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Supporting Information

Genetic Algorithm-Assisted Optimization of Partially dyed-TiO_2 for Low-Temperature Processable Photoanodes of DSSC

Eun Gyoung Bae, Hyunho Kim, Yun-Hwa Hwang, Kee-Sun Sohn* and Myoungho Pyo*

Department of Printed Electronics and Engineering in World Class University (WCU) Program, Sunchon National University, Sunchon, Chonnam 540-742, Republic of Korea

E-mail: kssohn@sunchon.ac.kr (K.-S. Sohn); mho@sunchon.ac.kr (M. Pyo)

Content:

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Preparation of partially dyed-TiO_2

Different sizes of TiO_2 nanoparticles were dispersed in ethanol solutions containing various concentrations of N3. The TiO_2 nanoparticles of the average diameters of 7 nm (MKN-TiO_2-C07, MK nano), 14 nm (P90, Degussa), 21 nm (P25, Degussa), and 40 nm (#22N-0801A, Inframat Advanced Materials LLC) were purchased and used as received. The average particle sizes of TiO_2, determined by the Scherrer's equation from X-ray diffraction or the FESEM images, were in a good agreement with the values reported by suppliers. To control the amounts of N3 adsorbed on TiO_2, TiO_2 powers (0.1 g) were dispersed in N3 solutions (1 mL) of various concentrations (3, 7, 12, 17 mM). After shaking overnight, the solution was repeatedly washed with ethanol by centrifugation until obtaining a colorless supernatent.

The amounts of dye-loading were spectroscopically determined. Partially dyed-TiO_2 (10 mg) was redispersed in NaOH aq. solutions and the concentration of N3 after complete desorption was determined from absorption maxima, using $\varepsilon = 1.23 \times 10^4\ M^{-1}\ cm^{-1}$ at 500 nm. Fig. S1 demonstrates the difference of Visible spectra, depending on the N3 concentration during dye adsorption on TiO_2. In general, the absorption maximum increases with the increase of N3 concentration, but the increasing rate becomes less at high N3 concentrations indicative of closeness to a complete coverage with N3. The dye-loading is also affected by the TiO_2 size due to surface area difference. The surface coverage of N3 was explained in the text.

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Visible spectra of N3 desorbed from partially dyed-TiO_2

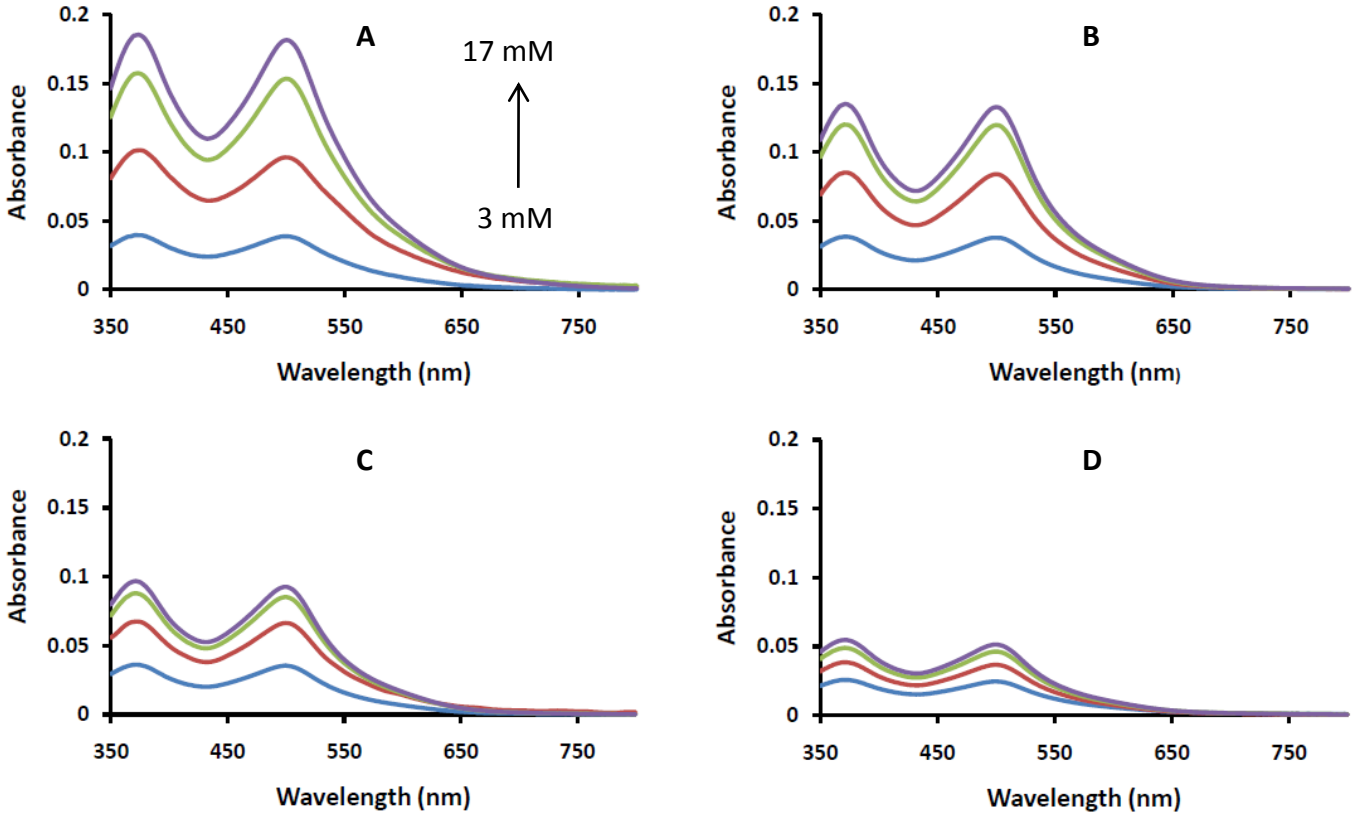

Figure S1. Visible spectra of NaOH aq. solution containing N3 desorbed from partially-dyed TiO_2. Partially dyed-TiO_2 prepared from TiO_2 of diameters of (A) 7, (B) 14, (C) 21, and (D) 40 nm and dyed in 3, 7, 12, and 17 mM N3 solutions.

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Preparation of photoanodes

According to the GA-selected decision parameters, partially dyed-TiO_2 nanoparticles with various sizes and dye-loadings were mixed in ethanol and shaked for 12 hours. 30 kinds of solutions with the different compositions and solid contents were prepared per each generation. Immediately after brief shaking of the solution, the photoanodes were produced on cleaned and $TiCl_4$-treated FTO glasses by a doctor blade method. The $TiCl_4$ treatment was performed by dipping FTO in a titanium(IV) solution at 70 ^oC for 30 min. The film thickness was adjusted by the solid content of the solution and the tape thickness. After evaporating the solvent at RT, the tape was removed and the partially dyed-TiO_2 film was subjected to the compression (3635 x-Press, SPEX SamplePrep LLC). The pressure was controlled at 28, 50, 72, and 94 MPa.

Cell fabrication

The counter electrode was prepared by applying 2 drops of 5 mM H_2PtCl_6 on FTO and sintering at 400 ^oC for 15 min. The Pt counter and photoanode were assembled face-to-face, using hot melting foil (Solaronix SX1170-60)) sandwiched between two electrodes. The space between the electrodes was filled with an electrolyte solution through two holes. The two holes were then completely sealed using Surlyn film and cover glass. The electrolyte solution contained 0.2 M lithium iodide, 0.05 M iodine, 0.5 M t-butylpyridine, and 0.7 M 1,2-dimethyl-3-propylimidazolium iodide in acetonitrile. The mask of a slightly larger hole (0.283 cm^2) than the active area of N3/TiO_2 (0.196 cm^2) was affixed to the photoanode side.

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Decision parameters

Preparation of partially dyed-TiO_2 (PDT)

TiO_2 size: (T1) 7nm; (T2) 14 nm; (T3) 21 nm; (T4) 40 nm

N3 concentration: (D1) 3 mM; (D2) 7 mM; (D3) 12 mM; (D4) 17 mM

When assumed the use of all 4 TiO_2 (However, this does not necessarily mean that all 4 TiO_2 were incorporated into photoanodes. See composition of PDT below.), the total number of cases for the selection PDT becomes $4 \times 4 \times 4 \times 4 = 2^8$ (Note that there are 4 different N3 solutions for each TiO_2.).

Preparation of photoanodes with PDT

Composition (wt%) of PDT

	PDT			
	T1	T2	T3	T4
W1	0	0	100	0
. . . . .	*see next page*			
W128	0	100	0	0

X

Control of film thickness

	PDT dispersed in 1 mL ethanol	tape thickness
F1	0.10 g	1
F2	0.10 g	2
F3	0.15 g	1
F4	0.15 g	2
F5	0.20 g	1
F6	0.20 g	2
F7	0.30 g	1
F8	0.30 g	2

X

Pressure applied

P1	28MPa
P2	50MPa
P3	72MPa
P4	94MPa

Total Number of cases = $2^8 \times 2^7 \times 2^3 \times 2^2 = 2^{20}$

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Composition (wt%) of PDT

	T1	T2	T3	T4
W1	0	0	100	0
W2	10	0	90	0
W3	0	10	90	0
W4	0	0	90	10
W5	20	0	80	0
W6	0	20	80	0
W7	0	0	80	20
W8	10	10	80	0
W9	10	0	80	10
W10	0	10	80	10
W11	30	0	70	0
W12	0	30	70	0
W13	0	0	70	30
W14	20	10	70	0
W15	20	0	70	10
W16	10	20	70	0
W17	10	0	70	20
W18	0	20	70	10
W19	0	10	70	20
W20	10	10	70	10
W21	0	40	60	0
W22	30	10	60	0
W23	30	0	60	10
W24	10	30	60	0
W25	0	30	60	10
W26	10	0	60	30
W27	0	10	60	30
W28	20	20	60	0
W29	20	0	60	20
W30	0	20	60	20
W31	20	10	60	10
W32	10	20	60	10

	T1	T2	T3	T4
W33	10	10	60	20
W34	0	50	50	0
W35	10	40	50	0
W36	0	40	50	10
W37	30	20	50	0
W38	30	0	50	20
W39	20	30	50	0
W40	0	30	50	20
W41	20	0	50	30
W42	0	20	50	30
W43	30	10	50	10
W44	10	30	50	10
W45	10	10	50	30
W46	20	20	50	10
W47	10	20	50	20
W48	20	10	50	20
W49	0	60	40	0
W50	10	50	40	0
W51	0	50	40	10
W52	20	40	40	0
W53	0	40	40	20
W54	10	40	40	10
W55	30	30	40	0
W56	0	30	40	30
W57	30	0	40	30
W58	30	20	40	10
W59	30	10	40	20
W60	20	30	40	10
W61	10	30	40	20
W62	10	20	40	30
W63	20	10	40	30
W64	20	20	40	20

	T1	T2	T3	T4
W65	0	70	30	0
W66	10	60	30	0
W67	0	60	30	10
W68	20	50	30	0
W69	0	50	30	20
W70	10	50	30	10
W71	30	40	30	0
W72	0	40	30	30
W73	20	40	30	10
W74	10	40	30	20
W75	30	30	30	10
W76	30	10	30	30
W77	10	30	30	30
W78	20	30	30	20
W79	30	20	30	20
W80	20	20	30	30
W81	0	80	20	0
W82	10	70	20	0
W83	0	70	20	10
W84	20	60	20	0
W85	0	60	20	20
W86	10	60	20	10
W87	30	50	20	0
W88	0	50	20	30
W89	20	50	20	10
W90	10	50	20	20
W91	30	40	20	10
W92	10	40	20	30
W93	20	40	20	20
W94	30	20	20	30
W95	20	30	20	30
W96	30	30	20	20

	T1	T2	T3	T4
W97	0	90	10	0
W98	10	80	10	0
W99	0	80	10	10
W100	20	70	10	0
W101	0	70	10	20
W102	10	70	10	10
W103	30	60	10	0
W104	0	60	10	30
W105	20	60	10	10
W106	10	60	10	20
W107	30	50	10	10
W108	10	50	10	30
W109	20	50	10	20
W110	30	40	10	20
W111	20	40	10	30
W112	30	30	10	30
W113	30	40	0	30
W114	20	50	0	30
W115	30	50	0	20
W116	20	60	0	20
W117	10	60	0	30
W118	30	60	0	10
W118	10	70	0	20
W120	20	70	0	10
W121	0	70	0	30
W122	30	70	0	0
W123	10	80	0	10
W124	0	80	0	20
W125	20	80	0	0
W126	0	90	0	10
W127	10	90	0	0
W128	0	100	0	0

T1 & T4 contents = 0 ~ 30 wt%, T2 & T3 contents = 0 ~ 100 wt%

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1st Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
1G-1	30	40	20	10	D4	D2	D4	D3	F7	28	3.59 ± 0.32
1G-2	0	0	90	10	D2	D3	D4	D4	F4	72	4.93 ± 0.13
1G-3	20	20	50	10	D3	D2	D1	D4	F1	94	3.22 ± 0.03
1G-4	0	10	80	10	D2	D1	D1	D1	F3	50	3.42 ± 0.08
1G-5	0	0	70	30	D2	D3	D4	D3	F3	28	3.36 ± 0.16
1G-6	30	10	40	20	D3	D4	D3	D2	F8	94	4.42 ± 0.08
1G-7	30	10	30	30	D2	D2	D3	D2	F3	94	3.92 ± 0.16
1G-8	20	40	20	20	D2	D3	D1	D4	F7	50	4.48 ± 0.11
1G-9	10	40	20	30	D1	D4	D2	D4	F8	50	4.13 ± 0.11
1G-10	0	30	60	10	D2	D1	D4	D4	F2	72	4.20 ± 0.13
1G-11	20	40	10	30	D2	D3	D4	D2	F2	50	3.28 ± 0.09
1G-12	30	30	20	20	D3	D3	D1	D3	F6	72	4.07 ± 0.12
1G-13	20	60	20	0	D3	D2	D2	D3	F6	94	4.02 ± 0.15
1G-14	10	20	60	10	D1	D4	D3	D1	F6	50	4.70 ± 0.19
1G-15	30	10	40	20	D3	D1	D4	D3	F1	28	2.52 ± 0.19
1G-16	20	40	10	30	D3	D4	D4	D2	F2	50	2.84 ± 0.19
1G-17	30	50	0	20	D1	D1	D1	D1	F7	72	1.63 ± 0.08
1G-18	10	30	50	10	D1	D3	D3	D3	F4	50	4.36 ± 0.10
1G-19	20	20	50	10	D2	D1	D1	D2	F3	28	2.72 ± 0.08
1G-20	0	70	0	30	D4	D1	D4	D3	F1	72	1.86 ± 0.07
1G-21	30	20	40	10	D2	D4	D2	D3	F1	94	2.92 ± 0.02
1G-22	0	90	10	0	D3	D4	D2	D1	F4	72	4.29 ± 0.10
1G-23	0	30	50	20	D1	D1	D1	D4	F6	28	3.70 ± 0.13
1G-24	10	50	40	0	D3	D4	D3	D4	F6	50	4.50 ± 0.12
1G-25	10	10	60	20	D3	D4	D2	D1	F3	50	4.03 ± 0.08
1G-26	20	20	40	20	D2	D1	D3	D4	F5	94	4.31 ± 0.07
1G-27	0	40	30	30	D2	D3	D1	D3	F5	94	4.94 ± 0.03
1G-28	0	40	40	20	D4	D4	D3	D4	F5	50	4.77 ± 0.12
1G-29	30	20	40	10	D4	D1	D4	D3	F2	94	4.25 ± 0.11
1G-30	0	40	50	10	D1	D4	D1	D4	F1	94	3.28 ± 0.14

