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Supporting information

Dew point temperature as an invariant replacement for relative humidity for advanced perovskite solar cell fabrication systems

*Yohan Ko,‡ Chanyong Lee,‡ Youbin Kim, Yechan Kim, Yong Ju Yun, and Yongseok Jun**

Dept. of Materials Chemistry & Engineering, Dept. of Energy Engineering, Konkuk University, Seoul 143-701, Republic of Korea

Calculations

Dew point temperatures (T_{dp}, °C) shown in the main article were calculated by the Magnus Equation using a relationship between relative humidity (RH, %) and air temperature (T, °C).

$$\gamma(T,RH) = \ln\left(\frac{RH}{100}\right) + \frac{bT}{c+T} \qquad \textbf{(S1)}$$

$$T_{dp} = \frac{c\gamma(T,RH)}{b-\gamma(T,RH)} \qquad \textbf{(S2)}$$

Each constant b and c has the value of 18.678 and 257.14 °C, respectively. These constant values were taken from David Bolton's[1]. The resultant equation guarantees a maximum error of 0.1 %, for ranges of −30 °C ≤ T ≤ 35 °C and 1 % < RH < 100 %.

Table S1. Calculated dew point temperatures from the Magnus formula at given air temperature and relative humidity (RH).

RH / Temp.	10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100 %
13 °C	-17.96	-9.46	-4.18	-0.29	2.82	5.42	7.66	9.63	11.40	13.00
14 °C	-17.19	-8.62	-3.31	0.61	3.74	6.36	8.62	10.61	12.39	14.00
15 °C	-16.41	-7.79	-2.44	1.51	4.67	7.30	9.58	11.58	13.37	15.00
16 °C	-15.64	-6.96	-1.57	2.41	5.59	8.24	10.54	12.55	14.36	16.00
17 °C	-14.87	-6.13	-0.70	3.31	6.51	9.19	11.49	13.53	15.35	17.00
18 °C	-14.10	-5.30	0.17	4.21	7.43	10.13	12.45	14.50	16.34	18.00
19 °C	-13.33	-4.47	1.04	5.10	8.35	11.07	13.41	15.47	17.32	19.00
20 °C	-12.56	-3.64	1.91	6.00	9.27	12.01	14.37	16.45	18.31	20.00
21 °C	-11.80	-2.81	2.77	6.90	10.19	12.95	15.32	17.42	19.30	21.00
22 °C	-11.03	-1.99	3.64	7.79	11.11	13.89	16.28	18.39	20.29	22.00
23 °C	-10.26	-1.16	4.51	8.69	12.03	14.83	17.24	19.37	21.27	23.00
24 °C	-9.50	-0.33	5.37	9.58	12.95	15.77	18.20	20.34	22.26	24.00
25 °C	-8.73	0.49	6.24	10.48	13.87	16.71	19.15	21.31	23.25	25.00
26 °C	-7.97	1.32	7.10	11.37	14.79	17.64	20.11	22.29	24.23	26.00
27 °C	-7.21	2.14	7.97	12.27	15.70	18.58	21.07	23.26	25.22	27.00
28 °C	-6.44	2.97	8.83	13.16	16.62	19.52	22.02	24.23	26.21	28.00
29 °C	-5.68	3.79	9.69	14.05	17.54	20.46	22.98	25.20	27.19	29.00
30 °C	-4.92	4.62	10.56	14.95	18.46	21.40	23.94	26.17	28.18	30.00

