Multifunctional P-type Additive for Enhanced Efficiency in Perovskite Solar Cells

Liang Wang,†[a] Fengyang Yu,†[e] Shuzhang Yang,†[c] Xiaoyong Cai,[i] Qianji Han,*[d] Qingqing Miao,*[f,g,h] Tingli Ma*[b] and Shuzi Hayase*[a]

[a.] *Info-Powered Energy System Research Center (I-PERC), The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan.*

[b.] *Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology;Fukuoka, 804-8550, Japan.*

[c.] *College of Chemical Engineering, Hebei Normal University of Science & Technology, Qinhuangdao, 066600, P.R. China.*

[d.] *State Key Laboratory of Photovoltaic Science and Technology, Department of Materials Science, Institute of Optoelectronics, Fudan University, Shanghai, 200433, P.R. China.*

[e.] *Dalian National Laboratory for Clean Energy, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, Dalian, 116023, P.R. China.*

[f.] *Beijing Key Laboratory of Ionic Liquids Clean Process, CAS Key Laboratory of Green Process and Engineering, Institute of Process Engineering, Chinese Academy of Sciences, Beijing 100190, P.R. China.*

[g.] *Longzihu New Energy Laboratory, Zhengzhou Institute of Emerging Industrial Technology, Henan University, Zhengzhou 450000, P. R. China.*

[h.] *Langfang Technological Centre of Green Industry, Langfang 065001, P.R. China.*

[i.] *CAS Key Laboratory of Standardization and Measurement for Nanotechnology, CAS Center for Excellence in Nanoscience, National Center for Nanoscience and Technology, Beijing 100190, P. R. China.*

† †These authors contributed equally to this work.