(red color) the highest η used for the next generation (Eliticism)

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1st Generation : Cell parameters for 4 independent samples (1G-1 ~ 1G-10)

1G-1	1	2	3	4	average
η(%)	4.02	3.52	3.25	3.58	3.59 ± 0.32
J_{sc}(mA/cm^2)	7.89	6.50	6.39	6.76	6.89 ± 0.69
V_{oc}(mV)	671.85	696.63	671.85	694.24	683.6 ±13.7
FF(%)	75.79	77.83	75.61	76.31	76.4 ± 1.0

1G-2	1	2	3	4	average
η(%)	4.98	4.95	4.74	5.03	4.93 ± 0.13
J_{sc}(mA/cm^2)	10.75	10.59	10.31	11.06	10.68 ± 0.31
V_{oc}(mV)	642.26	649.46	641.47	642.26	643.9 ±3.8
FF(%)	72.22	71.91	71.69	70.86	71.7 ± 0.6

1G-3	1	2	3	4	average
η(%)	3.26	3.22	3.21	3.18	3.22 ± 0.03
J_{sc}(mA/cm^2)	5.85	5.82	5.75	5.68	5.78 ± 0.08
V_{oc}(mV)	726.21	725.42	727.81	725.42	726.2 ± 1.1
FF(%)	76.79	76.31	76.82	77.25	76.8 ± 0.4

1G-4	1	2	3	4	average
η(%)	3.44	3.51	3.42	3.32	3.42 ± 0.08
J_{sc}(mA/cm^2)	6.17	6.47	6.30	6.01	6.24 ± 0.20
V_{oc}(mV)	734.22	715.02	715.02	731.01	723.8 ± 10.2
FF(%)	75.85	75.94	75.99	75.70	75.9 ± 0.1

1G-5	1	2	3	4	average
η(%)	3.58	3.20	3.34	3.33	3.36 ± 0.16
J_{sc}(mA/cm^2)	6.30	5.58	5.84	5.79	5.88 ± 0.30
V_{oc}(mV)	735.81	739.01	739.80	739.80	738.6 ± 1.9
FF(%)	77.19	77.60	77.44	77.73	77.5 ± 0.2

1G-6	1	2	3	4	average
η(%)	4.36	4.52	4.34	4.44	4.42 ± 0.08
J_{sc}(mA/cm^2)	8.88	9.32	8.88	9.44	9.13 ± 0.29
V_{oc}(mV)	663.05	668.65	664.65	651.06	661.9 ± 7.6
FF(%)	74.01	72.58	73.63	72.23	73.1 ± 0.8

1G-7	1	2	3	4	average
η(%)	4.01	3.77	3.80	4.10	3.92 ± 0.16
J_{sc}(mA/cm^2)	7.67	7.03	7.35	8.15	7.55 ± 0.48
V_{oc}(mV)	690.23	694.24	683.04	678.24	686.4 ± 7.2
FF(%)	75.82	77.22	75.75	74.24	75.8 ± 1.2

1G-8	1	2	3	4	average
η(%)	4.42	4.53	4.36	4.61	4.48 ± 0.11
J_{sc}(mA/cm^2)	8.69	8.82	9.00	9.33	8.96 ± 0.28
V_{oc}(mV)	677.45	678.24	653.46	663.86	668.3 ± 11.9
FF(%)	75.09	75.64	74.12	74.42	74.8 ± 0.7

1G-9	1	2	3	4	average
η(%)	4.07	4.05	4.29	4.12	4.13 ± 0.11
J_{sc}(mA/cm^2)	8.32	8.45	8.62	8.60	8.50 ± 0.14
V_{oc}(mV)	659.85	659.85	663.05	647.86	657.7 ± 6.7
FF(%)	74.06	72.68	74.97	74.00	73.9 ± 0.9

1G-10	1	2	3	4	average
η(%)	4.35	4.26	4.08	4.09	4.20 ± 0.13
J_{sc}(mA/cm^2)	8.18	7.91	7.50	7.77	7.84 ± 0.28
V_{oc}(mV)	711.83	711.02	711.83	705.42	710.0 ± 3.1
FF(%)	74.78	75.83	76.36	74.64	75.4 ± 0.8

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1st Generation : Cell parameters for 4 independent samples (1G-11 ~ 1G-20)

1G-11	1	2	3	4	average
η(%)	3.20	3.21	3.30	3.40	3.28 ± 0.09
J_{sc}(mA/cm^2)	6.06	6.32	5.87	6.45	6.18 ± 0.26
V_{oc}(mV)	695.83	699.84	721.42	699.84	704.2 ± 11.6
FF(%)	75.97	72.53	77.85	75.26	75.4 ± 2.2

1G-12	1	2	3	4	average
η(%)	3.94	4.05	4.23	4.04	4.07 ± 0.12
J_{sc}(mA/cm^2)	7.71	7.86	7.87	7.76	7.80 ± 0.08
V_{oc}(mV)	694.24	677.45	702.23	677.45	687.8 ± 12.4
FF(%)	73.69	76.01	76.52	76.79	75.8 ± 1.4

1G-13	1	2	3	4	average
η(%)	3.81	4.11	4.02	4.15	4.02 ± 0.15
J_{sc}(mA/cm^2)	7.63	8.35	8.39	8.40	8.19 ± 0.38
V_{oc}(mV)	660.65	660.65	651.06	663.05	658.9 ± 5.3
FF(%)	75.64	74.57	73.70	74.57	74.6 ± 0.8

1G-14	1	2	3	4	average
η(%)	4.87	4.85	4.52	4.56	4.70 ± 0.19
J_{sc}(mA/cm^2)	9.70	9.44	8.74	8.24	9.03 ± 0.66
V_{oc}(mV)	675.04	684.63	685.44	718.22	690.8 ± 18.9
FF(%)	74.45	75.00	75.37	77.02	75.5 ± 1.1

1G-15	1	2	3	4	average
η(%)	2.79	2.49	2.45	2.36	2.52 ± 0.19
J_{sc}(mA/cm^2)	4.87	4.43	4.38	4.10	4.45 ± 0.32
V_{oc}(mV)	724.61	723.82	725.42	733.41	726.8 ± 4.4
FF(%)	79.02	77.72	76.98	78.38	78.0 ± 0.9

1G-16	1	2	3	4	average
η(%)	2.63	2.79	3.08	2.87	2.84 ± 0.19
J_{sc}(mA/cm^2)	5.12	5.23	5.66	5.24	5.31 ± 0.24
V_{oc}(mV)	691.04	690.23	716.62	712.62	702.6 ± 14.0
FF(%)	74.41	77.16	76.01	76.84	76.1 ± 1.2

1G-17	1	2	3	4	average
η(%)	1.57	1.56	1.73	1.64	1.63 ± 0.08
J_{sc}(mA/cm^2)	2.91	3.01	3.17	3.10	3.05 ± 0.11
V_{oc}(mV)	687.04	684.63	686.23	685.44	685.8 ± 1.0
FF(%)	78.54	75.82	79.44	77.31	77.8 ± 1.6

1G-18	1	2	3	4	average
η(%)	4.33	4.25	4.38	4.48	4.36 ± 0.10
J_{sc}(mA/cm^2)	8.05	8.07	8.21	8.28	8.15 ± 0.11
V_{oc}(mV)	703.03	691.83	693.43	707.02	698.8 ± 7.4
FF(%)	76.57	76.08	76.96	76.54	76.5 ± 0.4

1G-19	1	2	3	4	average
η(%)	2.82	2.64	2.67	2.73	2.72 ± 0.08
J_{sc}(mA/cm^2)	5.23	4.72	4.80	4.94	4.92 ± 0.22
V_{oc}(mV)	710.23	702.23	711.02	707.83	707.8 ± 4.0
FF(%)	76.01	79.68	78.25	78.05	78.0 ± 1.5

1G-20	1	2	3	4	average
η(%)	1.94	1.88	1.79	1.81	1.86 ± 0.07
J_{sc}(mA/cm^2)	3.54	3.52	3.26	3.30	3.41 ± 0.15
V_{oc}(mV)	710.23	714.22	715.02	718.22	714.4 ± 3.3
FF(%)	77.28	74.84	76.56	76.59	76.3 ± 1.0

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1st Generation : Cell parameters for 4 independent samples (1G-21 ~ 1G-30)

1G-21	1	2	3	4	average
η(%)	2.91	2.91	2.95	2.90	2.92 ± 0.02
J_{sc}(mA/cm^2)	5.26	5.68	5.40	5.21	5.39 ± 0.21
V_{oc}(mV)	728.62	710.23	719.01	727.81	721.4 ± 8.6
FF(%)	75.97	72.22	75.95	76.55	75.2 ± 2.0

1G-22	1	2	3	4	average
η(%)	4.20	4.35	4.22	4.40	4.29 ± 0.2
J_{sc}(mA/cm^2)	7.99	8.16	7.76	8.20	8.03 ± 0.2
V_{oc}(mV)	696.63	696.63	702.23	699.03	698.6 ± 2.7
FF(%)	75.41	76.44	77.35	76.70	76.5 ± 0.8

1G-23	1	2	3	4	average
η(%)	3.60	3.61	3.70	3.87	3.70 ± 0.13
J_{sc}(mA/cm^2)	7.10	7.31	7.34	7.73	7.37 ± 0.26
V_{oc}(mV)	670.25	658.26	664.65	665.45	664.7 ± 4.9
FF(%)	75.72	75.07	75.89	75.24	75.5 ± 0.4

1G-24	1	2	3	4	average
η(%)	4.38	4.60	4.40	4.60	4.50 ± 0.12
J_{sc}(mA/cm^2)	8.40	8.85	8.55	8.79	8.65 ± 0.21
V_{oc}(mV)	683.04	684.63	677.45	691.83	684.4 ± 5.9
FF(%)	76.28	75.85	75.94	75.70	75.9 ± 0.3

1G-25	1	2	3	4	average
η(%)	4.15	4.00	4.00	3.97	4.03 ± 0.08
J_{sc}(mA/cm^2)	7.32	7.04	6.99	7.00	7.09 ± 0.16
V_{oc}(mV)	743.00	743.81	743.00	742.21	743.0 ± 0.7
FF(%)	76.34	76.51	76.99	76.42	76.6 ± 0.3

1G-26	1	2	3	4	average
η(%)	4.34	4.28	4.23	4.39	4.31 ± 0.07
J_{sc}(mA/cm^2)	7.90	8.04	8.08	8.39	8.10 ± 0.21
V_{oc}(mV)	723.02	695.03	690.23	697.43	701.4 ± 14.7
FF(%)	75.98	76.56	75.82	75.05	75.9 ± 0.6

1G-27	1	2	3	4	average
η(%)	4.98	4.95	4.90	4.93	4.94 ± 0.03
J_{sc}(mA/cm^2)	9.02	9.49	9.15	8.97	9.16 ± 0.23
V_{oc}(mV)	738.21	715.02	729.41	731.81	728.6 ± 9.8
FF(%)	74.83	72.97	73.39	75.16	74.1 ± 1.1

1G-28	1	2	3	4	average
η(%)	4.72	4.90	4.63	4.84	4.77 ± 0.12
J_{sc}(mA/cm^2)	8.34	8.68	8.15	9.07	8.56 ± 0.40
V_{oc}(mV)	733.41	732.62	734.22	713.43	728.4 ± 10.0
FF(%)	77.18	77.07	77.31	74.75	76.6 ± 1.2

1G-29	1	2	3	4	average
η(%)	4.38	4.11	4.22	4.28	4.25 ± 0.11
J_{sc}(mA/cm^2)	7.97	7.64	7.55	7.62	7.70 ± 0.19
V_{oc}(mV)	718.22	710.23	724.61	719.82	718.2 ± 6.0
FF(%)	76.50	75.78	77.24	78.02	76.9 ± 1.0

1G-30	1	2	3	4	average
η(%)	3.43	3.15	3.16	3.36	3.28 ± 0.14
J_{sc}(mA/cm^2)	6.06	5.52	5.59	6.07	5.81 ± 0.30
V_{oc}(mV)	743.81	746.21	748.60	741.40	745.0 ± 3.1
FF(%)	76.14	76.46	75.57	74.63	75.7 ± 0.9

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2nd Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
2G-1	20	40	20	20	D1	D4	D3	D4	F7	50	3.88 ± 0.07
2G-2	30	30	20	20	D3	D4	D1	D4	F5	28	3.42 ± 0.09
2G-3	20	40	20	20	D3	D3	D1	D3	F5	50	3.48 ± 0.19
2G-4	0	30	40	30	D4	D4	D3	D4	F6	72	4.59 ± 0.14
2G-5	0	50	20	30	D4	D2	D3	D3	F6	72	4.46 ± 0.20
2G-6	0	30	50	20	D4	D1	D4	D4	F3	72	4.70 ± 0.10
2G-7	0	40	30	30	D2	D3	D1	D3	F6	94	5.31 ± 0.06
2G-8	20	40	20	20	D1	D4	D1	D4	F7	50	4.07 ± 0.13
2G-9	20	20	40	20	D2	D1	D3	D4	F6	94	4.33 ± 0.08
2G-10	20	60	20	0	D3	D2	D2	D3	F5	94	4.57 ± 0.08
2G-11	20	60	20	0	D2	D3	D3	D4	F5	28	3.53 ± 0.09
2G-12	20	50	30	0	D3	D3	D3	D4	F4	28	3.43 ± 0.07
2G-13	0	40	30	30	D3	D1	D1	D4	F4	94	4.34 ± 0.03
2G-14	10	60	20	10	D3	D4	D4	D4	F5	94	4.36 ± 0.16
2G-15	0	90	10	0	D3	D4	D2	D1	F3	72	3.35 ± 0.15
2G-16	0	0	70	30	D2	D3	D4	D3	F4	28	3.79 ± 0.09
2G-17	10	30	30	30	D1	D4	D2	D4	F3	28	2.45 ± 0.10
2G-18	20	20	60	0	D2	D3	D4	D3	F8	50	3.99 ± 0.16
2G-19	0	60	20	20	D4	D3	D3	D1	F5	50	4.50 ± 0.09
2G-20	20	40	40	0	D3	D4	D3	D4	F6	28	3.94 ± 0.05
2G-21	0	20	80	0	D4	D1	D2	D4	F8	28	4.85 ± 0.14
2G-22	10	0	60	30	D2	D1	D4	D4	F2	94	3.55 ± 0.17
2G-23	10	10	60	20	D3	D4	D2	D1	F7	50	5.04 ± 0.07
2G-24	20	40	20	20	D2	D3	D1	D4	F3	50	3.73 ± 0.21
2G-25	0	40	30	30	D1	D4	D1	D3	F7	94	5.23 ± 0.01
2G-26	30	10	40	20	D2	D3	D3	D2	F8	94	3.89 ± 0.10
2G-27	0	70	10	20	D3	D1	D3	D1	F1	72	2.48 ± 0.10
2G-28	30	20	40	10	D2	D1	D4	D3	F2	94	3.80 ± 0.20
2G-29	30	20	40	10	D2	D4	D2	D3	F1	72	3.51 ± 0.14
2G-30	0	40	30	30	D2	D3	D1	D3	F5	94	4.90 ± 0.21

