Supporting Information

Fabrication of TiO_2 Layer by Spray Layer-by-Layer for Electron Transport Layer in Bulk Heterojunction Solar Cells

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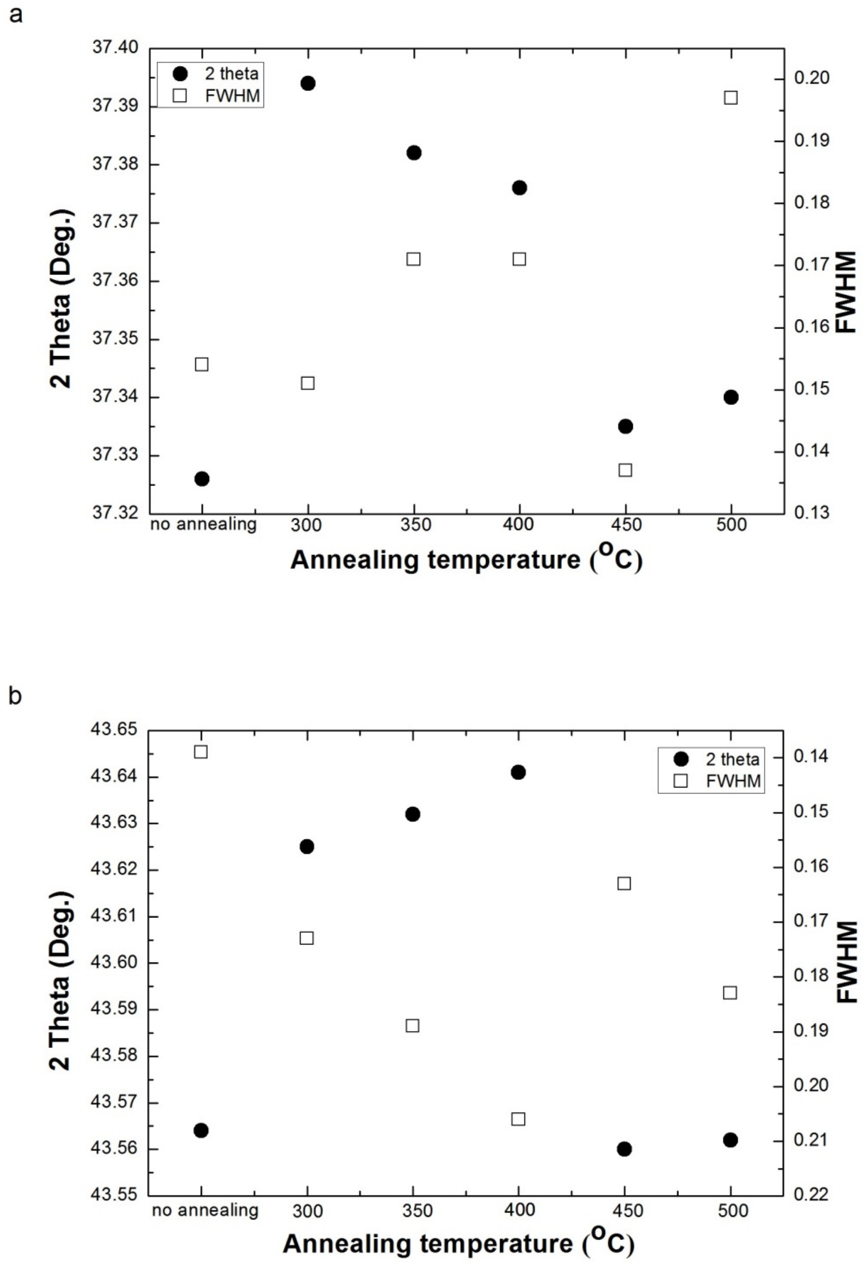

Figure SS1. 2 theta and FWHM of (a) TiO_2 anatase phase and (b) TiO2 rutile phase when fabricated with Spray LBL on glass and annealing at difference temperature

