

Supporting information for

**Extremely low trap-state energy level perovskite solar cells
passivated by NH₂-POSS with improved efficiency and stability**

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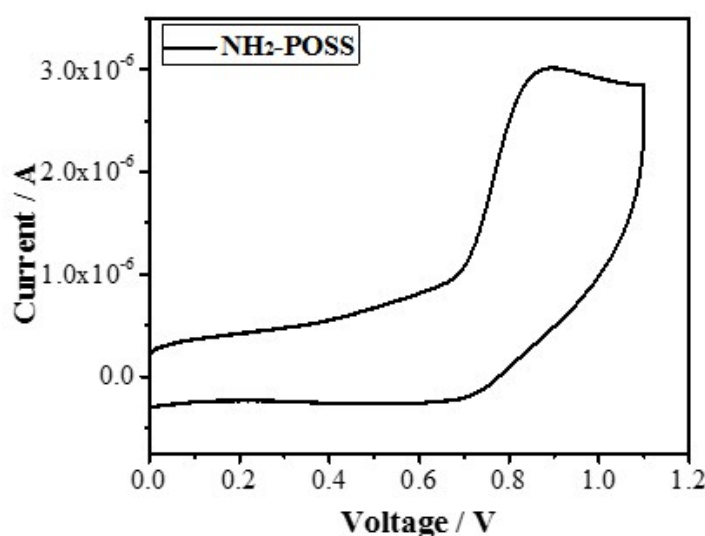


Figure S1 The cyclic voltammogram of (NH₂-POSS in CH₂Cl₂) at Pt electrode. Scan rate 50mV/s, T=25°C, reference electrode is Ag/AgCl

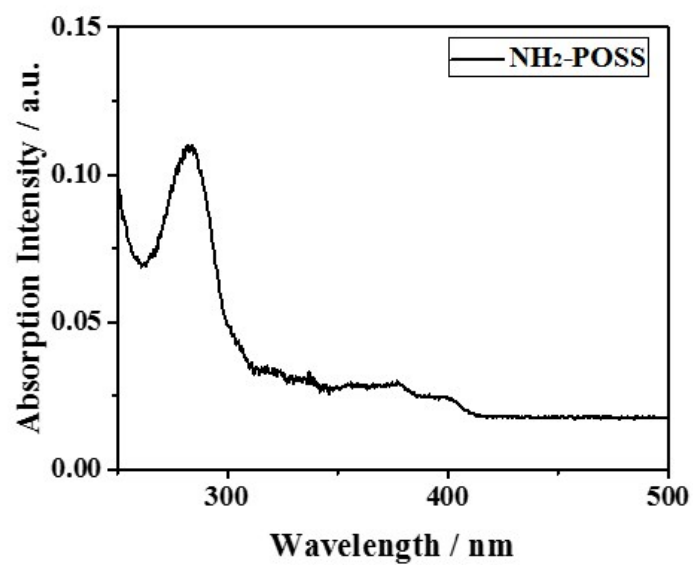


Figure S2 Absorption spectrum of $\text{NH}_2\text{-POSS}$ dissolved in CH_2Cl_2

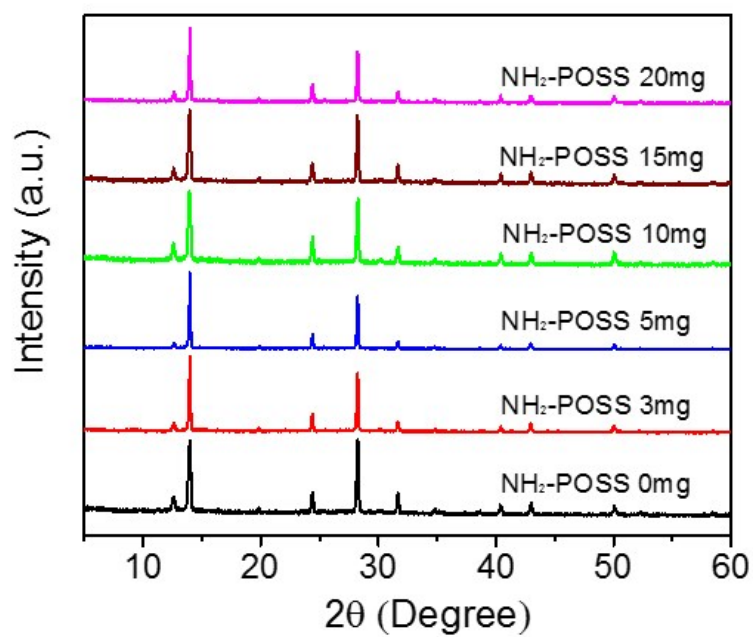


Figure S3 XRD patterns of perovskite films functionalized with different content $\text{NH}_2\text{-POSS}$ on SnO_2 substrate.