(red color) the highest η used for the next generation (Eliticism)

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2nd Generation : Cell parameters for 4 independent samples (2G-1 ~ 2G-10)

2G-1	1	2	3	4	average
η(%)	3.81	3.82	3.93	3.95	3.88 ± 0.07
J_{sc}(mA/cm^2)	7.48	7.40	7.54	7.99	7.60 ± 0.26
V_{oc}(mV)	664.65	679.84	676.64	658.26	669.9 ± 10.1
FF(%)	76.66	75.87	77.03	75.06	76.2 ± 0.9

2G-2	1	2	3	4	average
η(%)	3.37	3.33	3.42	3.54	3.42 ± 0.09
J_{sc}(mA/cm^2)	6.27	6.30	6.40	6.31	6.32 ± 0.06
V_{oc}(mV)	688.64	688.64	686.23	726.21	697.43 ± 19.2
FF(%)	78.10	76.77	77.92	77.24	77.5 ± 0.6

2G-3	1	2	3	4	average
η(%)	3.42	3.33	3.40	3.76	3.48 ± 0.19
J_{sc}(mA/cm^2)	5.91	5.92	6.38	7.23	6.36 ± 0.62
V_{oc}(mV)	735.81	730.21	695.83	694.24	714.0 ± 22.1
FF(%)	78.58	76.88	76.51	75.00	76.7 ± 1.47

2G-4	1	2	3	4	average
η(%)	4.74	4.47	4.47	4.68	4.59 ± 0.14
J_{sc}(mA/cm^2)	9.12	8.64	8.65	9.33	8.94 ± 0.35
V_{oc}(mV)	692.64	688.64	693.43	679.84	6.88.6 ± 6.23
FF(%)	74.96	75.19	74.55	73.87	74.64 ± 0.58

2G-5	1	2	3	4	average
η(%)	4.31	4.51	4.73	4.30	4.46 ± 0.20
J_{sc}(mA/cm^2)	8.69	9.00	9.27	7.91	8.72 ± 0.59
V_{oc}(mV)	662.25	687.04	681.44	710.23	685.2 ± 19.8
FF(%)	74.94	72.87	74.79	76.59	74.8 ± 1.5

2G-6	1	2	3	4	average
η(%)	4.71	4.67	4.83	4.59	4.70 ± 0.10
J_{sc}(mA/cm^2)	9.33	9.84	9.43	9.20	9.45 ± 0.28
V_{oc}(mV)	674.24	667.05	678.24	672.64	673.0 ± 4.6
FF(%)	74.84	71.16	75.56	74.10	73.9 ± 1.9

2G-7	1	2	3	4	average
η(%)	5.25	5.31	5.39	5.29	5.31 ± 0.06
J_{sc}(mA/cm^2)	10.19	10.33	10.41	10.18	10.28 ± 0.11
V_{oc}(mV)	693.43	699.03	699.03	708.62	700.0 ± 6.3
FF(%)	74.28	73.6	74.02	73.39	73.8 ± 0.4

2G-8	1	2	3	4	average
η(%)	4.19	3.89	4.11	4.07	4.07 ± 0.13
J_{sc}(mA/cm^2)	8.39	7.35	7.98	7.99	7.93 ± 0.43
V_{oc}(mV)	668.65	678.24	669.44	667.85	671.1 ± 4.8
FF(%)	74.73	77.96	76.99	76.28	76.5 ± 1.4

2G-9	1	2	3	4	average
η(%)	4.26	4.27	4.36	4.44	4.33 ± 0.08
J_{sc}(mA/cm^2)	8.83	9.19	8.81	9.12	8.99 ± 0.20
V_{oc}(mV)	659.05	652.66	659.05	655.06	656.5 ± 3.2
FF(%)	73.10	71.27	74.98	74.28	73.41 ± 1.6

2G-10	1	2	3	4	average
η(%)	4.67	4.58	4.50	4.52	4.57 ± 0.08
J_{sc}(mA/cm^2)	9.04	8.63	8.75	8.73	8.79 ± 0.18
V_{oc}(mV)	680.64	687.04	680.64	683.84	683.0 ± 3.1
FF(%)	75.83	77.23	75.46	75.63	76.0 ± 0.8

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2nd Generation : Cell parameters for 4 independent samples (2G-11 ~ 2G-20)

2G-11	1	2	3	4	average
η(%)	3.51	3.46	3.48	3.66	3.53 ± 0.09
J_{sc}(mA/cm^2)	6.56	6.51	6.51	7.18	6.69 ± 0.33
V_{oc}(mV)	691.04	692.64	693.43	695.83	693.2 ± 2.0
FF(%)	77.44	76.73	77.00	73.29	76.1 ± 1.9

2G-12	1	2	3	4	average
η(%)	3.37	3.47	3.37	3.51	3.43 ± 0.07
J_{sc}(mA/cm^2)	6.43	6.54	6.32	6.56	6.46 ± 0.11
V_{oc}(mV)	689.44	688.64	683.84	688.64	687.6 ± 2.6
FF(%)	75.92	77.05	78.08	77.76	77.2 ± 1.0

2G-13	1	2	3	4	average
η(%)	4.34	4.38	4.32	4.32	4.34 ± 0.03
J_{sc}(mA/cm^2)	8.49	8.55	8.47	8.50	8.50 ± 0.03
V_{oc}(mV)	675.04	675.85	674.24	675.04	675.0 ± 0.7
FF(%)	75.78	75.85	75.57	75.38	75.7 ± 0.2

2G-14	1	2	3	4	average
η(%)	4.32	4.14	4.48	4.49	4.36 ± 0.16
J_{sc}(mA/cm^2)	8.47	7.59	8.21	8.23	8.13 ± 0.38
V_{oc}(mV)	674.24	700.63	713.43	715.02	700.8 ± 18.9
FF(%)	75.57	77.89	76.44	76.32	76.6 ± 1.0

2G-15	1	2	3	4	average
η(%)	3.39	3.47	3.40	3.12	3.35 ± 0.15
J_{sc}(mA/cm^2)	6.24	6.52	6.24	5.81	6.20 ± 0.29
V_{oc}(mV)	714.22	710.23	714.22	712.62	712.8 ± 1.9
FF(%)	75.91	75.01	76.33	75.47	75.7 ± 0.6

2G-16	1	2	3	4	average
η(%)	3.66	3.85	3.83	3.80	3.79 ± 0.09
J_{sc}(mA/cm^2)	6.68	7.15	7.09	6.91	6.96 ± 0.21
V_{oc}(mV)	724.61	708.62	708.62	718.22	715.0 ± 7.8
FF(%)	75.63	76.01	76.14	76.56	76.1 ± 0.4

2G-17	1	2	3	4	average
η(%)	2.60	2.37	2.40	2.42	2.45 ± 0.10
J_{sc}(mA/cm^2)	4.67	4.89	5.15	5.18	4.97 ± 0.24
V_{oc}(mV)	719.01	702.23	715.02	713.43	712.4 ± 7.2
FF(%)	77.23	68.95	65.10	65.45	69.2 ± 5.6

2G-18	1	2	3	4	average
η(%)	3.85	4.04	4.19	3.87	3.99 ± 0.16
J_{sc}(mA/cm^2)	8.84	8.60	8.94	9.05	8.86 ± 0.19
V_{oc}(mV)	660.65	651.06	660.65	642.26	653.7 ± 8.8
FF(%)	65.92	72.10	70.99	66.47	68.9 ± 3.1

2G-19	1	2	3	4	average
η(%)	4.60	4.54	4.47	4.40	4.50 ± 0.09
J_{sc}(mA/cm^2)	8.75	9.31	8.67	8.53	8.82 ± 0.34
V_{oc}(mV)	698.24	700.63	707.83	698.24	701.2 ± 4.5
FF(%)	75.32	69.65	72.88	73.90	72.9 ± 2.4

2G-20	1	2	3	4	average
η(%)	4.00	3.93	3.96	3.87	3.94 ± 0.05
J_{sc}(mA/cm^2)	8.03	7.78	7.83	7.15	7.70 ± 0.38
V_{oc}(mV)	673.45	679.84	681.44	705.42	685.0 ± 14.0
FF(%)	74.03	74.22	74.19	76.66	74.8 ± 1.3

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2nd Generation : Cell parameters for 4 independent samples (2G-21 ~ 2G-30)

2G-21	1	2	3	4	average
η(%)	5.05	4.85	4.72	4.78	4.85 ± 0.14
J_{sc}(mA/cm^2)	10.52	10.64	9.83	9.96	10.24 ± 0.40
V_{oc}(mV)	663.86	635.87	694.24	691.04	671.3 ± 27.2
FF(%)	72.29	71.62	69.16	69.47	70.6 ± 1.6

2G-22	1	2	3	4	average
η(%)	3.42	3.39	3.66	3.72	3.55 ± 0.17
J_{sc}(mA/cm^2)	6.25	6.26	7.03	7.09	6.66 ± 0.47
V_{oc}(mV)	701.43	707.02	696.63	699.03	701.0 ± 4.5
FF(%)	77.94	76.63	74.77	75.11	76.1 ± 1.5

2G-23	1	2	3	4	average
η(%)	4.93	5.07	5.07	5.09	5.04 ± 0.07
J_{sc}(mA/cm^2)	9.40	10.46	9.87	9.58	9.83 ± 0.46
V_{oc}(mV)	688.64	676.64	687.84	692.64	686.4 ± 6.9
FF(%)	76.13	71.60	74.72	76.79	74.8 ± 2.3

2G-24	1	2	3	4	average
η(%)	4.03	3.59	3.73	3.56	3.73 ± 0.21
J_{sc}(mA/cm^2)	7.28	6.79	6.84	6.51	6.86 ± 0.3
V_{oc}(mV)	703.03	693.43	695.83	702.23	689.6 ± 4.7
FF(%)	78.79	76.24	78.30	77.97	77.8 ± 1.1

2G-25	1	2	3	4	average
η(%)	5.24	5.22	5.23	5.21	5.23 ± 0.01
J_{sc}(mA/cm^2)	10.86	10.64	10.19	9.77	10.37 ± 0.48
V_{oc}(mV)	671.85	686.23	707.02	709.42	693.6 ± 17.9
FF(%)	71.78	71.46	72.51	75.19	72.7 ± 1.7

2G-26	1	2	3	4	average
η(%)	3.96	3.88	3.75	3.98	3.89 ± 0.10
J_{sc}(mA/cm^2)	8.62	8.46	8.13	8.36	8.39 ± 0.21
V_{oc}(mV)	638.26	639.86	640.66	647.06	641.5 ± 3.9
FF(%)	71.89	71.66	72.13	73.50	72.3 ± 0.8

2G-27	1	2	3	4	average
η(%)	2.61	2.37	2.43	2.51	2.48 ± 0.10
J_{sc}(mA/cm^2)	4.54	4.32	4.38	4.54	4.45 ± 0.11
V_{oc}(mV)	728.62	704.63	706.23	709.42	712.2 ± 11.1
FF(%)	78.92	78.02	78.54	77.75	78.3 ± 0.5

2G-28	1	2	3	4	average
η(%)	4.01	3.77	3.53	3.88	3.80 ± 0.20
J_{sc}(mA/cm^2)	7.62	7.20	6.71	7.50	7.26 ± 0.41
V_{oc}(mV)	685.44	682.24	683.04	686.23	684.2 ± 1.9
FF(%)	76.80	76.61	77.04	75.53	76.5 ± 0.7

2G-29	1	2	3	4	average
η(%)	3.41	3.46	3.72	3.45	3.51 ± 0.14
J_{sc}(mA/cm^2)	6.16	6.21	6.71	6.07	6.29 ± 0.29
V_{oc}(mV)	713.43	712.62	711.02	723.82	715.2 ± 5.8
FF(%)	77.67	78.20	77.85	78.53	78.1 ± 0.4

2G-30	1	2	3	4	average
η(%)	5.08	5.10	4.73	4.70	4.90 ± 0.20
J_{sc}(mA/cm^2)	9.02	9.55	8.96	8.65	9.16 ± 0.37
V_{oc}(mV)	754.58	742.72	720.46	730.96	728.6 ± 14.7
FF(%)	74.64	71.90	73.27	74.33	73.5 ± 1.2

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3rd Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
3G-1	10	60	20	10	D4	D4	D4	D4	F5	94	4.20 ±0.11
3G-2	0	40	30	30	D2	D3	D1	D3	F8	94	5.02 ± 0.10
3G-3	30	20	40	10	D2	D1	D4	D3	F5	94	3.58 ± 0.11
3G-4	20	60	20	0	D3	D2	D2	D3	F2	94	4.26 ± 0.07
3G-5	0	40	30	30	D2	D3	D1	D3	F8	72	5.00 ± 0.17
3G-6	20	40	20	20	D1	D4	D3	D4	F8	50	3.67 ± 0.04
3G-7	10	60	20	10	D4	D2	D3	D3	F8	28	3.67 ± 0.14
3G-8	10	10	80	0	D4	D1	D2	D4	F6	72	5.08 ± 0.08
3G-9	10	50	20	20	D1	D4	D1	D4	F2	94	3.95 ± 0.05
3G-10	20	0	60	20	D2	D1	D4	D4	F7	50	4.27 ± 0.12
3G-11	30	40	30	0	D2	D3	D1	D3	F7	50	4.01 ± 0.05
3G-12	30	20	20	30	D1	D4	D1	D4	F7	94	3.68 ± 0.13
3G-13	10	60	30	0	D1	D4	D1	D3	F1	72	3.62 ± 0.19
3G-14	20	20	40	20	D2	D4	D2	D3	F7	94	4.74 ± 0.07
3G-15	10	20	60	10	D2	D3	D4	D3	F5	28	3.89 ± 0.16
3G-16	10	40	20	30	D3	D4	D1	D4	F7	50	4.02 ± 0.07
3G-17	0	20	80	0	D3	D3	D2	D4	F7	28	4.76 ± 0.11
3G-18	20	50	30	0	D4	D1	D3	D4	F4	28	3.60 ± 0.13
3G-19	20	60	20	0	D1	D4	D1	D3	F6	28	3.78 ± 0.07
3G-20	10	0	80	10	D4	D4	D4	D3	F4	28	3.89 ± 0.12
3G-21	20	60	20	0	D2	D3	D3	D4	F5	50	3.83 ± 0.05
3G-22	30	20	40	10	D4	D2	D4	D2	F7	72	3.91 ± 0.02
3G-23	20	40	10	30	D3	D4	D4	D2	F7	50	3.73 ± 0.10
3G-24	20	40	20	20	D1	D4	D3	D4	F2	50	2.79 ± 0.11
3G-25	0	30	40	30	D2	D1	D3	D4	F6	72	4.16 ± 0.16
3G-26	30	20	40	10	D4	D4	D4	D3	F2	94	3.07 ± 0.12
3G-27	0	40	30	30	D2	D3	D1	D3	F7	94	5.41 ± 0.07
3G-28	30	20	20	30	D2	D4	D1	D1	F3	72	2.91 ± 0.18
3G-29	10	30	50	10	D1	D2	D2	D1	F5	72	4.36 ± 0.21
3G-30	0	40	30	30	D2	D3	D1	D3	F6	94	5.31 ± 0.06