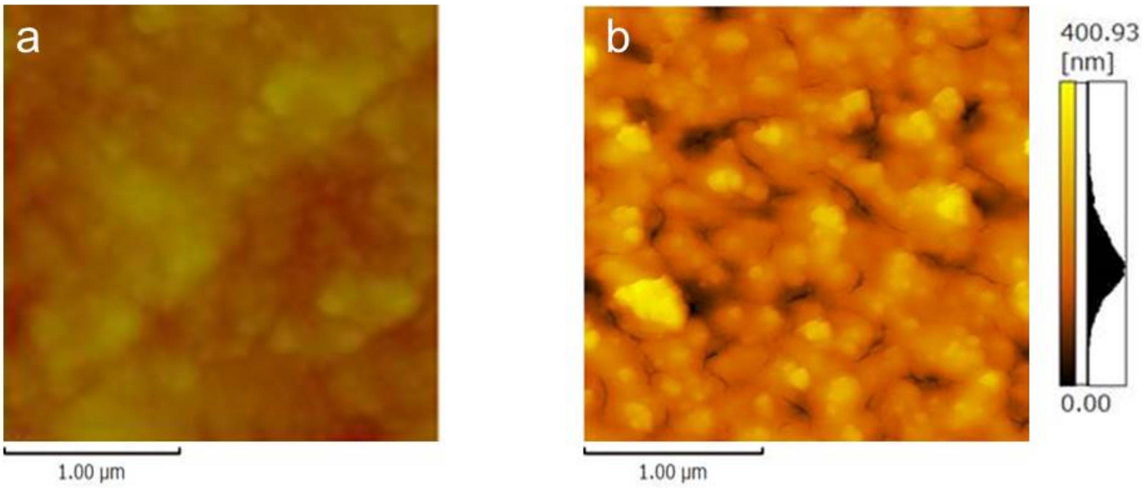

Figure SS2. AFM image of (a) FTO layer, Rms of surface=32 nm (b) TiO_2 layer on FTO when fabricated with Spray LBL and annealing at 450 ^{o}C, Rms of surface=50 nm

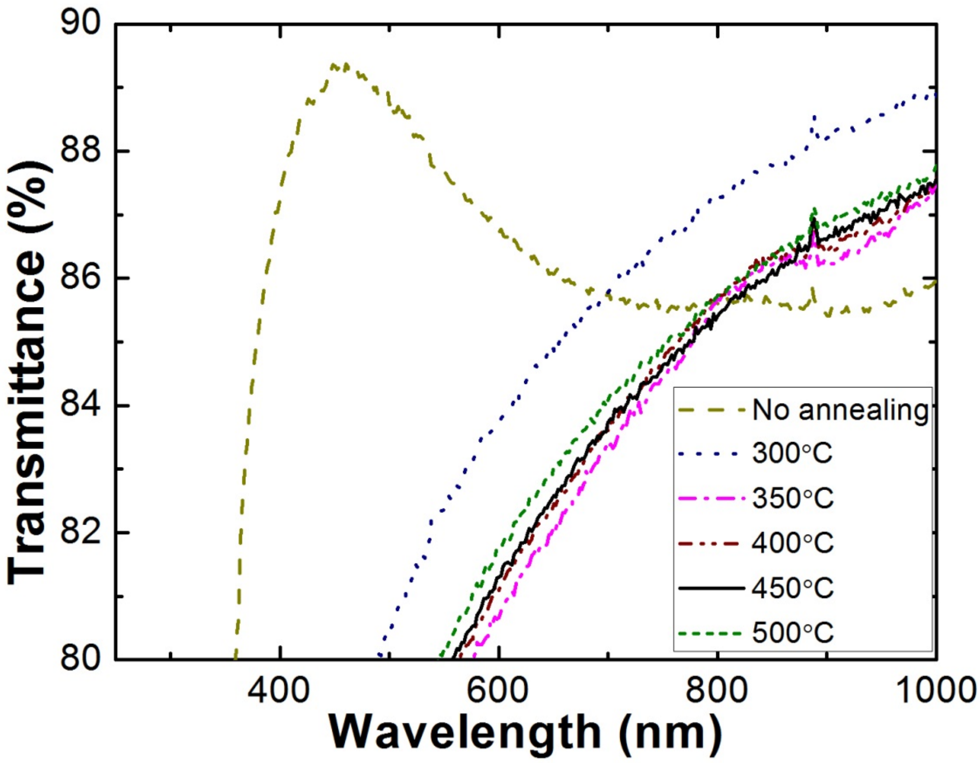

Figure SS3. Transmittance of TiO_2 layer fabricate by spray LBL technique on glass substrate and annealing with difference temperature