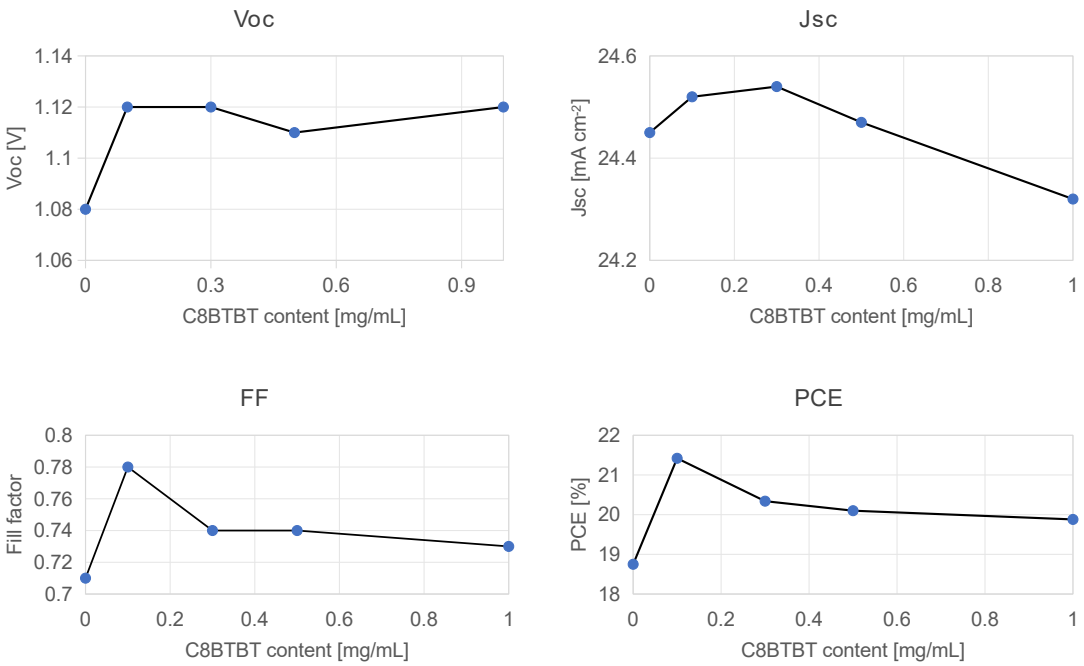

Figure S1 Optimization of C8BTBT concentration

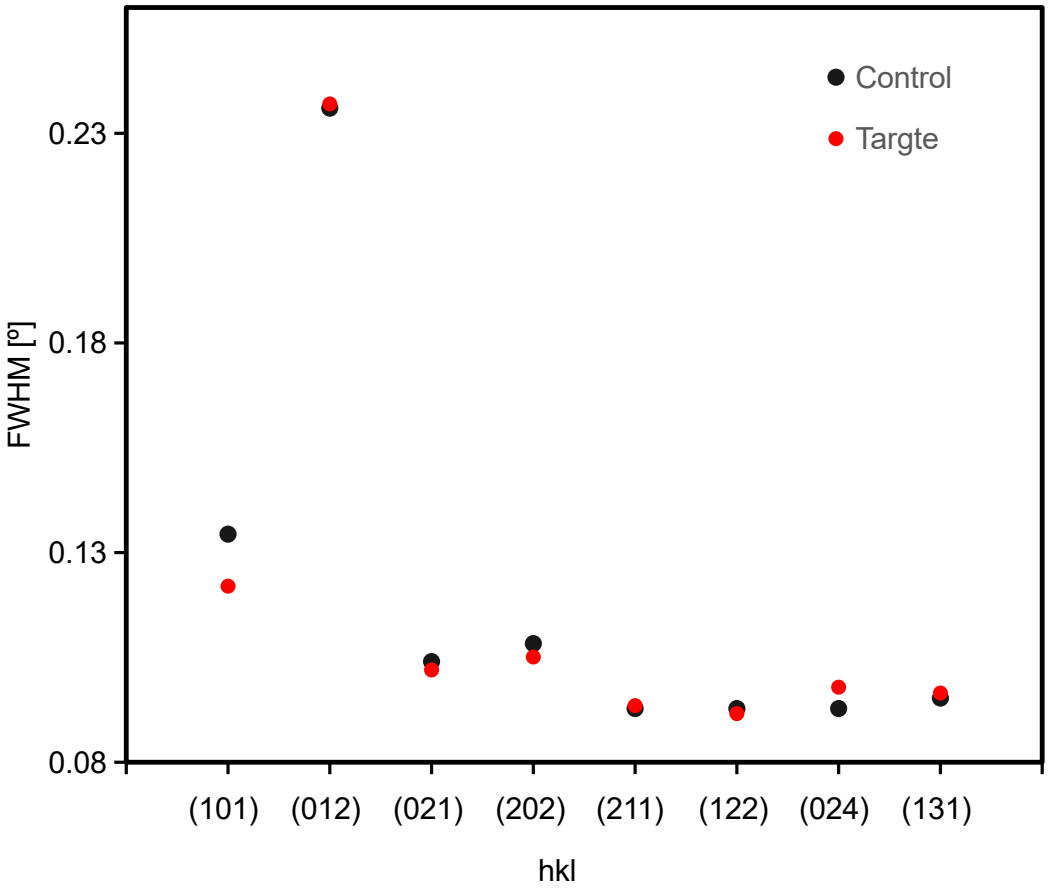

Figure S2 FWHM changes after C8BTBT adding