(red color) the highest η used for the next generation (Eliticism)

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3rd Generation : Cell parameters for 4 independent samples (3G-1 ~ 3G-10)

3G-1	1	2	3	4	average
η(%)	4.20	4.09	4.34	4.16	4.20 ± 0.11
J_{sc}(mA/cm^2)	7.98	7.45	8.30	7.95	7.92 ± 0.35
V_{oc}(mV)	705.42	726.21	716.62	703.03	712.8 ± 10.7
FF(%)	74.56	75.55	73.07	74.41	74.4 ± 1.0

3G-2	1	2	3	4	average
η(%)	5.13	4.89	5.00	5.04	5.02 ± 0.10
J_{sc}(mA/cm^2)	10.00	9.87	9.63	10.03	9.88 ± 0.18
V_{oc}(mV)	708.62	687.04	711.02	686.23	698.2 ± 13.4
FF(%)	72.38	72.08	73.10	73.22	72.7 ± 0.6

3G-3	1	2	3	4	average
η(%)	3.55	3.50	3.52	3.73	3.58 ± 0.11
J_{sc}(mA/cm^2)	6.67	6.62	6.59	6.99	6.72 ± 0.18
V_{oc}(mV)	689.44	688.64	691.83	692.64	690.6 ± 1.9
FF(%)	77.17	76.70	77.25	77.06	77.1 ± 0.2

3G-4	1	2	3	4	average
η(%)	4.34	4.16	4.25	4.28	4.26 ± 0.07
J_{sc}(mA/cm^2)	8.22	7.71	7.99	7.98	7.98 ± 0.21
V_{oc}(mV)	697.43	702.23	701.43	699.03	700.0 ± 2.2
FF(%)	75.68	76.93	75.86	76.74	76.3 ± 0.6

3G-5	1	2	3	4	average
η(%)	4.88	5.24	4.90	4.96	5.00 ± 0.17
J_{sc}(mA/cm^2)	10.14	10.60	10.05	10.28	10.27 ± 0.24
V_{oc}(mV)	679.05	688.64	669.44	667.05	676.1 ± 9.9
FF(%)	70.91	71.82	72.88	72.32	72.0 ± 0.8

3G-6	1	2	3	4	average
η(%)	3.73	3.67	3.66	3.63	3.67 ± 0.04
J_{sc}(mA/cm^2)	7.70	7.44	7.75	7.16	7.51 ± 0.27
V_{oc}(mV)	655.85	666.25	649.46	672.64	661.1 ± 10.4
FF(%)	73.83	74.01	72.85	75.36	74.01 ± 1.03

3G-7	1	2	3	4	average
η(%)	3.63	3.70	3.51	3.85	3.67 ± 0.14
J_{sc}(mA/cm^2)	7.75	7.52	7.21	8.12	7.65 ± 0.38
V_{oc}(mV)	655.85	670.25	655.06	659.85	660.3 ± 7.0
FF(%)	71.45	73.45	74.23	71.92	72.8 ± 1.3

3G-8	1	2	3	4	average
η(%)	4.98	5.17	5.05	5.12	5.08 ± 0.08
J_{sc}(mA/cm^2)	10.37	10.70	10.58	10.24	10.47 ± 0.21
V_{oc}(mV)	677.45	690.23	684.63	704.63	689.2 ± 11.5
FF(%)	70.94	70.08	69.69	70.95	70.4 ± 0.6

3G-9	1	2	3	4	average
η(%)	3.88	3.98	3.98	3.94	3.95 ± 0.05
J_{sc}(mA/cm^2)	7.14	7.50	7.45	7.31	7.35 ± 0.16
V_{oc}(mV)	722.22	710.23	707.83	708.62	712.2 ± 6.7
FF(%)	75.33	74.72	75.49	76.10	75.4 ± 0.6

3G-10	1	2	3	4	average
η(%)	4.28	4.11	4.40	4.30	4.27 ± 0.12
J_{sc}(mA/cm^2)	8.48	7.90	8.61	8.40	8.35 ± 0.31
V_{oc}(mV)	687.04	691.83	684.63	683.04	686.6 ± 3.8
FF(%)	73.46	75.18	74.56	74.98	74.6 ± 0.8

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3rd Generation : Cell parameters for 4 independent samples (3G-11 ~ 3G-20)

3G-11	1	2	3	4	average
η(%)	4.05	4.04	3.95	4.00	4.01 ± 0.05
J_{sc}(mA/cm^2)	8.02	8.00	7.82	7.77	7.90 ± 0.13
V_{oc}(mV)	676.64	673.45	675.04	679.05	676.1 ± 2.4
FF(%)	74.67	75.03	74.85	75.86	75.1 ± 0.5

3G-12	1	2	3	4	average
η(%)	3.62	3.66	3.87	3.58	3.68 ± 0.13
J_{sc}(mA/cm^2)	7.12	7.18	7.27	7.00	7.14 ± 0.11
V_{oc}(mV)	672.64	671.85	691.04	671.85	676.9 ± 9.5
FF(%)	75.64	75.94	77.09	76.01	76.2 ± 0.6

3G-13	1	2	3	4	average
η(%)	3.76	3.73	3.62	3.35	3.62 ± 0.19
J_{sc}(mA/cm^2)	6.73	6.67	6.29	5.77	6.37 ± 0.44
V_{oc}(mV)	737.41	730.21	739.01	740.61	736.8 ± 4.6
FF(%)	75.72	76.72	77.89	78.46	77.2 ± 1.22

3G-14	1	2	3	4	average
η(%)	4.81	4.67	4.69	4.80	4.74 ± 0.07
J_{sc}(mA/cm^2)	9.62	9.36	9.43	9.59	9.50 ± 0.13
V_{oc}(mV)	683.84	684.63	694.24	684.63	686.8 ± 5.0
FF(%)	73.10	72.87	71.71	73.20	72.7 ± 0.7

3G-15	1	2	3	4	average
η(%)	3.99	3.72	3.78	4.05	3.89 ± 0.16
J_{sc}(mA/cm^2)	7.33	6.89	6.91	7.68	7.20 ± 0.38
V_{oc}(mV)	716.62	711.83	716.62	721.42	716.6 ± 3.9
FF(%)	75.93	75.79	76.28	73.13	75.3 ± 1.5

3G-16	1	2	3	4	average
η(%)	3.92	4.05	4.07	4.04	4.02 ± 0.07
J_{sc}(mA/cm^2)	8.73	8.52	8.43	8.16	8.46 ± 0.24
V_{oc}(mV)	657.45	679.84	667.05	677.45	670.5 ± 10.3
FF(%)	68.30	69.86	72.39	73.04	70.9 ± 2.21

3G-17	1	2	3	4	average
η(%)	4.71	4.89	4.64	4.81	4.76 ± 0.11
J_{sc}(mA/cm^2)	9.91	9.91	9.88	10.07	9.94 ± 0.09
V_{oc}(mV)	655.85	688.64	674.24	677.45	674.1 ± 13.6
FF(%)	72.43	71.64	69.61	70.45	71.0 ± 1.3

3G-18	1	2	3	4	average
η(%)	3.76	3.54	3.45	3.63	3.60 ± 0.13
J_{sc}(mA/cm^2)	7.06	6.51	6.39	6.88	6.71 ± 0.31
V_{oc}(mV)	693.43	689.44	692.64	695.03	692.6 ± 2.4
FF(%)	76.80	78.80	77.97	76.05	77.4 ± 1.2

3G-19	1	2	3	4	average
η(%)	3.73	3.77	3.74	3.88	3.78 ± 0.07
J_{sc}(mA/cm^2)	7.20	6.79	7.37	7.39	7.19 ± 0.28
V_{oc}(mV)	677.45	713.43	681.44	682.24	688.6 ± 16.7
FF(%)	76.54	77.79	74.54	76.97	76.5 ± 1.4

3G-20	1	2	3	4	average
η(%)	3.86	3.88	4.06	3.76	3.89 ± 0.12
J_{sc}(mA/cm^2)	7.17	7.59	7.69	7.08	7.38 ± 0.30
V_{oc}(mV)	714.22	716.62	720.62	720.62	718.0 ± 3.2
FF(%)	75.40	71.32	73.17	73.71	73.4 ± 1.7

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3rd Generation : Cell parameters for 4 independent samples (3G-21 ~ 3G-30)

3G-21	1	2	3	4	average
η(%)	3.90	3.79	3.83	3.81	3.83 ± 0.05
J_{sc}(mA/cm^2)	7.50	7.25	7.30	7.52	7.39 ± 0.14
V_{oc}(mV)	713.43	702.23	712.62	710.23	709.6 ± 5.1
FF(%)	72.90	74.50	73.68	71.39	73.1 ± 1.3

3G-22	1	2	3	4	average
η(%)	3.90	3.93	3.89	3.92	3.91 ± 0.02
J_{sc}(mA/cm^2)	8.74	8.74	8.44	8.44	8.59 ± 0.17
V_{oc}(mV)	671.85	670.25	685.44	677.45	676.3 ± 6.9
FF(%)	66.41	67.08	67.36	68.54	67.4 ± 0.9

3G-23	1	2	3	4	average
η(%)	3.74	3.61	3.73	3.85	3.73 ± 0.10
J_{sc}(mA/cm^2)	7.52	7.51	7.46	7.37	7.47 ± 0.07
V_{oc}(mV)	699.84	702.23	697.43	715.02	703.6 ± 7.8
FF(%)	71.15	68.46	71.69	73.11	71.1 ± 2.0

3G-24	1	2	3	4	average
η(%)	2.75	2.95	2.68	2.77	2.79 ± 0.11
J_{sc}(mA/cm^2)	5.19	5.56	5.98	5.08	5.45 ± 0.41
V_{oc}(mV)	715.02	716.62	684.63	734.22	712.6 ± 20.6
FF(%)	74.09	74.03	65.45	74.28	72.0 ± 4.3

3G-25	1	2	3	4	average
η(%)	3.92	4.24	4.21	4.26	4.16 ± 0.16
J_{sc}(mA/cm^2)	7.77	8.82	8.99	9.33	8.73 ± 0.67
V_{oc}(mV)	701.43	676.64	681.44	677.45	684.2 ± 11.7
FF(%)	71.88	71.11	68.82	67.41	69.8 ± 2.06

3G-26	1	2	3	4	average
η(%)	3.13	3.12	3.14	2.89	3.07 ± 0.12
J_{sc}(mA/cm^2)	6.01	5.99	5.71	5.53	5.81 ± 0.23
V_{oc}(mV)	712.62	710.23	743.00	722.22	722.0 ± 14.9
FF(%)	73.06	73.37	74.09	72.28	73.2 ± 0.8

3G-27	1	2	3	4	average
η(%)	5.46	5.31	5.43	5.42	5.41 ± 0.07
J_{sc}(mA/cm^2)	10.94	10.58	10.94	10.98	10.86 ± 0.19
V_{oc}(mV)	678.24	679.84	674.24	674.24	676.6 ± 2.9
FF(%)	73.54	73.88	73.57	73.29	73.6 ± 0.2

3G-28	1	2	3	4	average
η(%)	3.09	3.03	2.77	2.73	2.91 ± 0.18
J_{sc}(mA/cm^2)	6.02	5.82	5.79	5.71	5.84 ± 0.13
V_{oc}(mV)	719.01	713.43	700.63	697.43	707.6 ± 10.3
FF(%)	71.53	72.96	68.32	68.69	70.4 ± 2.2

3G-29	1	2	3	4	average
η(%)	4.19	4.17	4.48	4.59	4.36 ± 0.21
J_{sc}(mA/cm^2)	8.48	8.44	8.5	9.29	8.68 ± 0.41
V_{oc}(mV)	715.02	711.02	715.02	706.23	711.8 ± 4.2
FF(%)	69.09	69.57	73.78	70.01	70.6 ± 2.1

3G-30	1	2	3	4	average
η(%)	5.19	5.21	5.33	5.39	5.28 ± 0.10
J_{sc}(mA/cm^2)	10.19	10.33	10.41	10.18	10.21 ± 0.12
V_{oc}(mV)	693.43	699.03	699.03	708.62	701.9 ± 6.2
FF(%)	74.28	73.6	74.02	73.39	73.7 ± 0.4