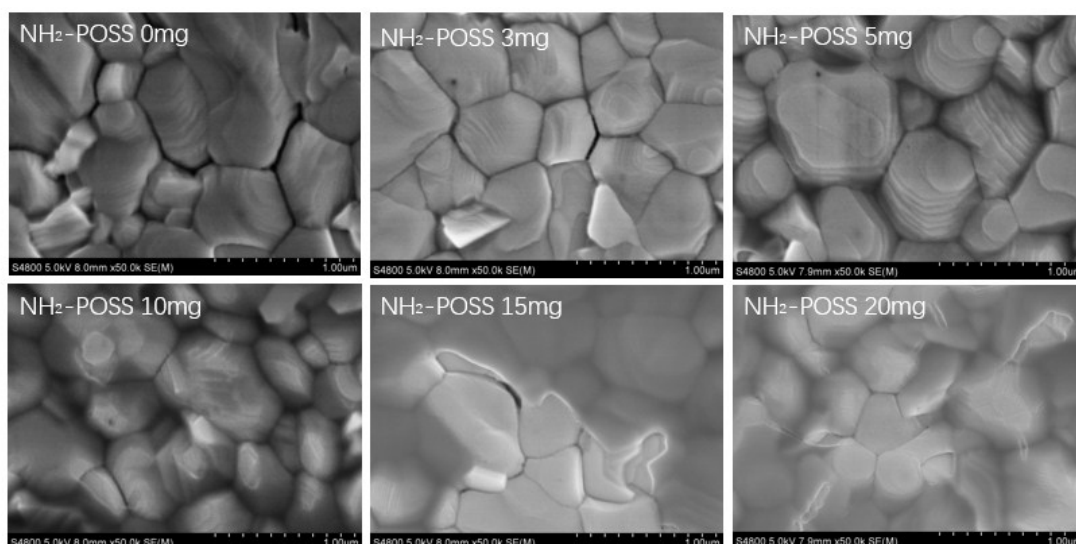


Figure S4 SEM images of perovskite films functionalized with different content NH_2 -POSS.

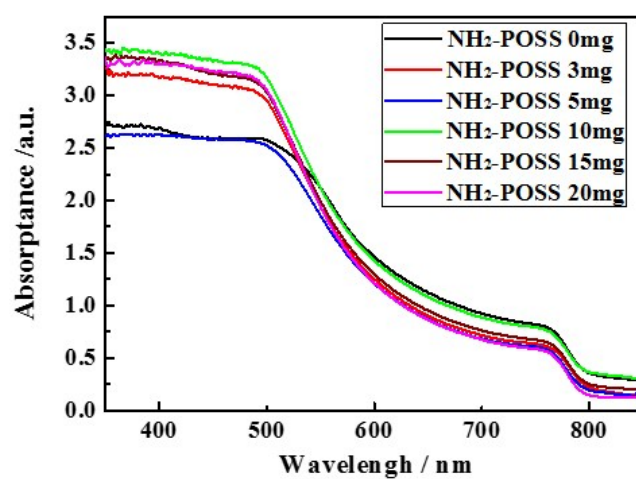


Figure S5 Absorption spectra of perovskite films with various NH_2 -POSS content layer