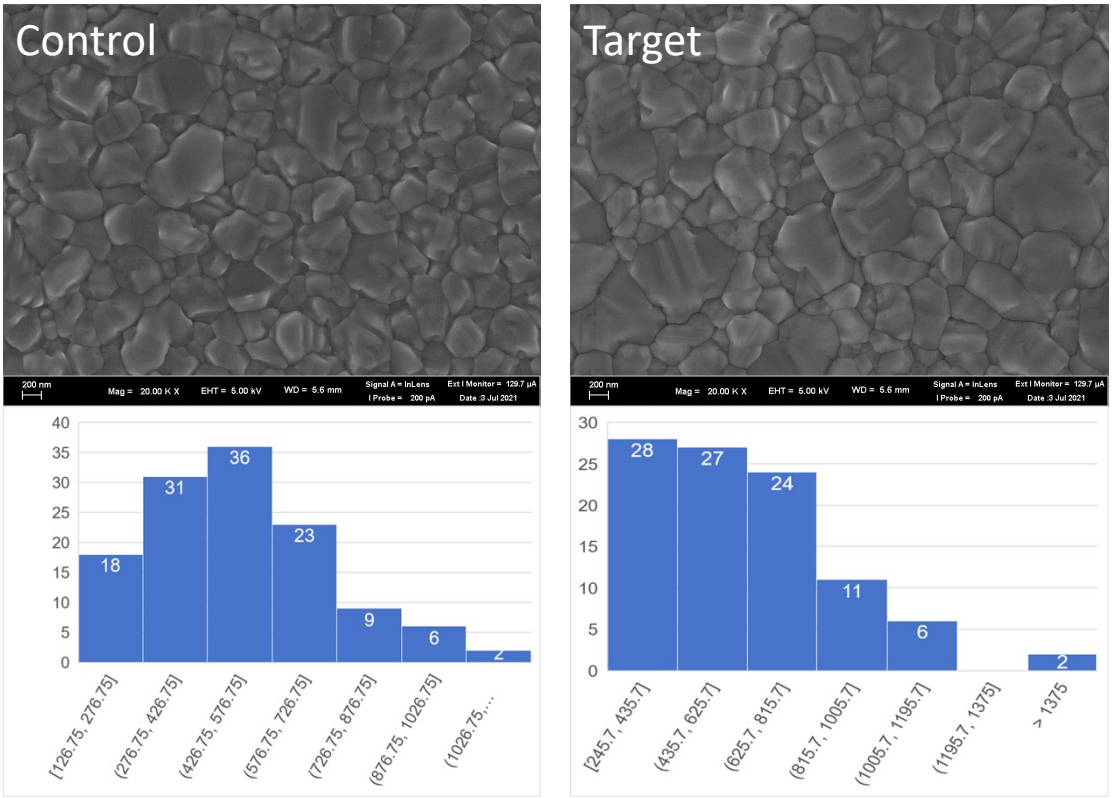

Figure S3.Grain size analysis

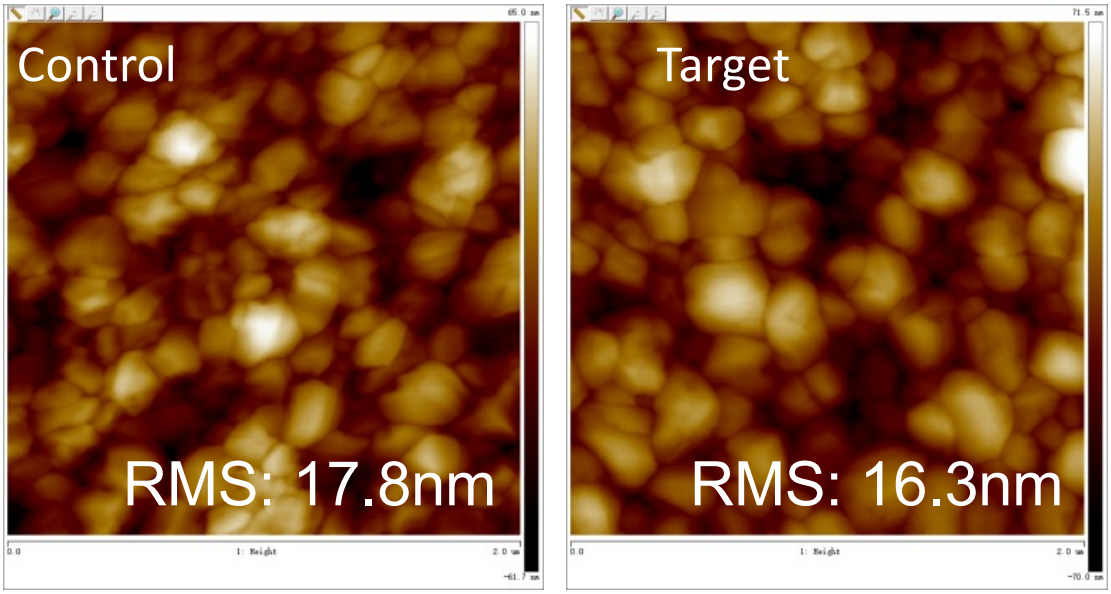

Figure S4 AFM images for control and target samples

