

Supplementary Information

Efficient Roll-to-Roll Intense Pulsed Light Treatment of ZnO Layer for Scalable Flexible Organic Photovoltaics

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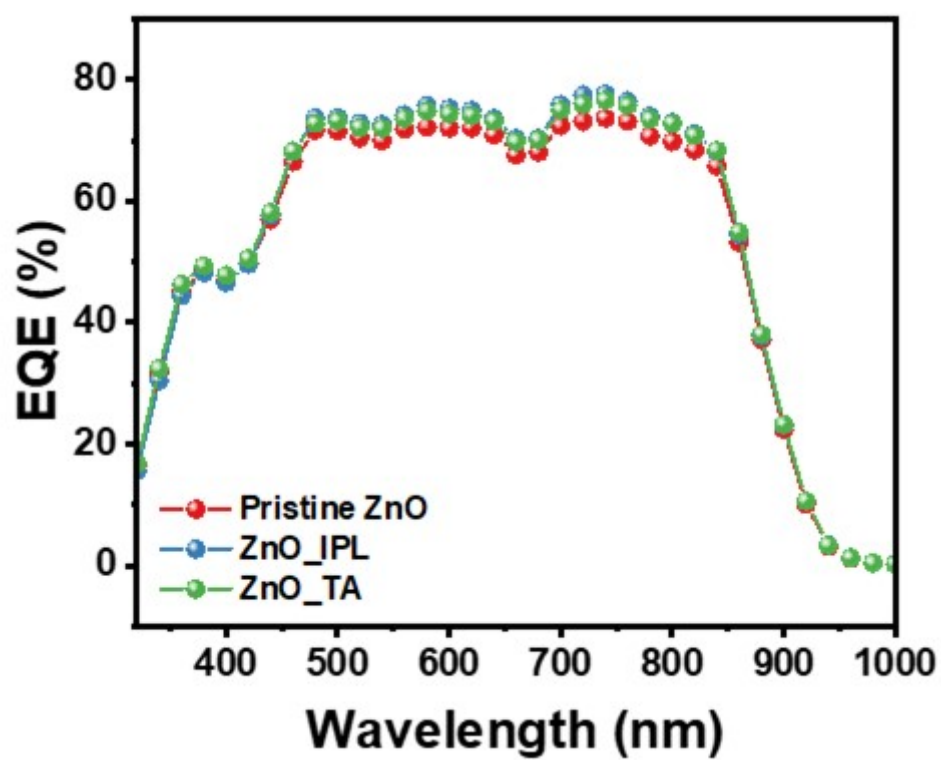


Fig. S1 EQE spectra of flexible OSCs with pristine ZnO, ZnO_IPL, and ZnO_TA.

Table S1 Measured and calculated J_{sc} values of flexible OSCs incorporating pristine ZnO, ZnO_IPL, and ZnO_TA

ZnO layer	<i>Measured J_{sc} (mA/cm²)</i>	<i>Calculated J_{sc} (mA/cm²)</i>
Pristine ZnO	23.17	22.32
ZnO_IPL	23.65	23.13
ZnO_TA	24.14	23.01

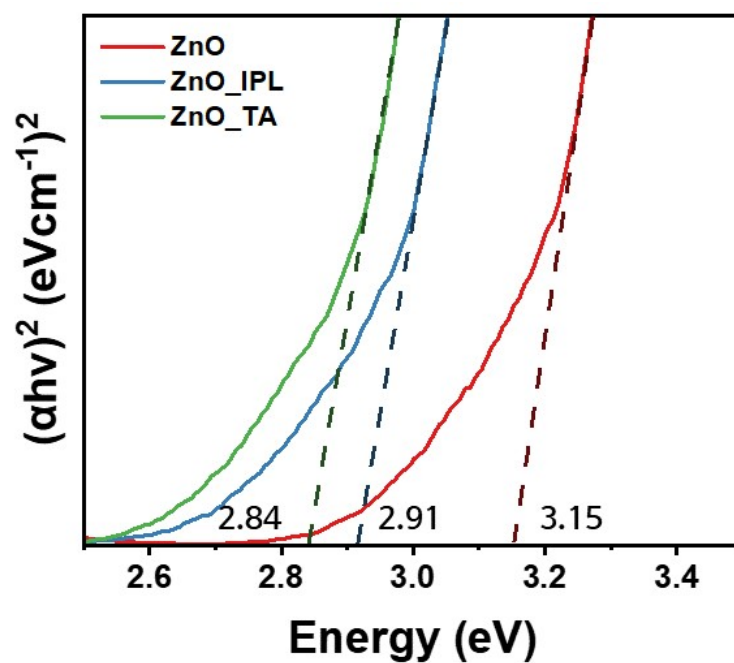


Fig. S2 Optical band gap energy estimation of the pristine ZnO, ZnO_IPL, and ZnO_TA films.