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4th Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
4G-1	20	20	30	30	D3	D1	D3	D4	F2	50	3.03 ± 0.15
4G-2	30	40	30	0	D3	D3	D4	D3	F1	72	2.90 ± 0.06
4G-3	0	80	0	20	D1	D3	D1	D1	F7	50	4.45 ± 0.09
4G-4	30	20	20	30	D3	D4	D1	D4	F7	94	4.40 ± 0.03
4G-5	20	40	10	30	D1	D4	D4	D2	F7	50	3.98 ± 0.17
4G-6	10	50	20	20	D3	D4	D1	D4	F2	94	3.56 ± 0.11
4G-7	20	20	40	20	D1	D2	D4	D3	F8	94	3.43 ± 0.11
4G-8	20	20	40	20	D2	D4	D2	D3	F8	50	4.25 ± 0.04
4G-9	0	30	50	20	D4	D1	D4	D4	F7	94	5.16 ± 0.02
4G-10	0	70	30	0	D1	D4	D1	D3	F4	28	3.97 ± 0.09
4G-11	30	30	40	0	D4	D3	D1	D3	F7	72	4.13 ± 0.11
4G-12	10	20	50	20	D4	D1	D1	D1	F7	50	3.89 ± 0.12
4G-13	0	60	20	20	D2	D1	D3	D4	F5	50	4.00 ± 0.10
4G-14	10	60	30	0	D1	D4	D1	D3	F2	72	3.75 ± 0.09
4G-15	30	20	40	10	D4	D2	D4	D2	F5	94	4.42 ± 0.19
4G-16	30	20	40	10	D2	D1	D4	D3	F7	72	4.12 ± 0.09
4G-17	10	60	30	0	D4	D4	D1	D3	F1	72	3.00 ± 0.12
4G-18	10	0	80	10	D1	D4	D4	D3	F4	28	3.65 ± 0.10
4G-19	10	40	20	30	D4	D2	D3	D3	F5	72	4.28 ± 0.04
4G-20	30	0	50	20	D1	D2	D2	D1	F8	28	3.38 ± 0.05
4G-21	0	40	30	30	D2	D3	D1	D3	F7	72	5.24 ± 0.05
4G-22	30	0	50	20	D3	D2	D3	D1	F7	94	4.64 ± 0.05
4G-23	20	0	60	20	D2	D3	D4	D4	F7	50	4.27 ± 0.11
4G-24	20	60	20	0	D2	D1	D3	D4	F5	50	3.00 ± 0.05
4G-25	0	30	40	30	D4	D2	D4	D2	F6	72	4.59 ± 0.15
4G-26	0	10	80	10	D4	D1	D2	D4	F7	72	5.59 ± 0.04
4G-27	20	20	40	20	D3	D4	D4	D3	F7	94	4.54 ± 0.03
4G-28	10	40	30	20	D4	D2	D3	D3	F2	28	2.67 ± 0.13
4G-29	0	40	40	20	D4	D4	D1	D3	F7	94	5.44 ± 0.04
4G-30	0	40	30	30	D2	D3	D1	D3	F7	94	5.42 ± 0.11

(red color) the highest η used for the next generation (Eliticism)

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4th Generation : Cell parameters for 4 independent samples (4G-1 ~ 4G-10)

4G-1	1	2	3	4	average
η(%)	2.96	3.22	2.87	3.08	3.03 ± 0.15
J_{sc}(mA/cm^2)	5.28	5.61	4.94	5.40	5.31 ± 0.28
V_{oc}(mV)	733.41	725.42	735.81	726.21	730.2 ± 5.2
FF(%)	76.30	79.02	78.97	78.51	78.2 ± 1.3

4G-2	1	2	3	4	average
η(%)	2.81	2.95	2.90	2.93	2.90 ± 0.06
J_{sc}(mA/cm^2)	5.15	5.15	5.03	5.03	5.09 ± 0.07
V_{oc}(mV)	747.81	750.20	754.20	750.20	750.6 ± 2.7
FF(%)	73.03	76.39	76.36	77.67	75.8 ± 2.0

4G-3	1	2	3	4	average
η(%)	4.33	4.42	4.50	4.53	4.45 ± 0.09
J_{sc}(mA/cm^2)	8.24	8.06	8.16	8.44	8.23 ± 0.16
V_{oc}(mV)	703.03	707.83	712.62	703.82	706.8 ± 4.4
FF(%)	74.75	77.43	77.34	76.29	76.5 ± 1.3

4G-4	1	2	3	4	average
η(%)	4.37	4.41	4.43	4.38	4.40 ± 0.03
J_{sc}(mA/cm^2)	8.16	8.42	8.22	8.22	8.25 ± 0.11
V_{oc}(mV)	698.24	683.84	697.43	686.23	691.4 ± 7.5
FF(%)	76.81	76.66	77.37	77.61	77.1 ± 0.5

4G-5	1	2	3	4	average
η(%)	3.97	3.74	4.12	4.08	3.98 ± 0.17
J_{sc}(mA/cm^2)	7.33	6.63	7.21	7.62	7.20 ± 0.41
V_{oc}(mV)	687.84	702.23	691.04	694.24	693.8 ± 6.2
FF(%)	78.75	80.26	82.77	77.07	79.7 ± 2.4

4G-6	1	2	3	4	average
η(%)	3.49	3.46	3.69	3.61	3.56 ± 0.11
J_{sc}(mA/cm^2)	6.19	6.06	6.61	6.45	6.33 ± 0.25
V_{oc}(mV)	736.61	727.81	739.01	728.62	733.0 ± 5.6
FF(%)	76.46	78.32	75.65	76.80	76.8 ± 1.1

4G-7	1	2	3	4	average
η(%)	3.56	3.31	3.46	3.37	3.43 ± 0.11
J_{sc}(mA/cm^2)	7.28	6.72	6.91	6.81	6.93 ± 0.24
V_{oc}(mV)	663.05	665.45	667.05	666.25	665.5 ± 1.7
FF(%)	73.84	74.06	75.13	74.27	74.3 ± 0.6

4G-8	1	2	3	4	average
η(%)	4.20	4.27	4.27	4.25	4.25 ± 0.04
J_{sc}(mA/cm^2)	8.33	8.61	8.61	8.43	8.49 ± 0.14
V_{oc}(mV)	671.04	663.86	663.86	683.84	670.7 ± 9.4
FF(%)	75.06	74.74	74.74	73.76	74.6 ± 0.6

4G-9	1	2	3	4	average
η(%)	5.17	5.16	5.13	5.18	5.16 ± 0.02
J_{sc}(mA/cm^2)	10.09	9.86	9.83	9.87	9.91 ± 0.12
V_{oc}(mV)	674.24	683.04	690.23	688.64	684.0 ± 7.2
FF(%)	76.05	76.62	75.58	76.19	76.1 ± 0.4

4G-10	1	2	3	4	average
η(%)	3.94	3.85	4.05	4.03	3.97 ± 0.09
J_{sc}(mA/cm^2)	7.07	6.89	7.30	7.24	7.13 ± 0.19
V_{oc}(mV)	713.43	711.83	731.81	729.41	721.6 ± 10.5
FF(%)	78.18	78.54	75.80	76.24	77.2 ± 1.4

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4th Generation : Cell parameters for 4 independent samples (4G-11 ~ 4G-20)

4G-11	1	2	3	4	average
η(%)	4.02	4.28	4.12	4.10	4.13 ± 0.11
J_{sc}(mA/cm^2)	7.27	8.39	7.64	8.19	7.87 ± 0.51
V_{oc}(mV)	717.42	690.23	701.43	694.24	700.8 ± 12.0
FF(%)	77.09	73.86	76.96	72.19	75.0 ± 2.4

4G-12	1	2	3	4	average
η(%)	3.91	3.86	4.04	3.76	3.89 ± 0.12
J_{sc}(mA/cm^2)	7.24	7.22	7.68	6.99	7.28 ± 0.29
V_{oc}(mV)	700.63	695.03	693.43	701.43	697.6 ± 4.0
FF(%)	77.03	76.97	75.98	76.57	76.6 ± 0.5

4G-13	1	2	3	4	average
η(%)	3.87	4.09	3.99	4.06	4.00 ± 0.10
J_{sc}(mA/cm^2)	7.47	7.58	7.37	7.53	7.49 ± 0.09
V_{oc}(mV)	713.43	727.02	718.22	723.82	720.6 ± 6.0
FF(%)	72.68	74.20	75.34	74.46	74.2 ± 1.1

4G-14	1	2	3	4	average
η(%)	3.67	3.77	3.87	3.70	3.75 ± 0.09
J_{sc}(mA/cm^2)	6.49	6.64	6.91	6.56	6.65 ± 0.18
V_{oc}(mV)	724.61	736.61	721.42	730.21	728.2 ± 6.7
FF(%)	78.03	76.97	77.70	77.20	77.5 ± 0.5

4G-15	1	2	3	4	average
η(%)	4.55	4.36	4.19	4.60	4.42 ± 0.19
J_{sc}(mA/cm^2)	8.54	8.06	7.81	8.64	8.26 ± 0.40
V_{oc}(mV)	695.83	702.23	709.42	707.02	703.6 ± 6.0
FF(%)	76.51	77.08	75.58	75.20	76.1 ± 0.9

4G-16	1	2	3	4	average
η(%)	4.15	4.04	4.05	4.23	4.12 ± 0.09
J_{sc}(mA/cm^2)	8.06	7.75	7.68	8.20	7.92 ± 0.25
V_{oc}(mV)	685.44	690.23	689.44	671.85	684.2 ± 8.5
FF(%)	75.21	75.55	76.39	76.87	76.0 ± 0.8

4G-17	1	2	3	4	average
η(%)	3.09	3.10	2.94	2.86	3.00 ± 0.12
J_{sc}(mA/cm^2)	5.39	5.34	5.15	4.88	5.19 ± 0.23
V_{oc}(mV)	746.21	751.00	750.20	748.60	749.0 ± 2.1
FF(%)	76.79	77.32	76.18	78.20	77.12 ± 0.9

4G-18	1	2	3	4	average
η(%)	3.77	3.53	3.63	3.66	3.65 ± 0.10
J_{sc}(mA/cm^2)	6.91	6.95	6.73	6.78	6.85 ± 0.11
V_{oc}(mV)	701.43	699.84	701.43	701.43	701.0 ± 0.8
FF(%)	77.79	72.56	76.88	76.96	76.1 ± 2.4

4G-19	1	2	3	4	average
η(%)	4.30	4.28	4.30	4.23	4.29 ± 0.04
J_{sc}(mA/cm^2)	7.66	7.56	7.78	7.53	7.63 ± 0.11
V_{oc}(mV)	723.02	720.62	722.22	727.02	723.2 ± 2.7
FF(%)	77.67	78.49	76.59	77.23	77.5 ± 0.8

4G-20	1	2	3	4	average
η(%)	3.31	3.38	3.42	3.40	3.38 ± 0.05
J_{sc}(mA/cm^2)	6.26	6.29	6.56	6.58	6.42 ± 0.17
V_{oc}(mV)	687.84	684.63	677.45	683.84	683.4 ± 4.4
FF(%)	77.00	78.52	77.02	75.52	77.0 ± 1.2

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4th Generation : Cell parameters for 4 independent samples (4G-21 ~ 4G-30)

4G-21	1	2	3	4	average
η(%)	5.24	5.21	5.31	5.21	5.24 ± 0.05
J_{sc}(mA/cm^2)	9.67	9.60	9.72	9.82	9.70 ± 0.09
V_{oc}(mV)	703.82	715.02	713.43	705.42	709.4 ± 5.6
FF(%)	77.00	75.91	76.56	75.19	76.2 ± 0.8

4G-22	1	2	3	4	average
η(%)	4.61	4.70	4.64	4.59	4.64 ± 0.05
J_{sc}(mA/cm^2)	8.81	8.82	8.99	8.63	8.81 ± 0.15
V_{oc}(mV)	698.24	701.43	706.23	697.43	700.8 ± 0.4
FF(%)	74.93	75.97	73.14	76.31	75.1 ± 1.4

4G-23	1	2	3	4	average
η(%)	4.12	4.26	4.32	4.37	4.27 ± 0.11
J_{sc}(mA/cm^2)	7.92	7.91	7.79	8.03	7.91 ± 0.10
V_{oc}(mV)	693.43	697.43	703.82	710.23	701.2 ± 7.4
FF(%)	75.10	77.31	78.75	76.61	76.9 ± 1.5

4G-24	1	2	3	4	average
η(%)	3.02	2.95	2.97	3.06	3.00 ± 0.05
J_{sc}(mA/cm^2)	5.60	5.05	5.05	5.29	5.25 ± 0.26
V_{oc}(mV)	694.24	709.42	708.62	706.23	704.6 ± 7.1
FF(%)	77.51	82.21	83.20	81.98	81.2 ± 2.5

4G-25	1	2	3	4	average
η(%)	4.42	4.62	4.53	4.77	4.59 ± 0.15
J_{sc}(mA/cm^2)	8.44	9.05	8.65	9.08	8.81 ± 0.31
V_{oc}(mV)	689.44	691.04	696.63	695.83	693.2 ± 3.5
FF(%)	75.91	73.87	75.20	75.54	75.1 ± 0.9

4G-26	1	2	3	4	average
η(%)	5.59	5.63	5.62	5.54	5.59 ± 0.04
J_{sc}(mA/cm^2)	10.36	10.41	10.30	10.12	10.30 ± 0.13
V_{oc}(mV)	706.23	710.23	717.42	715.02	712.2 ± 5.0
FF(%)	76.32	76.09	76.05	76.57	76.3 ± 0.2

4G-27	1	2	3	4	average
η(%)	4.50	4.55	4.56	4.56	4.54 ± 0.03
J_{sc}(mA/cm^2)	8.27	8.47	8.70	8.46	8.47 ± 0.17
V_{oc}(mV)	705.42	698.24	703.03	701.43	702.0 ± 3.0
FF(%)	77.20	76.96	74.60	76.78	76.4 ± 1.2

4G-28	1	2	3	4	average
η(%)	2.66	2.78	2.50	2.75	2.67 ± 0.13
J_{sc}(mA/cm^2)	4.71	4.77	4.40	4.96	4.71 ± 0.23
V_{oc}(mV)	743.00	742.21	740.61	747.00	743.2 ± 2.7
FF(%)	76.13	78.54	76.66	74.23	76.4 ± 1.8

4G-29	1	2	3	4	average
η(%)	5.45	5.40	5.42	5.48	5.44 ± 0.04
J_{sc}(mA/cm^2)	10.28	10.38	10.30	10.09	10.26 ± 0.12
V_{oc}(mV)	702.23	696.63	701.43	711.83	703.0 ± 6.4
FF(%)	75.47	74.69	75.00	76.29	75.4 ± 0.7

4G-30	1	2	3	4	average
η(%)	5.29	5.37	5.52	5.51	5.42 ± 0.11
J_{sc}(mA/cm^2)	10.09	9.99	10.17	10.14	10.10 ± 0.08
V_{oc}(mV)	706.23	710.23	721.42	717.42	713.8 ± 6.9
FF(%)	74.24	75.72	75.31	75.69	75.2 ± 0.7