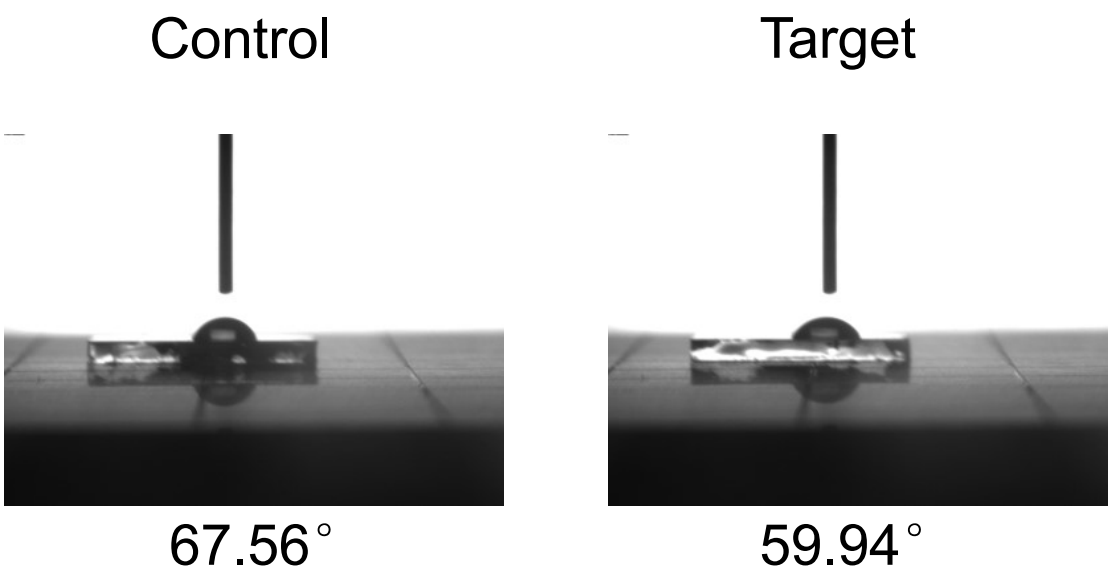

Figure S5 Water contact angel measurement for control and target samples

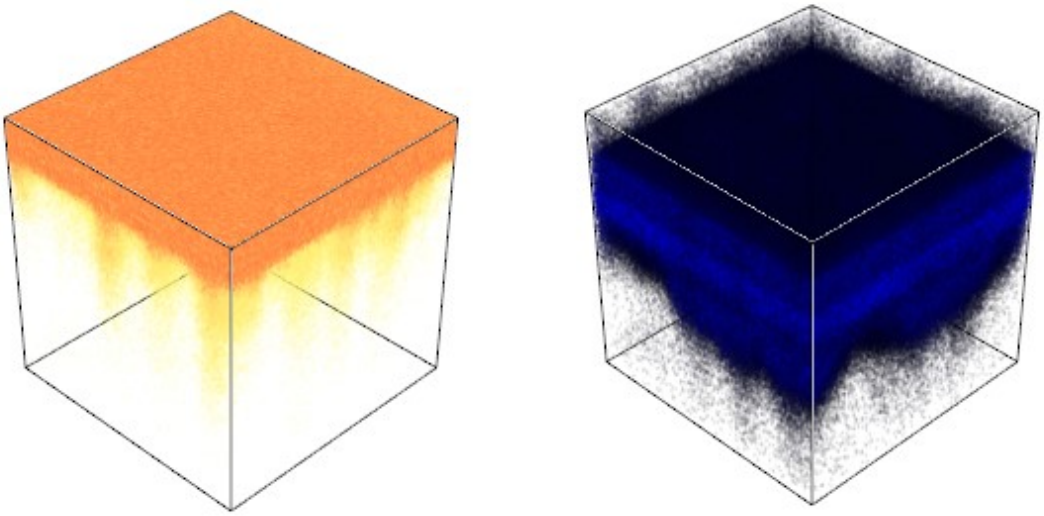

