (mA cm^{-2}) were calculated from the BET surface area SBET (m^2 g^{-1}), catalyst loading m (0.8 mg cm_{geo}^{-2}), and the measured current density j (mA cm_{geo}^{-2}) at η = 0.370 V:

$$\text{specific activity} = \frac{j}{10.S_{BET}.m}$$

The values of turnover frequency (TOF) were calculated by assuming that every metal atom is involved in the catalysis (lower TOF limits were calculated):

$$\text{TOF} = \frac{jS_{geo}}{4F.n}$$

Here, j (mA cm_{geo}^{-2}) is the measured current density at η = 0.370 V, S_{geo} (1.0 cm^2) is the surface area of FTO electrode, the number 4 means 4 electrons per mole of O_2, F is Faraday's constant (96485.3 C mol^{-1}), and n is the moles of the metal atom on the electrode calculated from m and the molecular weight of the coated catalysts.

Table S2 comparison of OER performance for Co_3O_4(3)/*lsm*-TiO_2 with other reported OER electrocatalysts in alkaline media.

Catalyst	**[KOH]/mole**	**Onset potential (V vs RHE)**	**η at 10 mA cm^{-2} (mV)**	**Tafel slope mV dec^{-1}**	**Mass activity at 1.6 V vs RHE (A g^{-1})**	**Ref.**
Co_3O_4(3)/*lsm*-TiO_2	0.1	1.65	445	87	4.25	This Work
	1.0	1.48	350	54	41.8	
	5.0	1.45	243	71	88.9	
Co-TiO_2 NCs	0.1	1.60	N/A	67	N/A	S1
Cobalt- Black TiO_2 NAs	1.0	1.582	352	65	N/A	S2
Co–S/Ti mesh	1.0	1.549	361	64	N/A	S3
Co_3O_4/MWCNT	0.1	1.51	390	65	N/A	S4
***meso*-Co_3O_4-35**	0.1	1.520	411	80	63	S5
***meso*-Co_3O_4-100**	0.1	1.53	426	66	53	S5
Co_3O_4 NPs	0.1	~ 1.57	449	63	31	S5
CoO/CNT	1.0	1.54	550	108	43	S6
***meso*-Co_3O_4**	1.0	N/A	476	N/A	22	S7
6 nm Co_3O_4 NPs	1.0	-	328	~70	35	S8
***meso*-Co_3O_4**	1.0	1.58	353	84	21.3 at 0.4 V	S9
Co_3O_4/Fe_3O_4 mesoporous	1.0	-	322	78	34.4 at 0.4 V	S9
Co_3O_4@CoO SC	0.5	-	430	89	234 at 0.4 V	S10
$NiCo_2O_4$/NiO	1.0	1.55	361	61	29.31 at 1.65 V	S11
$NiCo_2O_4$	1.0	-	431	139	8.05 at 1.65 V	S11

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