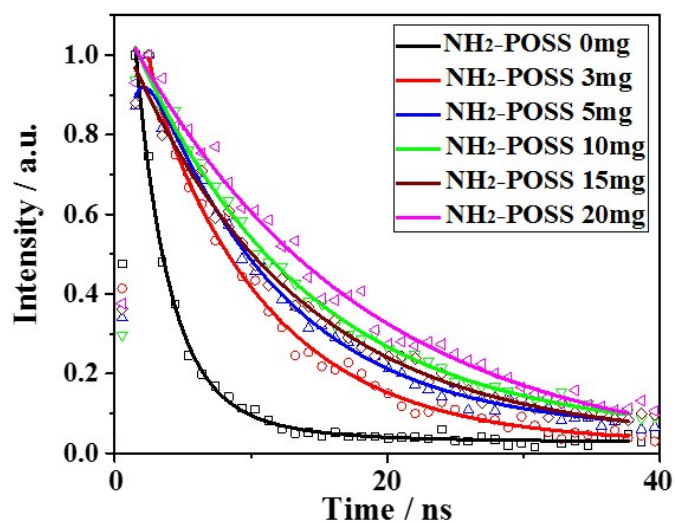


Figure S6 TRPL spectra of corresponding films and HTL on glass substrate.

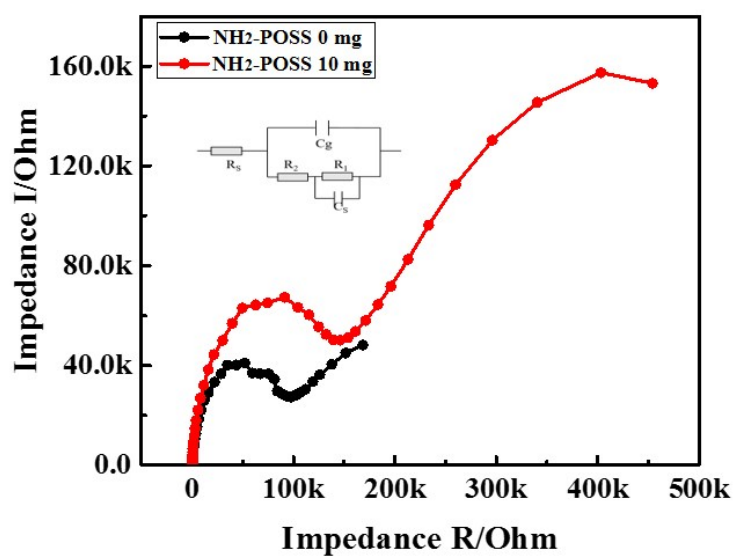


Figure S7 EIS images of control and NH₂-POSS passivation devices. The inset is the simplified equivalent circuit diagram.

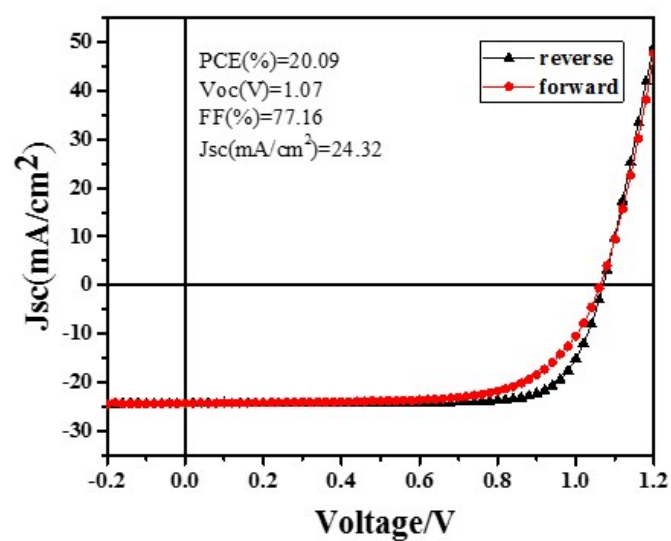


Figure S8 The best device performance of device under reverse scan(black:1.2V-0.2V) and forward scan(red:0V-1.2V)