Figure S6 ToF-SIMS 3D images

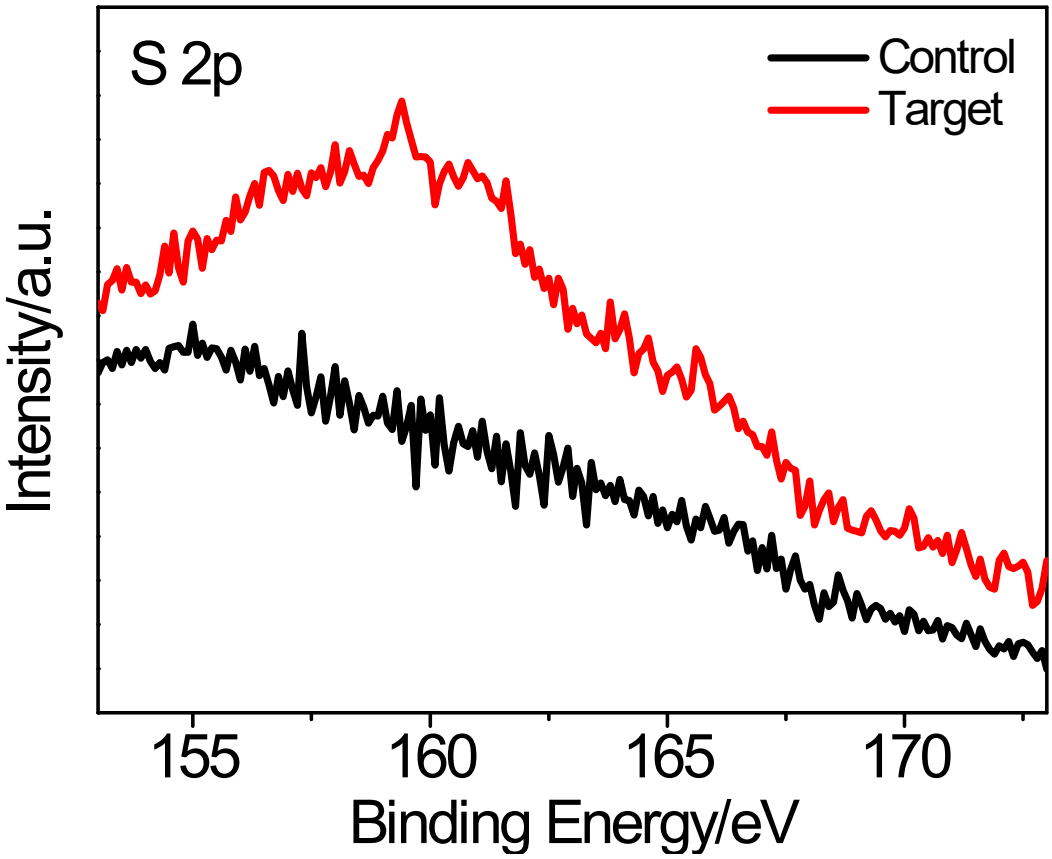

Figure S7 XPS spectra for S 2p in control and target samples