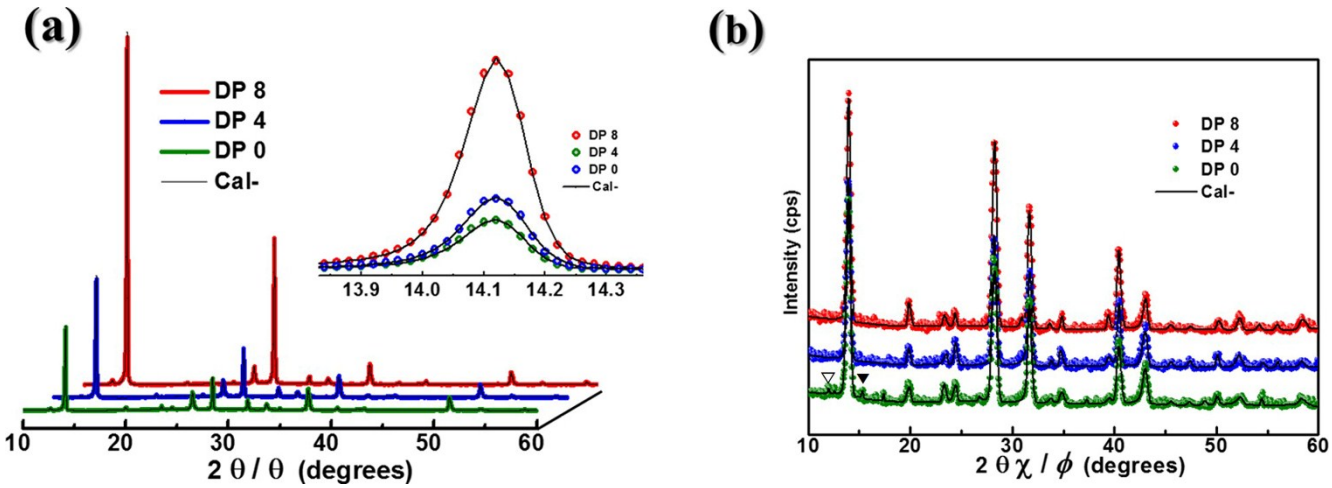

Figure S1. (a) Out-of-plane and (b) In-plane diffraction patterns of the perovskite films fabricated at various DPs. The X-ray beam was collimated with a beam slit analyzer.