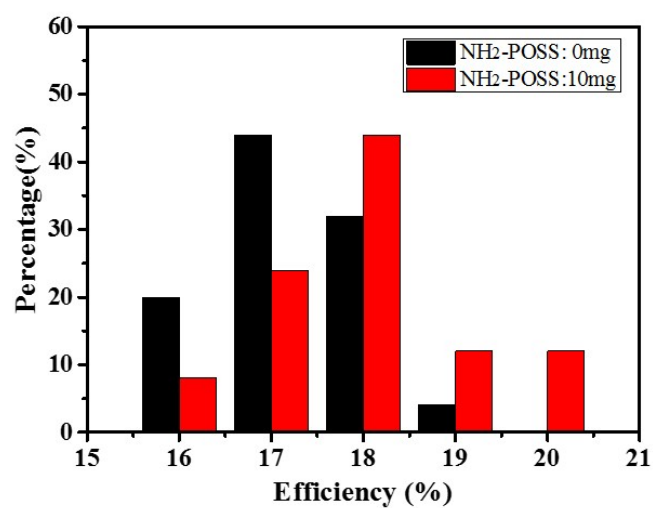


Figure S9 Histogram of PCE distribution in perovskite solar cells with/without NH_2 -POSS modification

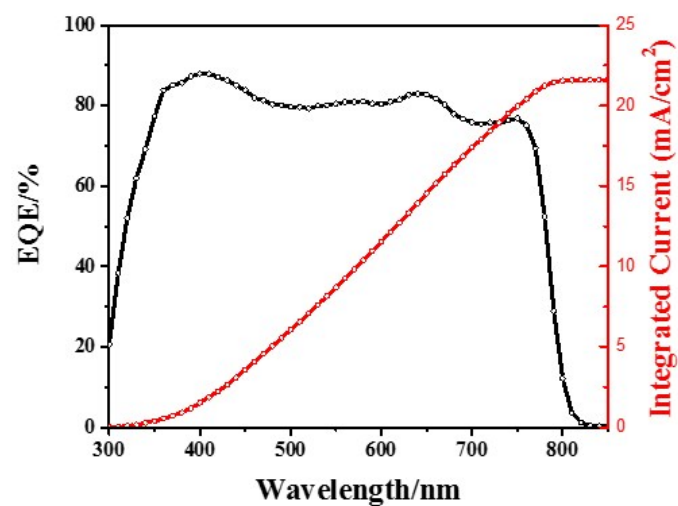


Figure S10. EQE spectra together with integrated J_{SC} of the perovskite solar cell without NH_2 -POSS modification.