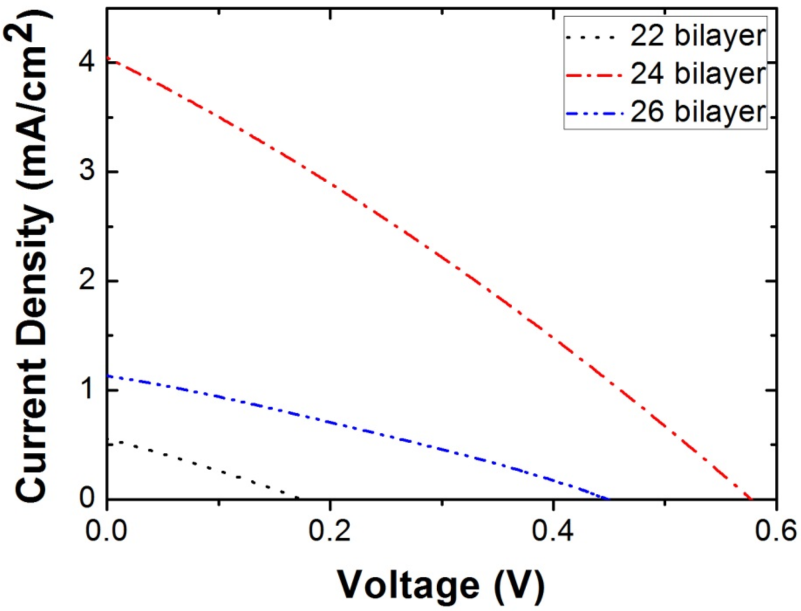

Figure SS4. The Current density –Voltage characteristic of bulk heterojunction solar cells when fabricate the electron transport layer by spray-LBL without annealing and change the thickness of TiO_2 layer by changing number of bilayers.

Table S1 Haze value and transmittance of FTO, TiO_2/FTO and TiO_2/FTO after annealing at 450 ^{o}C

	Transmittance (%)	Haze (%)
FTO	79.81	13.61
TiO_2/FTO	81.1	19.31
TiO_2/FTO after annealing	79.3	22.1

Table S2 The properties of solar cell when fabricated the electron transport layer with spray-LBL method without annealing and change the number of bilayer

Number of bilayer	Jsc (mA/sq.)	Voc (V)	FF	Eff (%)	TiO_2 Thickness (nm)
20	-	-	-	-	100
22	0.55	0.18	0.275	0.027	110
24	4.02	0.58	0.302	0.704	120
26	1.13	0.46	0.295	0.153	130

Fitting J-V graph via MATLAB program

We use one diode model to fitting the graph of J-V characteristic to estimates parameters : series resistance(R_s), shunt resistance(R_{sh}), ideality factor(n), saturation current density (J_0) and photo current density (J_{ph}) by using equation S5. When the x axis is Voltage and y axis is current density. The equivalent circuit was shows in Figure SS5, flow chart for graph fitting show in Figure SS6, example of graph fitting show in Figure SS7.

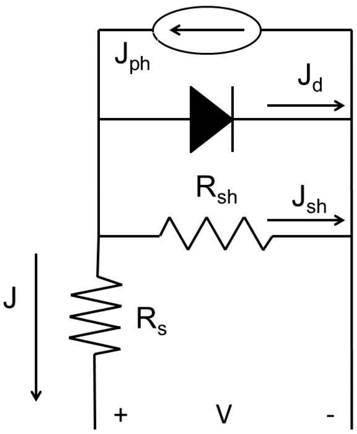

Figure SS5 Equivalent circuit of one diode model

From Figure SS4, the output current can write in equation:

$$J = J_{ph} - J_d - J_{sh} \tag{S1}$$

When

$$J_d = J_0(e^{\frac{q(V+JR_s)}{n_1 kT}} - 1) \tag{S2}$$

And

$$J_{sh} = (V + JR_s)/R_{sh} \tag{S3}$$

Replace S2 and S3 in S1;

$$J = J_{ph} - J_0(e^{\frac{q(V+JR_s)}{nkT}} - 1) - (V + JR_s)/R_{sh} \tag{S4}$$

$$0 = J_{ph} - J_0\left(e^{\frac{q(V+JR_s)}{nkT}} - 1\right) - \frac{V + JR_s}{R_{sh}} - J \tag{S5}$$