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5th Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
5G-1	20	20	40	20	D2	D4	D2	D3	F7	50	4.86 ± 0.06
5G-2	20	40	10	30	D2	D4	D2	D2	F8	50	3.77 ± 0.04
5G-3	30	20	20	30	D2	D4	D1	D4	F7	94	4.20 ± 0.04
5G-4	0	40	40	20	D4	D4	D1	D2	F7	94	4.83 ± 0.06
5G-5	10	0	90	0	D1	D3	D3	D1	F7	94	5.07 ± 0.05
5G-6	20	40	20	20	D1	D1	D2	D4	F5	50	3.22 ± 0.14
5G-7	0	90	0	10	D4	D1	D3	D1	F5	50	2.58 ± 0.13
5G-8	20	20	40	20	D3	D4	D4	D3	F8	94	3.96 ± 0.15
5G-9	0	10	80	10	D4	D1	D2	D4	F7	94	5.84 ± 0.02
5G-10	0	20	80	0	D4	D1	D2	D4	F7	94	4.69 ± 0.02
5G-11	0	0	90	10	D4	D1	D2	D3	F7	94	5.36 ± 0.12
5G-12	10	40	20	30	D1	D4	D1	D4	F7	94	4.65 ± 0.10
5G-13	10	20	50	20	D4	D2	D1	D1	F7	50	4.24 ± 0.07
5G-14	0	40	30	30	D4	D4	D1	D3	F5	94	4.17 ± 0.04
5G-15	20	40	40	0	D3	D1	D4	D4	F5	94	3.42 ± 0.09
5G-16	20	40	10	30	D2	D3	D1	D2	F7	50	3.94 ± 0.14
5G-17	0	50	40	10	D3	D3	D2	D1	F5	28	3.21 ± 0.08
5G-18	0	30	70	0	D3	D3	D3	D1	F3	28	4.22 ± 0.16
5G-19	0	80	0	20	D4	D4	D1	D1	F7	50	4.43 ± 0.14
5G-20	10	20	50	20	D4	D1	D4	D4	F7	94	4.69 ± 0.06
5G-21	30	10	40	20	D2	D1	D4	D3	F7	50	3.78 ± 0.09
5G-22	30	40	10	20	D1	D4	D4	D2	F7	72	3.45 ± 0.09
5G-23	20	20	50	10	D2	D4	D1	D4	F3	28	3.03 ± 0.03
5G-24	0	20	50	30	D2	D2	D1	D4	F2	28	3.02 ± 0.07
5G-25	0	40	30	30	D4	D2	D3	D3	F7	94	4.28 ± 0.09
5G-26	10	40	20	30	D2	D3	D1	D3	F5	72	4.05 ± 0.05
5G-27	0	60	10	30	D2	D4	D2	D2	F7	94	5.04 ± 0.11
5G-28	10	20	50	20	D4	D1	D4	D4	F7	50	4.80 ± 0.07
5G-29	0	30	40	30	D4	D3	D1	D3	F2	50	3.84 ± 0.15
5G-30	0	10	80	10	D4	D1	D2	D4	F7	72	5.52 ± 0.06

(red color) the highest η used for the next generation (Eliticism)

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5th Generation : Cell parameters for 4 independent samples (5G-1 ~ 5G-10)

5G-1	1	2	3	4	average
η(%)	4.85	4.82	4.83	4.94	4.86 ± 0.06
J_{sc}(mA/cm^2)	9.28	9.00	9.05	9.58	9.23 ± 0.26
V_{oc}(mV)	699.03	701.43	699.84	689.44	697.4 ± 5.4
FF(%)	74.77	76.37	76.17	74.83	75.5 ± 0.9

5G-2	1	2	3	4	average
η(%)	3.81	3.79	3.71	3.78	3.77 ± 0.04
J_{sc}(mA/cm^2)	7.42	6.89	7.18	7.39	7.22 ± 0.24
V_{oc}(mV)	676.64	711.83	670.25	678.24	684.2 ± 18.7
FF(%)	75.90	77.30	77.04	75.34	76.4 ± 0.9

5G-3	1	2	3	4	average
η(%)	4.14	4.20	4.20	4.24	4.20 ± 0.04
J_{sc}(mA/cm^2)	7.69	8.15	8.05	7.98	7.97 ± 0.19
V_{oc}(mV)	708.62	695.83	698.24	707.02	702.4 ± 6.3
FF(%)	75.92	74.10	74.79	75.09	75.0 ± 0.8

5G-4	1	2	3	4	average
η(%)	4.86	4.79	4.79	4.91	4.83 ± 0.06
J_{sc}(mA/cm^2)	9.63	9.15	9.21	9.90	9.47 ± 0.36
V_{oc}(mV)	689.44	696.63	721.42	687.04	698.6 ± 15.7
FF(%)	73.12	75.05	72.08	72.15	73.1 ± 1.4

5G-5	1	2	3	4	average
η(%)	5.03	5.04	5.13	5.09	5.07 ± 0.05
J_{sc}(mA/cm^2)	10.31	10.42	10.62	10.35	10.42 ± 0.14
V_{oc}(mV)	683.04	687.04	681.44	688.64	685.0 ± 3.4
FF(%)	71.34	70.39	70.86	71.39	71.0 ± 0.5

5G-6	1	2	3	4	average
η(%)	3.31	3.37	3.12	3.09	3.22 ± 0.14
J_{sc}(mA/cm^2)	5.65	5.92	5.47	5.46	5.62 ± 0.22
V_{oc}(mV)	727.81	726.21	716.62	717.42	722.0 ± 5.8
FF(%)	80.34	78.51	79.75	78.97	79.4 ± 0.8

5G-7	1	2	3	4	average
η(%)	2.61	2.46	2.76	2.49	2.58 ± 0.13
J_{sc}(mA/cm^2)	4.49	4.34	5.00	4.35	4.55 ± 0.31
V_{oc}(mV)	706.23	691.83	679.84	704.63	685.6 ± 12.3
FF(%)	82.24	82.03	81.07	81.32	81.7 ± 0.6

5G-8	1	2	3	4	average
η(%)	4.16	3.91	3.99	3.81	3.96 ± 0.15
J_{sc}(mA/cm^2)	8.65	7.96	8.49	7.89	8.25 ± 0.38
V_{oc}(mV)	675.04	674.24	675.85	679.84	676.2 ± 2.5
FF(%)	71.22	72.73	69.49	70.99	71.1 ± 1.3

5G-9	1	2	3	4	average
η(%)	5.92	5.92	5.95	5.96	5.94 ± 0.02
J_{sc}(mA/cm^2)	11.68	11.94	11.13	11.67	11.61 ± 0.34
V_{oc}(mV)	708.62	710.23	719.01	716.62	713.6 ± 5.0
FF(%)	71.52	69.76	74.31	71.26	71.7 ± 1.9

5G-10	1	2	3	4	average
η(%)	4.66	4.72	4.69	4.70	4.69 ± 0.02
J_{sc}(mA/cm^2)	9.60	9.30	8.91	9.06	9.22 ± 0.30
V_{oc}(mV)	696.63	711.02	716.62	702.23	706.6 ± 8.9
FF(%)	69.73	71.44	73.37	73.87	72.1 ± 1.9

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5th Generation : Cell parameters for 4 independent samples (5G-11 ~ 5G-20)

5G-11	1	2	3	4	average
η(%)	5.53	5.25	5.32	5.35	5.36 ± 0.12
J_{sc}(mA/cm^2)	10.99	10.81	10.76	10.00	10.64 ± 0.44
V_{oc}(mV)	706.23	703.82	704.63	723.82	709.6 ± 9.5
FF(%)	71.29	68.96	70.14	73.95	71.1 ± 2.1

5G-12	1	2	3	4	average
η(%)	4.68	4.50	4.67	4.73	4.65 ± 0.10
J_{sc}(mA/cm^2)	8.86	8.44	8.89	9.13	8.83 ± 0.29
V_{oc}(mV)	704.63	705.42	710.23	707.02	706.8 ± 2.5
FF(%)	74.99	75.52	74.01	73.28	74.5 ± 1.0

5G-13	1	2	3	4	average
η(%)	4.20	4.22	4.22	4.34	4.24 ± 0.07
J_{sc}(mA/cm^2)	7.89	8.23	8.28	8.45	8.21 ± 0.23
V_{oc}(mV)	693.43	690.23	695.83	691.83	692.8 ± 2.4
FF(%)	76.71	74.29	73.19	74.32	74.6 ± 1.5

5G-14	1	2	3	4	average
η(%)	4.22	4.17	4.18	4.13	4.17 ± 0.04
J_{sc}(mA/cm^2)	7.56	7.46	7.82	7.63	7.62 ± 0.15
V_{oc}(mV)	739.80	730.21	733.41	744.61	737.0 ± 6.5
FF(%)	75.44	76.49	72.86	72.63	74.4 ± 1.9

5G-15	1	2	3	4	average
η(%)	3.31	3.39	3.51	3.46	3.42 ± 0.09
J_{sc}(mA/cm^2)	5.96	6.06	6.20	6.19	6.10 ± 0.11
V_{oc}(mV)	723.02	711.02	722.22	722.22	719.6 ± 5.8
FF(%)	76.65	78.61	78.39	77.43	77.8 ± 0.9

5G-16	1	2	3	4	average
η(%)	4.01	3.98	4.03	3.74	3.94 ± 0.14
J_{sc}(mA/cm^2)	7.33	7.30	7.64	7.12	7.35 ± 0.22
V_{oc}(mV)	709.42	703.03	696.63	705.42	703.6 ± 5.4
FF(%)	77.22	77.56	75.79	74.50	76.3 ± 1.4

5G-17	1	2	3	4	average
η(%)	3.12	3.20	3.32	3.22	3.21 ± 0.08
J_{sc}(mA/cm^2)	5.34	5.68	5.67	5.49	5.54 ± 0.16
V_{oc}(mV)	743.81	758.99	746.21	744.61	748.4 ± 7.1
FF(%)	78.40	74.23	78.46	78.72	77.5 ± 2.2

5G-18	1	2	3	4	average
η(%)	4.36	4.08	4.36	4.09	4.22 ± 0.16
J_{sc}(mA/cm^2)	7.81	7.30	7.85	7.05	7.51 ± 0.39
V_{oc}(mV)	747.00	760.59	758.20	765.39	757.8 ± 7.8
FF(%)	74.67	73.52	73.25	75.86	74.3 ± 1.2

5G-19	1	2	3	4	average
η(%)	4.37	4.57	4.51	4.26	4.43 ± 0.14
J_{sc}(mA/cm^2)	7.91	8.16	7.74	7.83	7.91 ± 0.18
V_{oc}(mV)	715.82	732.62	752.60	719.01	730.0 ± 16.7
FF(%)	77.15	76.47	77.40	75.65	76.7 ± 0.8

5G-20	1	2	3	4	average
η(%)	4.71	4.76	4.61	4.69	4.69 ± 0.06
J_{sc}(mA/cm^2)	9.15	9.17	8.61	9.13	9.01 ± 0.27
V_{oc}(mV)	715.02	710.23	719.82	717.42	715.6 ± 4.1
FF(%)	72.02	73.05	74.40	71.67	72.8 ± 1.2

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5th Generation : Cell parameters for 4 independent samples (5G-21 ~ 5G-30)

5G-21	1	2	3	4	average
η(%)	3.73	3.91	3.71	3.78	3.78 ± 0.09
J_{sc}(mA/cm^2)	6.92	7.46	6.78	6.82	7.00 ± 0.32
V_{oc}(mV)	696.63	692.64	703.03	714.22	701.6 ± 9.4
FF(%)	77.42	75.69	77.76	77.60	77.1 ± 1.0

5G-22	1	2	3	4	average
η(%)	3.54	3.50	3.44	3.34	3.45 ± 0.09
J_{sc}(mA/cm^2)	6.51	7.45	6.26	6.12	6.58 ± 0.60
V_{oc}(mV)	695.83	679.05	706.23	695.83	694.2 ± 11.3
FF(%)	78.17	69.24	77.86	78.37	75.9 ± 4.5

5G-23	1	2	3	4	average
η(%)	3.06	3.04	3.00	3.03	3.03 ± 0.03
J_{sc}(mA/cm^2)	5.28	5.13	5.18	5.23	5.20 ± 0.06
V_{oc}(mV)	745.40	743.81	752.60	746.21	747.0 ± 3.9
FF(%)	77.78	79.73	76.93	77.48	78.0 ± 1.2

5G-24	1	2	3	4	average
η(%)	3.07	2.95	3.09	2.98	3.02 ± 0.07
J_{sc}(mA/cm^2)	5.08	4.94	5.14	5.01	5.04 ± 0.09
V_{oc}(mV)	769.39	762.19	774.99	764.59	767.8 ± 5.7
FF(%)	78.47	78.47	77.47	77.74	78.0 ± 0.5

5G-25	1	2	3	4	average
η(%)	4.41	4.23	4.24	4.22	4.28 ± 0.09
J_{sc}(mA/cm^2)	8.33	8.13	8.11	8.13	8.17 ± 0.11
V_{oc}(mV)	708.62	712.62	714.22	721.42	714.2 ± 5.4
FF(%)	74.76	72.97	73.23	72.04	73.3 ± 1.1

5G-26	1	2	3	4	average
η(%)	4.05	4.10	3.98	4.07	4.05 ± 0.05
J_{sc}(mA/cm^2)	7.31	7.27	7.30	7.23	7.28 ± 0.04
V_{oc}(mV)	729.41	739.80	735.81	732.62	734.4 ± 4.4
FF(%)	76.00	76.18	74.10	76.81	75.8 ± 1.2

5G-27	1	2	3	4	average
η(%)	5.00	5.00	4.95	5.19	5.04 ± 0.11
J_{sc}(mA/cm^2)	9.69	9.86	9.58	9.54	9.67 ± 0.14
V_{oc}(mV)	714.22	707.02	709.42	723.82	713.6 ± 7.4
FF(%)	72.29	71.69	72.79	75.23	73.0 ± 1.6

5G-28	1	2	3	4	average
η(%)	4.79	4.81	4.89	4.72	4.80 ± 0.07
J_{sc}(mA/cm^2)	9.61	9.12	9.03	9.11	9.22 ± 0.27
V_{oc}(mV)	708.62	712.62	711.83	711.02	711.0 ± 1.7
FF(%)	70.31	74.01	76.05	72.87	73.3 ± 2.4

5G-29	1	2	3	4	average
η(%)	3.97	3.67	3.75	3.97	3.84 ± 0.15
J_{sc}(mA/cm^2)	6.95	6.37	6.45	6.83	6.65 ± 0.28
V_{oc}(mV)	760.59	762.19	762.19	764.59	762.4 ± 1.7
FF(%)	75.11	75.58	76.26	76.14	75.8 ± 0.5

5G-30	1	2	3	4	average
η(%)	5.53	5.46	5.60	5.48	5.52 ± 0.06
J_{sc}(mA/cm^2)	10.73	10.63	10.25	10.42	10.51 ± 0.21
V_{oc}(mV)	716.62	714.22	719.82	725.42	719.0 ± 4.8
FF(%)	71.88	72.01	75.90	72.45	73.1 ± 1.9