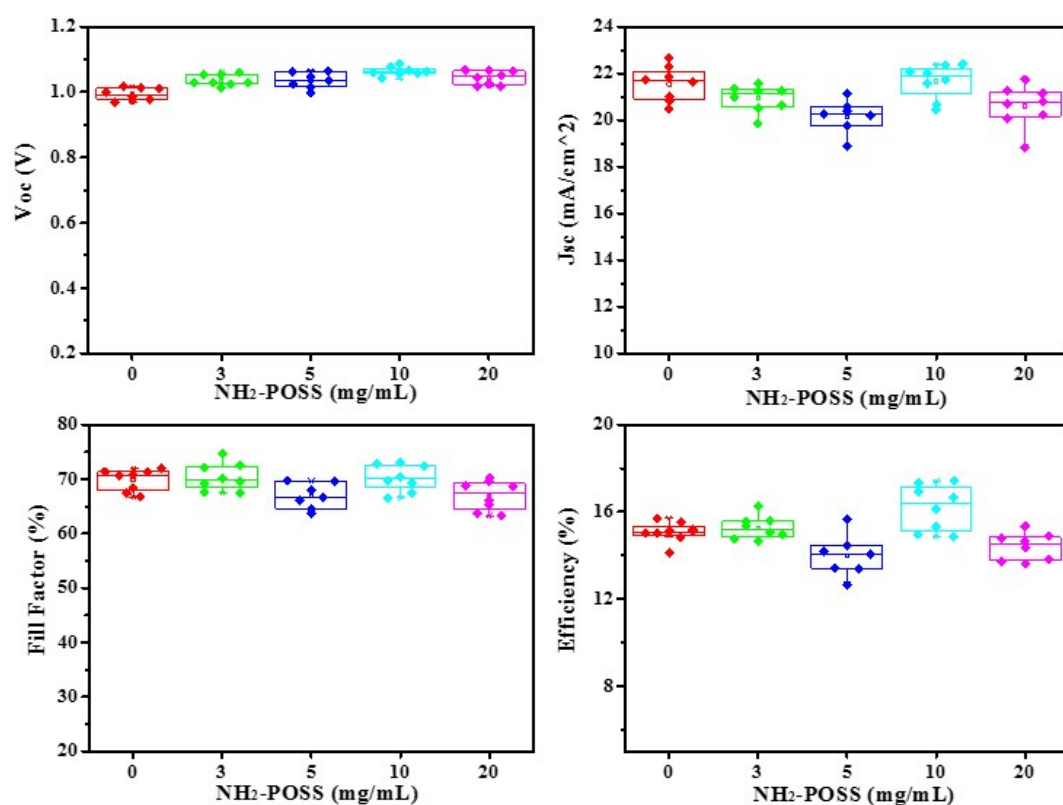


Figure S10 Photovoltaic metrics for 8 devices with different content NH_2 -POSS in CB solvent modification.

Table S1 Device characteristics of perovskite solar cells with different NH_2 -POSS in chlorobenzene solvent modification.

NH_2 -POSS 0mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	0.97	21.85	70.76	15.12
2	0.96	22.65	68.43	15.01
3	1.01	21.70	66.70	14.82
4	0.98	22.27	70.68	15.52
5	1.01	21.64	71.37	15.70
6	1.01	21.00	71.38	15.15
7	1.00	20.82	71.98	14.99
8	0.97	21.41	67.48	14.12

NH2-POSS 3mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	1.02	20.53	69.65	14.64
2	1.01	19.85	74.72	15.02
3	1.02	21.26	67.46	14.75
4	1.05	20.96	67.69	14.96
5	1.02	20.62	72.48	15.36
6	1.02	21.58	70.08	15.56
7	1.05	21.37	69.16	15.55
8	1.05	21.27	72.11	16.25

NH2-POSS 5mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	1.06	19.74	63.69	13.39
2	1.03	20.57	68.02	14.47
3	1.04	20.37	66.58	14.19
4	1.06	21.13	69.71	15.67
5	1.02	20.26	64.57	13.40
6	1.01	18.88	66.11	12.67

7	0.99	20.21	69.61	14.05
8	1.00	20.82	71.98	14.99

NH2-POSS 10mg

Sample	V_{OC} (V)	J_{SC} (mA/cm²)	FF(%)	PCE (%)
1	1.066	22.34	73.10	17.42
2	1.08	21.72	70.49	16.66
3	1.07	20.42	67.50	14.86
4	1.05	22.01	69.33	16.12
5	1.04	21.57	66.53	14.95
6	1.06	20.66	69.72	15.30
7	1.06	22.39	72.86	17.31
8	1.05	22.07	72.38	16.93

NH2-POSS 20 mg

Sample	V_{OC} (V)	J_{SC} (mA/cm²)	FF(%)	PCE (%)
1	1.06	20.22	63.25	13.62
2	1.06	20.80	66.06	14.67
3	1.01	21.14	63.69	13.70
4	1.06	21.26	65.34	14.79
5	1.05	18.83	69.66	13.80
6	1.01	20.07	70.25	14.34
7	1.04	20.69	68.75	14.87
8	1.02	21.74	68.62	15.34