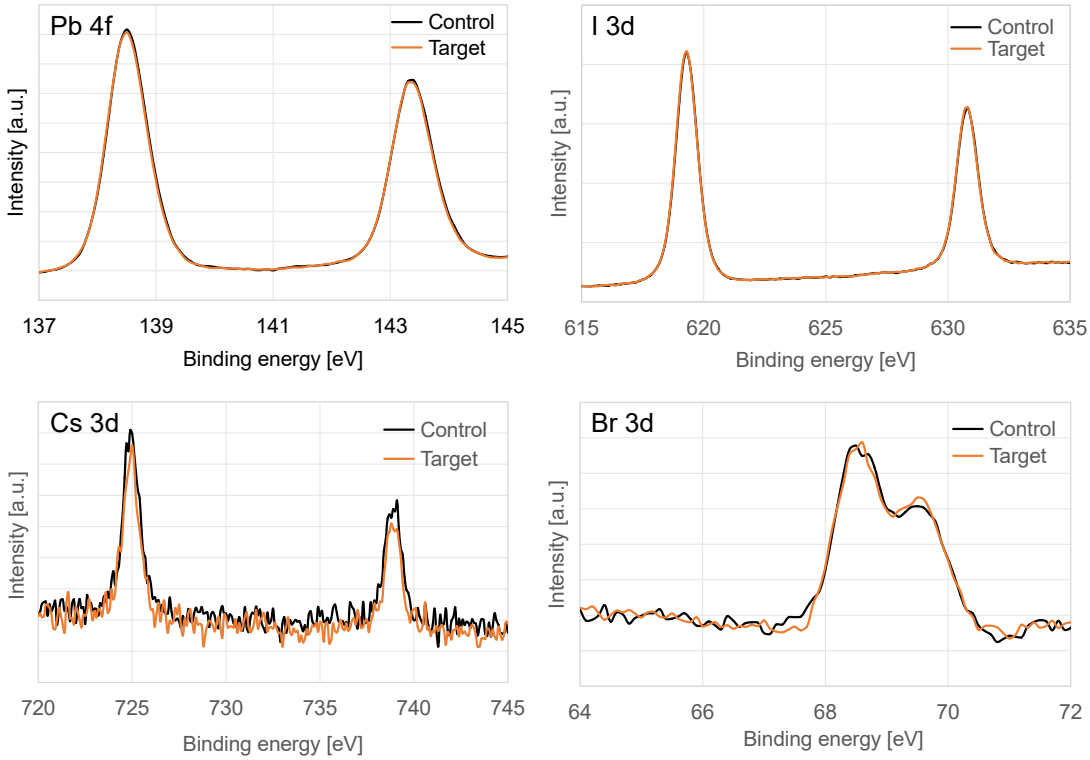

Figure S8 XPS spectra for control and target samples

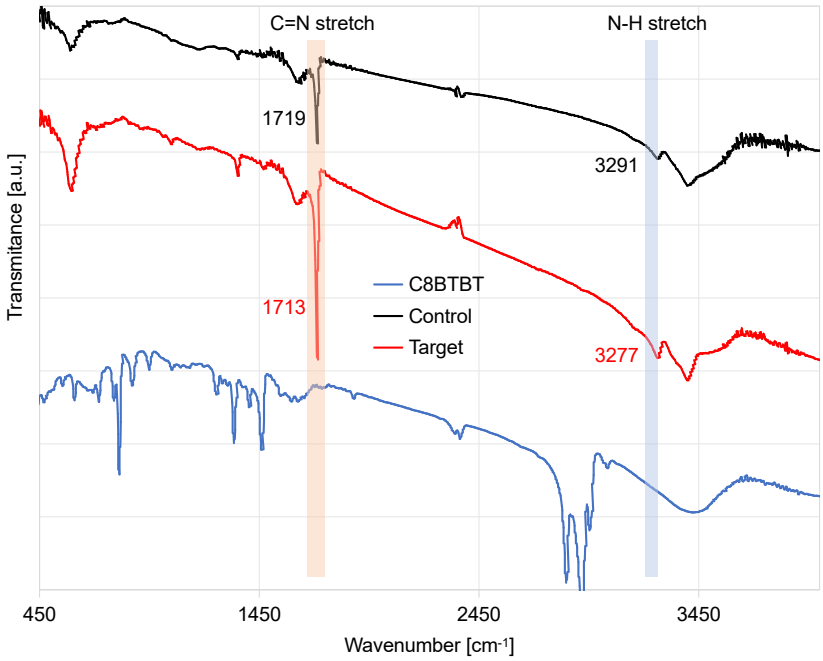

Figure S9 FTIR spectra