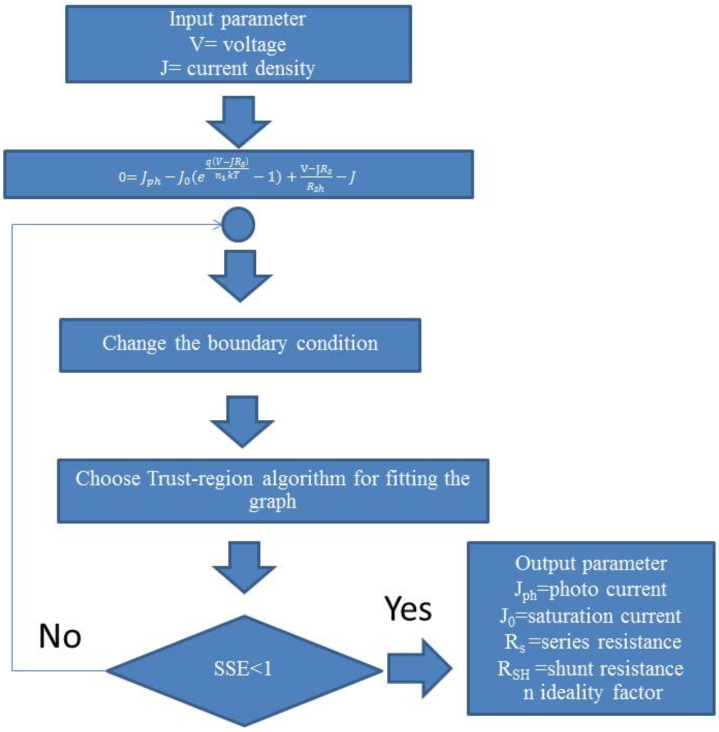

Figure SS6 Figure SS5Flow chart for fitting parameter: R_s, R_{sh}, n, J_0 and J_{ph} by using one diode model with Trust-region algorithm.

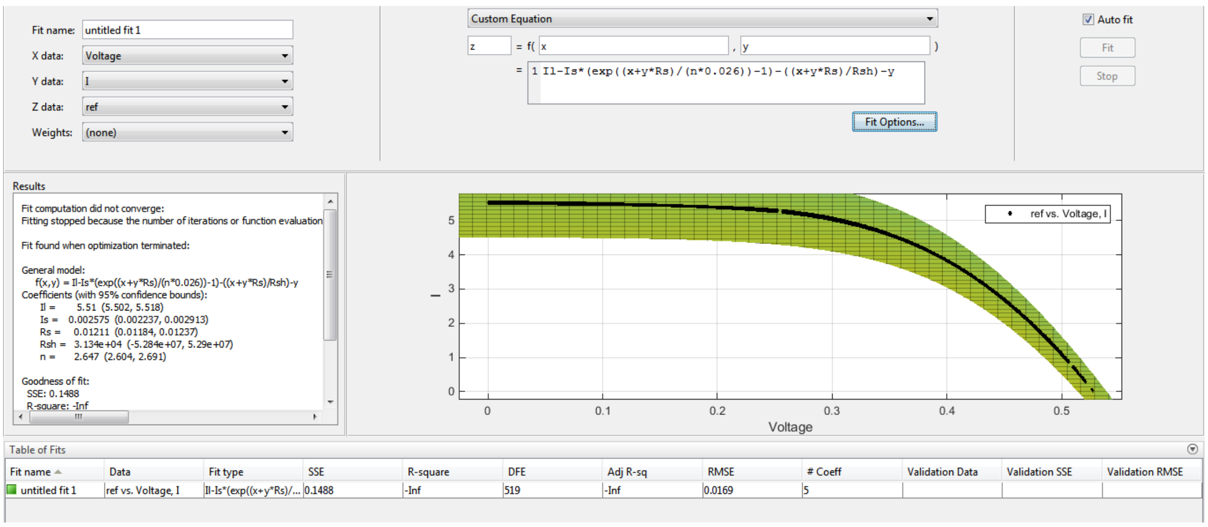

Figure SS7 Example of graph fitting via cftool in Matlab program. X data is voltage, Y data is current density and ref is 0.