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6th Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
6G-1	20	40	40	0	D3	D1	D4	D4	F6	94	3.37 ± 0.11
6G-2	0	40	40	20	D4	D3	D2	D3	F7	94	4.91 ± 0.10
6G-3	0	40	40	20	D4	D4	D3	D4	F7	94	5.35 ± 0.06
6G-4	20	20	60	0	D3	D1	D4	D2	F3	28	2.84 ± 0.13
6G-5	0	20	50	30	D2	D2	D1	D4	F7	94	4.50 ± 0.13
6G-6	0	0	90	10	D4	D1	D2	D3	F2	28	3.75 ± 0.18
6G-7	10	40	20	30	D3	D4	D1	D4	F7	94	4.97 ± 0.06
6G-8	20	40	20	20	D3	D3	D2	D4	F5	50	3.53 ± 0.07
6G-9	0	40	40	20	D4	D1	D1	D2	F7	94	3.80 ± 0.05
6G-10	0	10	80	10	D4	D4	D2	D4	F7	94	5.63 ± 0.04
6G-11	0	10	80	10	D4	D2	D2	D4	F7	94	5.67 ± 0.08
6G-12	0	20	80	0	D4	D1	D2	D4	F7	94	5.53 ± 0.15
6G-13	10	20	50	20	D2	D4	D1	D4	F7	94	4.48 ± 0.09
6G-14	0	0	100	0	D4	D2	D2	D4	F7	94	4.93 ± 0.04
6G-15	10	20	50	20	D4	D1	D3	D2	F7	94	4.37 ± 0.08
6G-16	0	20	80	0	D4	D1	D3	D4	F7	94	4.44 ± 0.19
6G-17	20	50	30	0	D2	D2	D2	D1	F6	94	3.62 ± 0.07
6G-18	30	70	0	0	D1	D4	D1	D2	F6	72	3.09 ± 0.15
6G-19	10	10	70	10	D1	D2	D3	D4	F7	94	4.54 ± 0.04
6G-20	0	60	10	30	D2	D3	D1	D2	F7	94	4.44 ± 0.16
6G-21	0	30	50	20	D4	D1	D2	D4	F7	94	5.02 ± 0.09
6G-22	10	0	90	0	D1	D3	D3	D1	F4	72	4.11 ± 0.05
6G-23	0	30	40	30	D4	D1	D1	D3	F2	50	3.08 ± 0.14
6G-24	10	50	20	20	D4	D2	D4	D1	F6	28	3.41 ± 0.20
6G-25	30	40	10	20	D2	D4	D2	D2	F8	94	3.15 ± 0.08
6G-26	0	0	80	20	D4	D1	D2	D4	F8	50	5.08 ± 0.05
6G-27	0	30	50	20	D2	D2	D1	D4	F7	94	4.40 ± 0.10
6G-28	20	40	10	30	D2	D4	D2	D2	F7	50	4.03 ± 0.08
6G-29	10	0	90	0	D4	D1	D2	D4	F7	72	5.34 ± 0.05
6G-30	0	10	80	10	D4	D1	D2	D4	F7	94	5.91 ± 0.06

(red color) the highest η used for the next generation (Eliticism)

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6th Generation : Cell parameters for 4 independent samples (6G-1 ~ 6G-10)

6G-1	1	2	3	4	average
η(%)	3.46	3.34	3.45	3.23	3.37 ± 0.11
J_{sc}(mA/cm^2)	6.69	6.56	6.63	6.22	6.52 ± 0.21
V_{oc}(mV)	696.63	693.43	698.24	691.04	694.8 ± 3.2
FF(%)	74.37	73.53	74.59	75.17	74.4 ± 0.7

6G-2	1	2	3	4	average
η(%)	4.96	4.85	5.02	4.81	4.91 ± 0.10
J_{sc}(mA/cm^2)	9.08	8.77	9.11	8.85	8.95 ± 0.16
V_{oc}(mV)	720.62	727.81	723.02	721.42	723.2 ± 3.2
FF(%)	75.88	75.99	76.27	75.28	75.9 ± 0.4

6G-3	1	2	3	4	average
η(%)	5.35	5.41	5.27	5.35	5.35 ± 0.06
J_{sc}(mA/cm^2)	10.47	10.51	9.97	9.92	10.21 ± 0.31
V_{oc}(mV)	699.03	699.84	716.62	723.02	709.6 ± 12.1
FF(%)	73.18	73.60	73.80	74.58	73.8 ± 0.6

6G-4	1	2	3	4	average
η(%)	2.88	2.90	2.99	2.69	2.84 ± 0.13
J_{sc}(mA/cm^2)	5.07	5.18	5.27	4.64	5.04 ± 0.3
V_{oc}(mV)	725.42	736.61	734.22	739.01	733.8 ± 5.9
FF(%)	78.29	76.07	77.35	78.46	77.5 ± 1.1

6G-5	1	2	3	4	average
η(%)	4.38	4.68	4.41	4.51	4.50 ± 0.13
J_{sc}(mA/cm^2)	8.47	8.78	8.61	8.43	8.57 ± 0.16
V_{oc}(mV)	707.83	709.42	702.23	710.23	707.4 ± 3.6
FF(%)	73.15	75.15	72.99	75.34	74.2 ± 1.3

6G-6	1	2	3	4	average
η(%)	3.83	3.80	3.49	3.87	3.75 ± 0.18
J_{sc}(mA/cm^2)	6.55	6.55	5.90	6.44	6.36 ± 0.31
V_{oc}(mV)	770.19	772.59	770.99	780.59	773.6 ± 4.8
FF(%)	75.90	75.17	76.67	77.09	76.2 ± 0.9

6G-7	1	2	3	4	average
η(%)	4.95	5.04	4.96	4.91	4.97 ± 0.06
J_{sc}(mA/cm^2)	9.23	9.35	9.30	9.17	9.26 ± 0.08
V_{oc}(mV)	703.03	709.42	700.63	715.82	707.2 ± 6.8
FF(%)	76.35	76.04	76.19	74.86	75.9 ± 0.7

6G-8	1	2	3	4	average
η(%)	3.49	3.47	3.62	3.55	3.53 ± 0.07
J_{sc}(mA/cm^2)	6.18	6.15	6.87	6.42	6.41 ± 0.33
V_{oc}(mV)	742.21	741.40	725.42	733.41	735.6 ± 7.9
FF(%)	76.06	76.01	72.73	75.40	75.1 ± 1.6

6G-9	1	2	3	4	average
η(%)	3.83	3.85	3.81	3.72	3.80 ± 0.05
J_{sc}(mA/cm^2)	7.29	7.28	7.36	7.02	7.24 ± 0.15
V_{oc}(mV)	688.64	693.43	683.04	691.04	689.0 ± 4.5
FF(%)	76.19	76.18	75.81	76.77	76.2 ± 0.4

6G-10	1	2	3	4	average
η(%)	5.68	5.60	5.60	5.63	5.63 ± 0.04
J_{sc}(mA/cm^2)	10.89	10.39	10.17	10.21	10.41 ± 0.33
V_{oc}(mV)	713.43	722.22	737.41	734.22	726.8 ± 11.1
FF(%)	73.11	74.61	74.73	75.10	74.4 ± 0.9

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6th Generation : Cell parameters for 4 independent samples (6G-11 ~ 6G-20)

6G-11	1	2	3	4	average
η(%)	5.70	5.70	5.72	5.55	5.67 ± 0.08
J_{sc}(mA/cm^2)	10.74	10.71	10.47	9.87	10.45 ± 0.40
V_{oc}(mV)	711.83	718.22	723.02	734.22	721.8 ± 9.5
FF(%)	74.58	74.10	75.55	76.52	75.2 ± 1.1

6G-12	1	2	3	4	average
η(%)	5.42	5.50	5.74	5.44	5.53 ± 0.15
J_{sc}(mA/cm^2)	10.42	10.63	11.06	10.88	10.75 ± 0.28
V_{oc}(mV)	695.03	690.23	697.43	684.63	691.8 ± 5.7
FF(%)	74.88	74.93	74.44	73.06	74.3 ± 0.9

6G-13	1	2	3	4	average
η(%)	4.37	4.44	4.58	4.51	4.48 ± 0.09
J_{sc}(mA/cm^2)	8.00	8.27	8.50	8.29	8.26 ± 0.21
V_{oc}(mV)	714.22	706.23	710.23	709.42	710.0 ± 3.3
FF(%)	76.43	76.06	75.89	76.75	76.3 ± 0.4

6G-14	1	2	3	4	average
η(%)	4.91	4.87	4.92	4.88	4.90 ± 0.02
J_{sc}(mA/cm^2)	8.98	8.95	9.04	8.85	8.96 ± 0.08
V_{oc}(mV)	728.62	730.21	731.81	727.02	729.4 ± 2.1
FF(%)	75.47	74.91	74.76	74.74	75.0 ± 0.3

6G-15	1	2	3	4	average
η(%)	4.43	4.32	4.44	4.30	4.37 ± 0.08
J_{sc}(mA/cm^2)	8.03	8.50	8.17	7.93	8.16 ± 0.25
V_{oc}(mV)	711.83	707.02	711.83	716.62	711.8 ± 3.9
FF(%)	77.52	71.87	76.41	75.56	75.3 ± 2.5

6G-16	1	2	3	4	average
η(%)	4.32	4.73	4.40	4.32	4.44 ± 0.19
J_{sc}(mA/cm^2)	8.00	8.56	8.68	8.11	8.34 ± 0.33
V_{oc}(mV)	713.43	725.42	704.63	709.42	713.2 ± 8.9
FF(%)	75.77	76.13	72.04	75.02	74.7 ± 1.9

6G-17	1	2	3	4	average
η(%)	3.67	3.54	3.68	3.58	3.62 ± 0.07
J_{sc}(mA/cm^2)	6.78	6.80	7.41	6.63	6.90 ± 0.35
V_{oc}(mV)	699.03	689.44	682.24	703.03	693.4 ± 9.4
FF(%)	77.51	75.46	72.68	76.76	75.6 ± 2.1

6G-18	1	2	3	4	average
η(%)	3.18	3.19	3.13	2.87	3.09 ± 0.15
J_{sc}(mA/cm^2)	5.92	5.87	5.78	5.26	5.71 ± 0.30
V_{oc}(mV)	695.83	695.83	699.84	703.03	698.6 ± 3.5
FF(%)	77.29	78.08	77.55	77.60	77.6 ± 0.3

6G-19	1	2	3	4	average
η(%)	4.59	4.53	4.56	4.49	4.54 ± 0.04
J_{sc}(mA/cm^2)	8.64	8.30	8.82	8.38	8.54 ± 0.24
V_{oc}(mV)	700.63	711.83	694.24	706.23	703.2 ± 7.5
FF(%)	75.81	76.64	74.42	75.95	75.7 ± 0.9

6G-20	1	2	3	4	average
η(%)	4.22	4.54	4.43	4.59	4.44 ± 0.16
J_{sc}(mA/cm^2)	7.63	8.23	7.98	8.28	8.03 ± 0.30
V_{oc}(mV)	723.02	717.42	723.82	720.62	721.2 ± 2.9
FF(%)	76.52	76.81	76.64	76.83	76.7 ± 0.2

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6th Generation : Cell parameters for 4 independent samples (6G-21 ~ 6G-30)

6G-21	1	2	3	4	average
η(%)	5.14	4.93	5.00	5.02	5.02 ± 0.09
J_{sc}(mA/cm^2)	9.88	9.92	9.80	10.40	10.00 ± 0.27
V_{oc}(mV)	703.03	698.24	709.42	678.24	697.2 ± 13.5
FF(%)	74.09	71.14	71.88	71.14	72.1 ± 1.4

6G-22	1	2	3	4	average
η(%)	4.11	4.03	4.14	4.15	4.11 ± 0.05
J_{sc}(mA/cm^2)	8.28	7.24	7.34	7.62	7.62 ± 0.47
V_{oc}(mV)	721.42	720.62	720.62	716.62	719.8 ± 2.2
FF(%)	68.78	77.36	78.26	76.08	75.1 ± 4.3

6G-23	1	2	3	4	average
η(%)	3.17	2.88	3.17	3.10	3.08 ± 0.14
J_{sc}(mA/cm^2)	5.70	5.11	5.82	5.59	5.56 ± 0.31
V_{oc}(mV)	724.61	723.02	723.02	728.62	724.8 ± 2.6
FF(%)	76.78	77.96	75.43	76.03	76.6 ± 1.1

6G-24	1	2	3	4	average
η(%)	3.26	3.47	3.67	3.23	3.41 ± 0.20
J_{sc}(mA/cm^2)	5.98	6.49	6.73	5.95	6.29 ± 0.39
V_{oc}(mV)	706.23	703.03	710.23	707.02	706.6 ± 3.0
FF(%)	77.28	76.00	76.88	76.92	76.8 ± 0.5

6G-25	1	2	3	4	average
η(%)	3.12	3.17	3.06	3.25	3.15 ± 0.08
J_{sc}(mA/cm^2)	6.14	6.13	5.92	6.50	6.17 ± 0.24
V_{oc}(mV)	679.84	683.84	684.63	673.45	680.4 ± 5.1
FF(%)	74.68	75.70	75.60	74.20	75.1 ± 0.7

6G-26	1	2	3	4	average
η(%)	5.10	5.01	5.11	5.09	5.08 ± 0.05
J_{sc}(mA/cm^2)	9.15	9.88	9.85	9.15	9.51 ± 0.42
V_{oc}(mV)	729.41	683.84	700.63	727.81	710.4 ± 22.1
FF(%)	76.50	74.19	74.07	76.40	75.3 ± 1.3

6G-27	1	2	3	4	average
η(%)	4.34	4.55	4.34	4.38	4.40 ± 0.10
J_{sc}(mA/cm^2)	8.25	8.82	8.54	8.18	8.45 ± 0.29
V_{oc}(mV)	693.43	692.64	683.84	704.63	693.6 ± 8.5
FF(%)	75.81	74.50	74.31	75.91	75.1 ± 0.9

6G-28	1	2	3	4	average
η(%)	4.10	4.09	3.99	3.93	4.03 ± 0.08
J_{sc}(mA/cm^2)	7.61	7.44	7.42	7.17	7.41 ± 0.18
V_{oc}(mV)	686.23	699.84	701.43	699.03	696.6 ± 7.0
FF(%)	78.47	78.52	76.68	78.47	78.0 ± 0.9

6G-29	1	2	3	4	average
η(%)	5.41	5.31	5.32	5.32	5.34 ± 0.05
J_{sc}(mA/cm^2)	9.63	9.64	9.66	9.62	9.64 ± 0.01
V_{oc}(mV)	735.81	723.82	724.61	727.02	727.8 ± 5.5
FF(%)	76.33	76.11	76.04	76.07	76.1 ± 0.1

6G-30	1	2	3	4	average
η(%)	5.88	5.93	5.92	5.9	5.91 ± 0.02
J_{sc}(mA/cm^2)	11.35	11.79	11.72	11.64	11.63 ± 0.19
V_{oc}(mV)	714.2	719.01	721.42	719.82	718.6 ± 3.1
FF(%)	72.54	69.97	70.03	70.43	70.7 ± 1.2

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7th Generation : Decision parameters and cell efficiencies