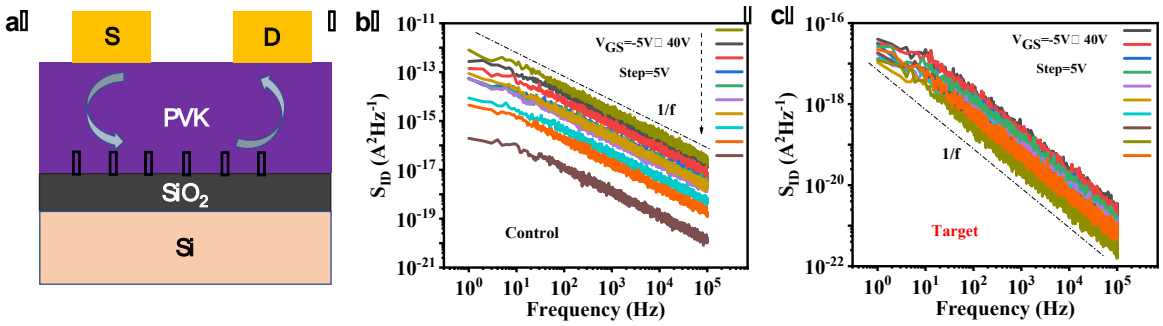

Figure S10 a. The setup for noise measurements. b and c. Drain current noise power spectral density observed in control and target samples