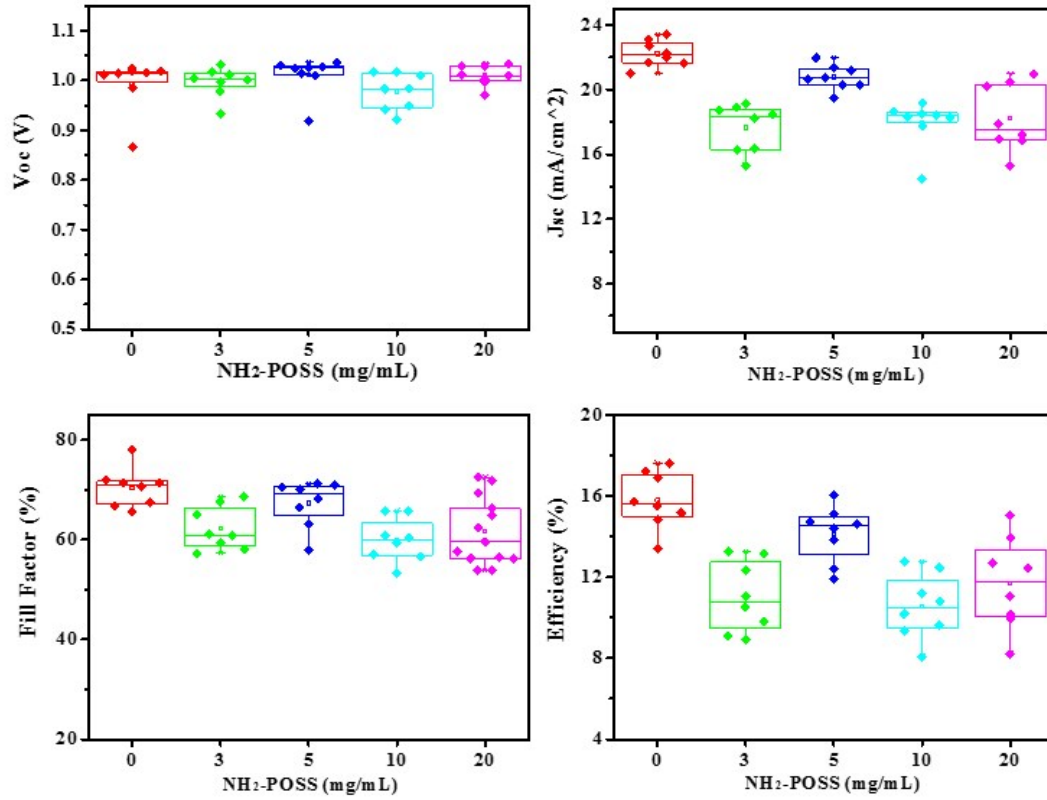


Figure S10 Photovoltaic metrics for 8 devices with different content NH₂-POSS in IPA solvent modification.

Table S2 Device characteristics of perovskite solar cells with different NH₂-POSS in isopropyl alcohol solvent modification.

NH₂-POSS 0mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF (%)	PCE (%)
1	0.86	23.40	65.53	13.40
2	1.01	21.97	77.99	17.62
3	1.02	23.12	70.66	16.89
4	1.01	21.70	66.70	14.82
5	1.01	22.71	74.50	17.23
6	0.98	22.27	70.68	15.52
7	1.01	21.64	71.37	15.70
8	1.01	21.00	71.38	15.15

NH2-POSS 3mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	1.01	16.36	59.29	9.81
2	0.97	16.25	57.24	9.10
3	1.01	19.12	67.60	13.15
4	0.99	18.23	60.73	11.03
5	1.00	15.32	58.03	8.91
6	1.00	18.89	65.08	12.36
7	0.93	18.46	61.05	10.52
8	1.03	18.73	68.65	13.26

NH2-POSS 5mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	1.02	21.37	63.11	13.85
2	1.02	21.96	71.31	16.03
3	1.01	21.19	57.80	12.37
4	1.01	20.30	70.03	14.41
5	1.02	20.70	70.91	15.13
6	1.02	20.29	70.50	14.73
7	1.03	20.66	68.17	14.60
8	0.91	19.48	66.45	11.89

NH2-POSS 10mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	0.98	18.53	59.33	10.8
2	0.92	18.32	57.06	9.63
3	0.94	18.44	53.20	9.32
4	1.01	18.64	65.70	12.46
5	1.01	18.27	60.35	11.21

6	0.94	17.74	60.93	10.17
7	1.01	19.17	65.84	12.75
8	0.98	14.51	56.61	8.08

NH₂-POSS 20mg

Sample	V _{OC} (V)	J _{SC} (mA/cm ²)	FF(%)	PCE (%)
1	1.02	16.84	71.87	12.46
2	1.00	16.95	64.93	11.03
3	0.97	17.23	59.57	9.95
4	1.01	17.89	56.18	10.16
5	1.02	20.48	66.22	13.95
6	1.00	20.17	62.34	12.69
7	1.03	20.97	69.41	15.04
8	0.99	15.27	53.94	8.21

Table S3 The fitting results of the equivalence circuit

NH ₂ -POSS	R _S (Ω cm ²)	C _g (F/cm ²)	R ₂ (Ω cm ²)	C _S (F/cm ²)	R ₁ (Ω cm ²)
10mg	208.8	1.139E-8	1.501E5	9.055E-7	2.624E5
0mg	95.44	1.158E-8	8.259E4	4.408E-7	6.691E4