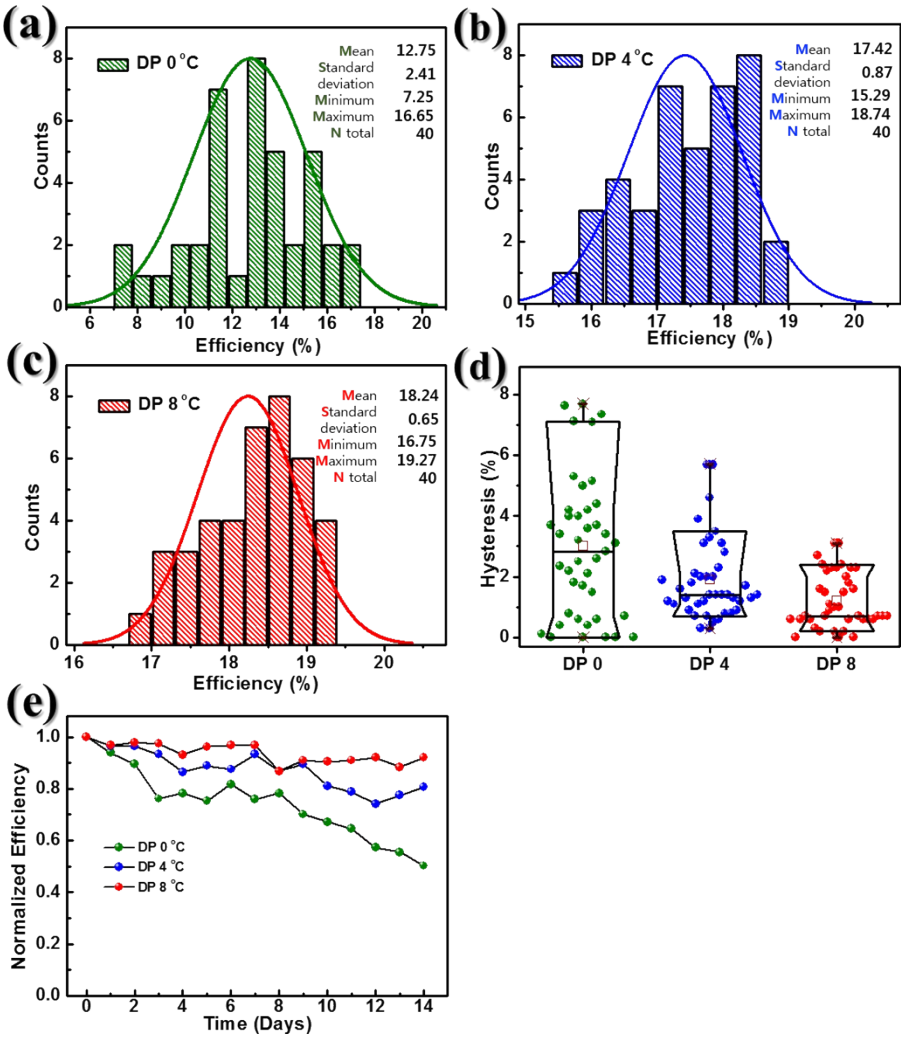

Figure S2. (a)-(c) Statistical results of the perovskite photovoltaics fabricated at various DPs. (d) Hysteresis of the perovskite photovoltaics in the statistical results defined as differences in efficiencies between reverse and forward scans. (e) Long term stability of non-encapsulated devices; the devices were stored in the dark under dry air and J-V curves were periodically measured under ambient condition (25–40% humidity, 18–27 °C).

Table S2. Time-correlated single photon counting (TCSPC) parameters fitted by using a bi-exponential decay function.

On TiO_2	τ_1 (ns)	f_1 (%)	τ_2 (ns)	f_2 (%)
DP 0	3.11	83.3	10	16.7
DP 4	6.64	63.9	14.2	36.1
DP 8	6.05	86.5	16.4	13.5

On Glass	τ_1 (ns)	f_1 (%)	τ_2 (ns)	f_2 (%)
DP 0	12.9	33.9	3	66.1
DP 4	21.5	26.3	3.87	73.7
DP 8	116	7.62	20.8	92.4

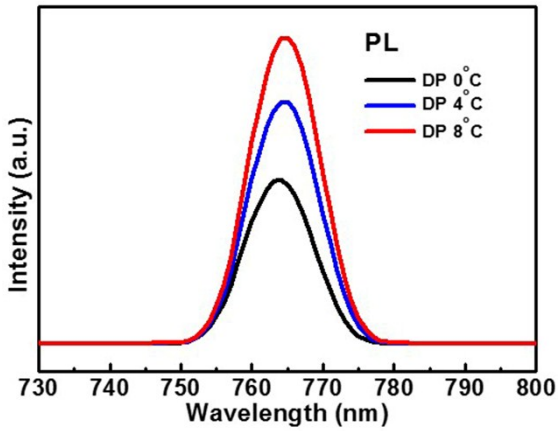

Figure S3. Steady-state photoluminescence spectra for the perovskite films fabricated at various DPs.

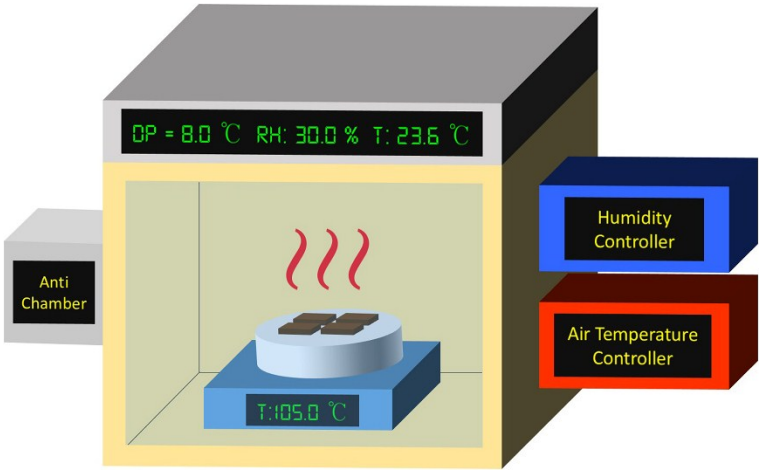

Figure S4. Schematic illustration of annealing system to adjust thermal equilibrium with relative humidity (RH).

REFERENCES

1. BOLTON, D., The Computation of Equivalent Potential Temperature. *American Meteorological Society* 1980**,** 108, (7), 1046-1053.