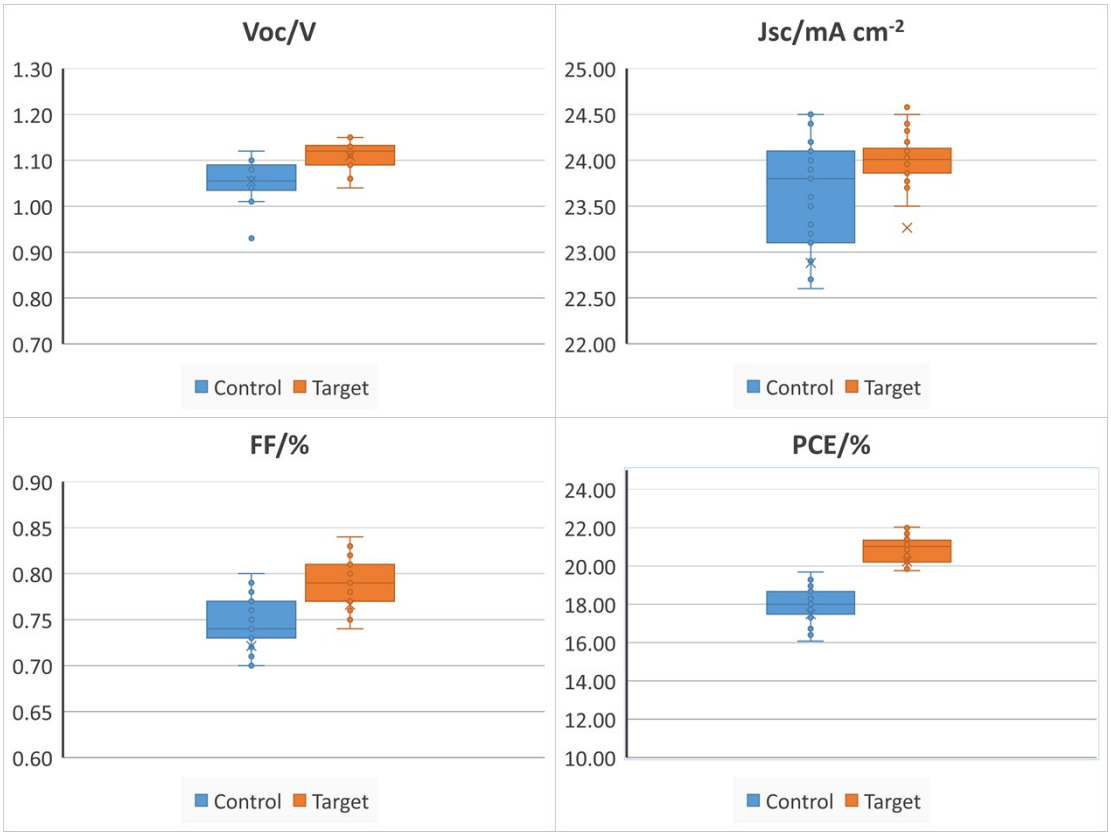

Figure S11 Box chart for control and target devices

Table S1 J-V parameters of 30 independent devices with and without C8BTBT

Control				Target			
Voc/V	Jsc/mA cm^{-2}	FF	PCE/%	Voc/V	Jsc/mA cm^{-2}	FF	PCE/%
1.09	24.40	0.74	19.68	1.12	24.58	0.80	22.02
1.10	24.20	0.73	19.43	1.14	24.12	0.80	22.00
1.09	23.90	0.74	19.28	1.13	24.32	0.80	21.99
1.06	24.10	0.75	19.16	1.12	23.90	0.81	21.68
1.06	24.50	0.73	18.96	1.15	24.13	0.78	21.64
1.11	22.70	0.75	18.90	1.11	24.20	0.80	21.49
1.07	23.10	0.76	18.78	1.11	24.40	0.79	21.40
1.01	24.00	0.77	18.66	1.12	23.82	0.80	21.34
1.08	22.90	0.75	18.55	1.12	24.05	0.79	21.28
1.05	23.80	0.74	18.49	1.09	24.00	0.81	21.19
1.12	22.60	0.73	18.48	1.14	24.10	0.77	21.15
1.05	24.10	0.73	18.47	1.09	23.96	0.81	21.15
1.04	22.90	0.77	18.34	1.07	24.06	0.82	21.11
1.04	24.10	0.73	18.30	1.15	24.40	0.75	21.05
1.01	24.10	0.75	18.26	1.12	23.77	0.79	21.03
0.93	24.20	0.80	18.00	1.09	23.80	0.81	21.01
1.02	23.20	0.76	17.98	1.04	24.01	0.84	20.98
1.05	23.10	0.74	17.95	1.06	23.70	0.83	20.85
0.97	23.60	0.78	17.86	1.14	23.98	0.76	20.78
0.96	23.50	0.79	17.82	1.10	23.88	0.79	20.75
0.97	23.50	0.78	17.78	1.03	24.12	0.83	20.62
0.94	24.50	0.77	17.73	1.05	23.86	0.82	20.54
1.02	23.90	0.72	17.55	1.08	23.50	0.80	20.30
1.10	22.70	0.70	17.48	1.07	23.90	0.79	20.20
1.01	23.80	0.72	17.31	1.10	24.03	0.76	20.09
0.91	24.10	0.77	16.89	1.11	24.12	0.75	20.08
1.00	23.30	0.72	16.78	1.06	23.91	0.79	20.02
1.03	23.20	0.70	16.73	1.13	23.86	0.74	19.95
1.00	23.10	0.71	16.40	1.08	24.50	0.75	19.85
0.91	24.20	0.73	16.08	1.06	24.20	0.77	19.75