	Composition of TiO_2(wt%)				Relative amount of dyes on TiO_2				Relative film thickness	Pressure applied (Mpa)	η(%)
	T1	T2	T3	T4	T1	T2	T3	T4			
7G-1	0	60	10	30	D2	D4	D1	D2	F7	94	5.00 ± 0.13
7G-2	10	20	50	20	D2	D3	D1	D4	F7	94	4.97 ± 0.03
7G-3	20	20	40	20	D1	D2	D4	D3	F7	94	4.35 ± 0.09
7G-4	0	20	50	30	D2	D2	D1	D4	F8	94	4.80 ± 0.07
7G-5	20	40	20	20	D4	D1	D2	D4	F5	50	4.05 ± 0.11
7G-6	10	20	50	20	D3	D3	D3	D2	F7	94	4.86 ± 0.12
7G-7	30	60	10	0	D2	D3	D1	D2	F8	50	3.54 ± 0.11
7G-8	10	10	80	0	D4	D1	D2	D4	F7	94	5.35 ± 0.09
7G-9	0	50	20	30	D3	D2	D4	D2	F8	72	4.12 ± 0.08
7G-10	20	40	10	30	D1	D4	D1	D2	F7	50	4.15 ± 0.09
7G-11	10	0	80	10	D2	D4	D4	D1	F3	50	3.69 ± 0.09
7G-12	0	0	80	20	D4	D1	D2	D4	F7	94	5.72 ± 0.04
7G-13	10	0	90	0	D4	D1	D2	D4	F3	72	4.37 ± 0.09
7G-14	20	20	60	0	D3	D1	D4	D2	F7	28	4.26 ± 0.10
7G-15	10	10	70	10	D2	D2	D2	D3	F7	94	5.12 ± 0.05
7G-16	10	0	80	10	D4	D1	D2	D4	F7	94	5.26 ± 0.05
7G-17	0	10	80	10	D3	D3	D2	D4	F7	94	5.40 ± 0.09
7G-18	0	30	40	30	D4	D1	D2	D4	F8	50	3.93 ± 0.04
7G-19	0	20	80	0	D3	D1	D4	D2	F7	94	4.84 ± 0.08
7G-20	20	20	60	0	D4	D1	D3	D4	F3	28	3.91 ± 0.09
7G-21	0	40	40	20	D4	D1	D1	D2	F6	94	4.02 ± 0.11
7G-22	20	50	30	0	D2	D2	D2	D1	F7	94	4.62 ± 0.09
7G-23	0	60	10	30	D3	D1	D1	D2	F7	94	3.86 ± 0.10
7G-24	20	40	40	0	D2	D3	D4	D4	F6	94	4.43 ± 0.03
7G-25	0	0	100	0	D2	D2	D1	D4	F7	94	4.61 ± 0.07
7G-26	0	10	80	10	D4	D1	D3	D2	F7	94	5.53 ± 0.07
7G-27	0	0	90	10	D4	D1	D2	D1	F6	72	5.48 ± 0.03
7G-28	0	0	90	10	D2	D2	D2	D3	F2	28	4.14 ± 0.04
7G-29	0	100	0	0	D1	D4	D4	D4	F2	50	4.17 ± 0.14
7G-30	0	10	80	10	D4	D1	D2	D4	F7	94	5.94 ± 0.06

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7th Generation : Cell parameters for 4 independent samples (7G-1 ~ 7G-10)

7G-1	1	2	3	4	average
η(%)	4.84	5.00	4.99	5.15	5.00 ± 0.13
J_{sc}(mA/cm^2)	9.88	10.09	9.75	10.65	10.09 ± 0.40
V_{oc}(mV)	687.04	679.05	704.63	701.43	693.0 ± 12.1
FF(%)	71.32	72.89	72.68	68.94	71.5 ± 1.8

7G-2	1	2	3	4	average
η(%)	4.93	5.00	4.99	4.95	4.97 ± 0.03
J_{sc}(mA/cm^2)	9.62	10.24	9.96	9.95	9.94 ± 0.25
V_{oc}(mV)	692.64	693.43	690.23	688.64	691.2 ± 2.2
FF(%)	73.99	70.42	72.56	72.28	72.3 ± 1.5

7G-3	1	2	3	4	average
η(%)	4.47	4.35	4.30	4.27	4.35 ± 0.09
J_{sc}(mA/cm^2)	8.80	8.52	8.45	8.46	8.56 ± 0.16
V_{oc}(mV)	690.23	691.83	692.64	691.83	691.6 ± 1.0
FF(%)	73.66	73.80	73.38	72.87	73.4 ± 0.4

7G-4	1	2	3	4	average
η(%)	4.87	4.81	4.82	4.70	4.80 ± 0.07
J_{sc}(mA/cm^2)	10.41	10.16	10.20	9.18	9.98 ± 0.55
V_{oc}(mV)	666.25	666.25	661.45	703.82	674.4 ± 19.7
FF(%)	70.19	71.11	71.47	72.76	71.4 ± 1.1

7G-5	1	2	3	4	average
η(%)	4.10	4.08	3.90	4.14	4.05 ± 0.11
J_{sc}(mA/cm^2)	7.70	7.79	8.04	7.57	7.77 ± 0.20
V_{oc}(mV)	711.02	711.83	699.84	712.62	708.8 ± 6.0
FF(%)	74.84	73.49	69.28	76.70	73.4 ± 3.2

7G-6	1	2	3	4	average
η(%)	4.91	4.81	4.72	5.00	4.86 ± 0.12
J_{sc}(mA/cm^2)	9.66	9.09	9.62	9.13	9.37 ± 0.31
V_{oc}(mV)	699.03	713.43	694.24	725.42	708.0 ± 14.2
FF(%)	72.78	74.17	70.63	75.57	73.3 ± 2.1

7G-7	1	2	3	4	average
η(%)	3.44	3.62	3.45	3.64	3.54 ± 0.11
J_{sc}(mA/cm^2)	7.23	7.37	7.13	7.65	7.34 ± 0.23
V_{oc}(mV)	656.66	663.86	664.65	660.65	661.5 ± 3.6
FF(%)	72.43	74.09	72.89	71.98	72.9 ± 0.9

7G-8	1	2	3	4	average
η(%)	5.40	5.22	5.39	5.40	5.35 ± 0.09
J_{sc}(mA/cm^2)	11.07	10.44	10.87	11.05	10.86 ± 0.29
V_{oc}(mV)	696.63	695.03	703.82	686.23	695.4 ± 7.2
FF(%)	70.04	71.94	70.51	71.17	70.9 ± 0.8

7G-9	1	2	3	4	average
η(%)	4.21	4.04	4.16	4.05	4.12 ± 0.08
J_{sc}(mA/cm^2)	8.88	8.70	8.80	8.52	8.72 ± 0.16
V_{oc}(mV)	660.65	658.26	658.26	655.06	658.1 ± 2.3
FF(%)	71.74	70.56	71.88	72.54	71.7 ± 0.8

7G-10	1	2	3	4	average
η(%)	4.17	4.05	4.10	4.27	4.15 ± 0.09
J_{sc}(mA/cm^2)	7.65	7.86	7.84	7.97	7.83 ± 0.13
V_{oc}(mV)	697.43	684.63	697.43	701.43	695.2 ± 7.3
FF(%)	78.16	75.22	74.99	76.29	76.2 ± 1.5

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7th Generation : Cell parameters for 4 independent samples (7G-11 ~ 7G-20)

7G-11	1	2	3	4	average
η(%)	3.66	3.63	3.83	3.66	3.69 ± 0.09
J_{sc}(mA/cm^2)	6.44	6.35	7.10	6.40	6.57 ± 0.35
V_{oc}(mV)	735.81	736.61	722.22	735.81	732.1 ± 6.9
FF(%)	77.29	77.62	74.61	77.65	76.8 ± 1.5

7G-12	1	2	3	4	average
η(%)	5.71	5.78	5.70	5.69	5.72 ± 0.04
J_{sc}(mA/cm^2)	11.22	10.35	11.23	9.99	10.70 ± 0.63
V_{oc}(mV)	727.81	754.20	727.81	761.40	742.8 ± 17.6
FF(%)	69.91	74.12	69.70	74.81	72.1 ± 2.7

7G-13	1	2	3	4	average
η(%)	4.34	4.46	4.26	4.42	4.37 ± 0.09
J_{sc}(mA/cm^2)	8.41	8.51	8.35	8.17	8.36 ± 0.14
V_{oc}(mV)	727.02	742.21	730.21	741.40	735.2 ± 7.7
FF(%)	71.03	70.61	69.89	72.97	71.1 ± 1.3

7G-14	1	2	3	4	average
η(%)	4.34	4.16	4.20	4.36	4.26 ± 0.10
J_{sc}(mA/cm^2)	8.73	8.53	7.99	8.85	8.52 ± 0.38
V_{oc}(mV)	679.05	678.24	706.23	679.84	685.8 ± 13.6
FF(%)	73.26	71.96	74.33	72.35	73.0 ± 1.1

7G-15	1	2	3	4	average
η(%)	5.06	5.16	5.10	5.15	5.12 ± 0.05
J_{sc}(mA/cm^2)	10.22	10.56	10.27	10.60	10.42 ± 0.19
V_{oc}(mV)	682.24	680.64	687.84	679.05	682.4 ± 3.8
FF(%)	72.58	71.82	72.20	71.55	72.0 ± 0.5

7G-16	1	2	3	4	average
η(%)	5.28	5.31	5.26	5.19	5.26 ± 0.05
J_{sc}(mA/cm^2)	10.82	10.73	11.25	10.15	10.74 ± 0.45
V_{oc}(mV)	699.03	706.23	687.04	706.23	699.6 ± 9.1
FF(%)	69.75	70.02	68.11	72.37	70.1 ± 1.8

7G-17	1	2	3	4	average
η(%)	5.41	5.33	5.34	5.52	5.40 ± 0.09
J_{sc}(mA/cm^2)	11.49	10.93	11.79	11.80	11.50 ± 0.41
V_{oc}(mV)	695.83	703.03	692.64	697.43	697.2 ± 4.4
FF(%)	67.65	69.41	65.37	67.07	67.4 ± 1.7

7G-18	1	2	3	4	average
η(%)	3.94	3.92	3.98	3.89	3.93 ± 0.04
J_{sc}(mA/cm^2)	8.53	8.90	8.54	8.54	8.63 ± 0.18
V_{oc}(mV)	661.45	639.86	654.25	655.85	652.9 ± 9.2
FF(%)	69.88	68.79	71.23	69.49	69.9 ± 1.0

7G-19	1	2	3	4	average
η(%)	4.95	4.84	4.77	4.80	4.84 ± 0.08
J_{sc}(mA/cm^2)	10.12	10.38	10.00	10.62	10.28 ± 0.28
V_{oc}(mV)	685.44	678.24	688.64	671.85	681.0 ± 7.5
FF(%)	71.35	68.82	69.23	67.30	69.2 ± 1.7

7G-20	1	2	3	4	average
η(%)	3.79	3.97	3.97	3.92	3.91 ± 0.09
J_{sc}(mA/cm^2)	7.15	7.27	7.29	7.30	7.25 ± 0.07
V_{oc}(mV)	716.62	727.02	719.01	722.22	721.2 ± 4.5
FF(%)	73.91	75.19	75.72	74.47	74.8 ± 0.8

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7th Generation : Cell parameters for 4 independent samples (7G-21 ~ 7G-30)

7G-21	1	2	3	4	average
η(%)	3.87	4.09	4.00	4.13	4.02 ± 0.11
J_{sc}(mA/cm^2)	7.90	8.30	8.25	8.29	8.19 ± 0.19
V_{oc}(mV)	678.24	670.25	671.04	671.85	672.9 ± 3.7
FF(%)	72.25	73.50	72.31	74.11	73.0 ± 0.9

7G-22	1	2	3	4	average
η(%)	4.60	4.70	4.69	4.50	4.62 ± 0.09
J_{sc}(mA/cm^2)	9.24	9.47	9.60	9.27	9.39 ± 0.2
V_{oc}(mV)	673.45	673.45	675.85	672.64	673.9 ± 1.4
FF(%)	73.96	73.62	72.30	72.14	73.0 ± 0.9

7G-23	1	2	3	4	average
η(%)	3.93	3.74	3.80	3.95	3.86 ± 0.10
J_{sc}(mA/cm^2)	7.88	7.27	7.56	7.73	7.61 ± 0.26
V_{oc}(mV)	666.25	675.04	676.64	675.04	673.2 ± 4.7
FF(%)	74.90	76.25	74.27	75.62	75.3 ± 0.9

7G-24	1	2	3	4	average
η(%)	4.45	4.39	4.47	4.42	4.43 ± 0.03
J_{sc}(mA/cm^2)	9.36	8.87	9.37	9.06	9.16 ± 0.24
V_{oc}(mV)	667.05	674.24	669.44	672.64	670.8 ± 3.2
FF(%)	71.21	73.43	71.27	72.49	72.1 ± 1.1

7G-25	1	2	3	4	average
η(%)	4.53	4.68	4.58	4.65	4.61 ± 0.07
J_{sc}(mA/cm^2)	9.33	10.02	9.72	9.49	9.67 ± 0.30
V_{oc}(mV)	690.23	674.24	671.85	688.64	681.2 ± 9.5
FF(%)	70.25	69.27	70.11	71.16	70.2 ± 0.8

7G-26	1	2	3	4	average
η(%)	5.46	5.62	5.49	5.57	5.53 ± 0.07
J_{sc}(mA/cm^2)	11.02	11.72	10.83	11.04	11.15 ± 0.39
V_{oc}(mV)	693.43	683.84	691.04	690.23	689.6 ± 4.1
FF(%)	71.46	70.07	73.38	73.08	72.0 ± 1.5

7G-27	1	2	3	4	average
η(%)	5.45	5.51	5.50	5.45	5.48 ± 0.03
J_{sc}(mA/cm^2)	10.51	10.78	11.04	10.70	10.76 ± 0.22
V_{oc}(mV)	699.84	705.42	700.63	705.42	702.8 ± 3.0
FF(%)	74.08	72.50	71.06	72.19	72.5 ± 1.2

7G-28	1	2	3	4	average
η(%)	4.12	4.11	4.19	4.14	4.14 ± 0.04
J_{sc}(mA/cm^2)	7.22	7.44	7.55	7.42	7.41 ± 0.14
V_{oc}(mV)	739.01	743.81	739.80	739.80	740.6 ± 2.2
FF(%)	77.23	74.30	75.03	75.43	75.5 ± 1.3

7G-29	1	2	3	4	average
η(%)	4.25	3.97	4.26	4.21	4.17 ± 0.14
J_{sc}(mA/cm^2)	7.79	7.02	7.78	7.76	7.59 ± 0.38
V_{oc}(mV)	714.22	719.82	713.43	717.42	716.2 ± 3.0
FF(%)	76.39	78.55	76.79	75.58	76.8 ± 1.3

7G-30	1	2	3	4	average
η(%)	6.02	5.89	5.89	5.95	5.94 ± 0.06
J_{sc}(mA/cm^2)	11.95	11.83	11.46	11.33	11.64 ± 0.29
V_{oc}(mV)	697.45	694.24	696.63	698.24	696.6 ± 1.7
FF(%)	72.17	71.72	73.74	73.93	72.9 ± 1.1