Table S2 The extracted resistance and capacitance values from fitting the impedance spectra of the pristine ZnO, ZnO_IPL, and ZnO_TA devices

ZnO layer	R_s (Ω)	R_l (Ω)	C_1 (nF)	R_2 (Ω)	C_2 (nF)
Pristine ZnO	15.5	12.4	34.8	759	8.02
ZnO_IPL	14.6	17.0	60.5	1540	8.04
ZnO_TA	14.7	15.6	45.6	1030	9.50

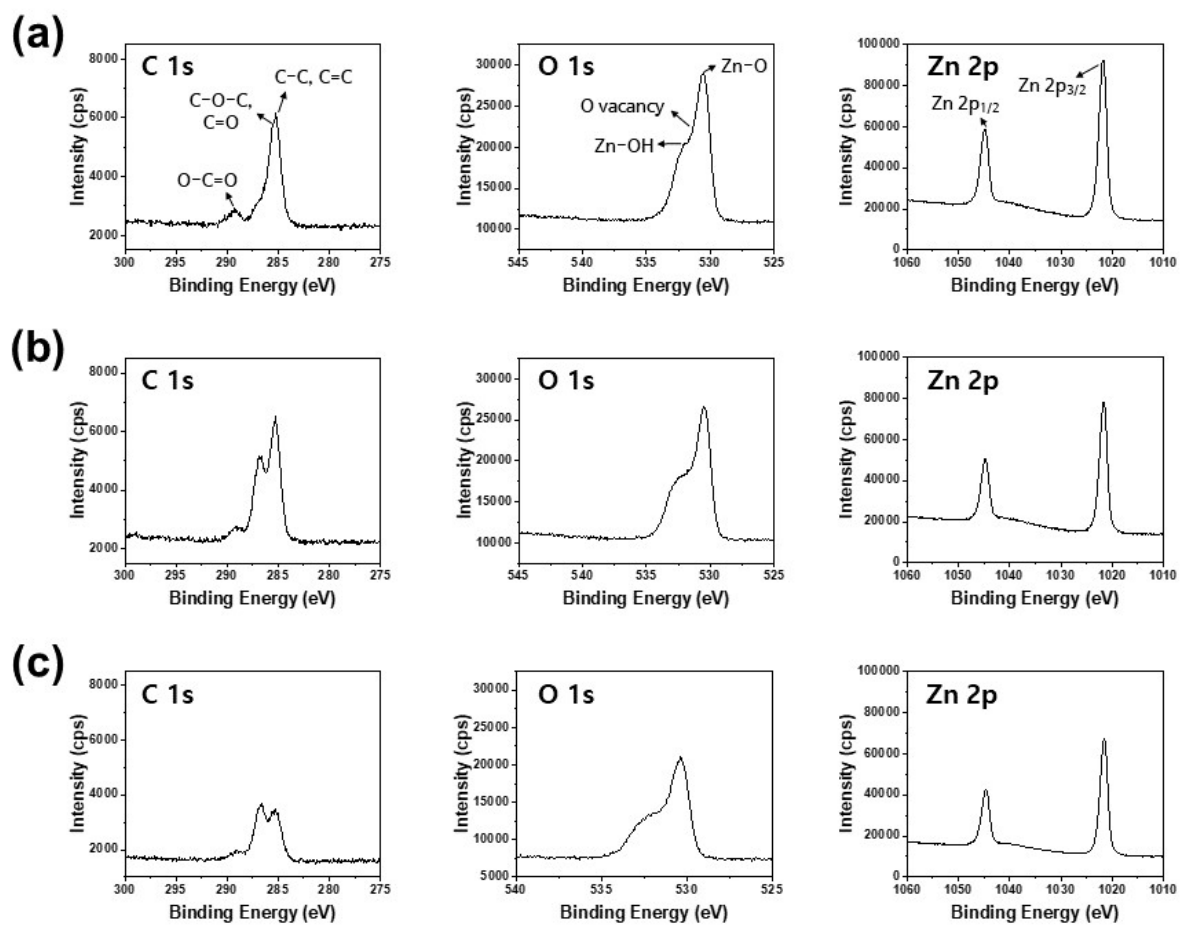


Fig. S3 High-resolution XPS spectra (C 1s, O 1s, and Zn 2p) of (a) the pristine ZnO, (b) ZnO_IPL, and (c) ZnO_TA films.

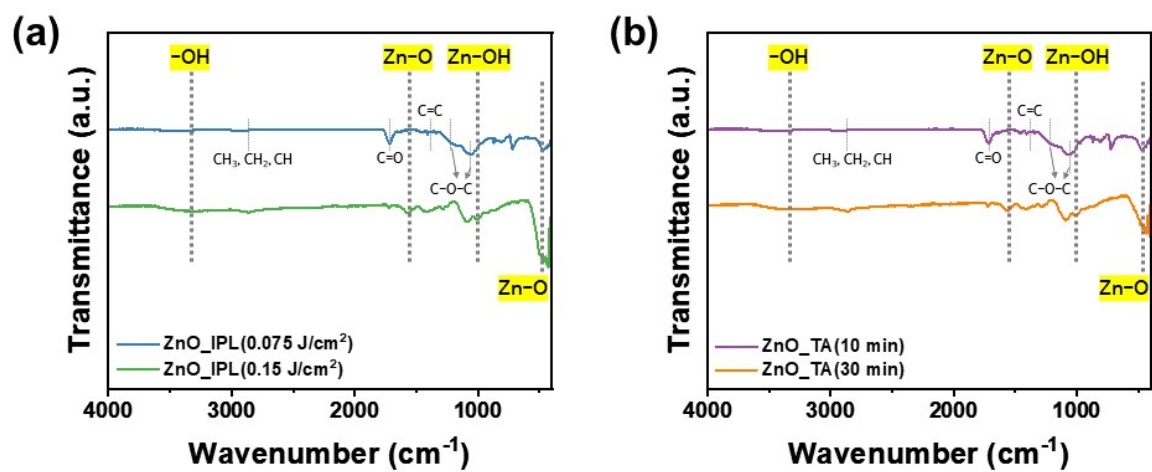


Fig. S4 FT-IR spectra of ZnO films based on (a) IPL and (b) TA conditions.

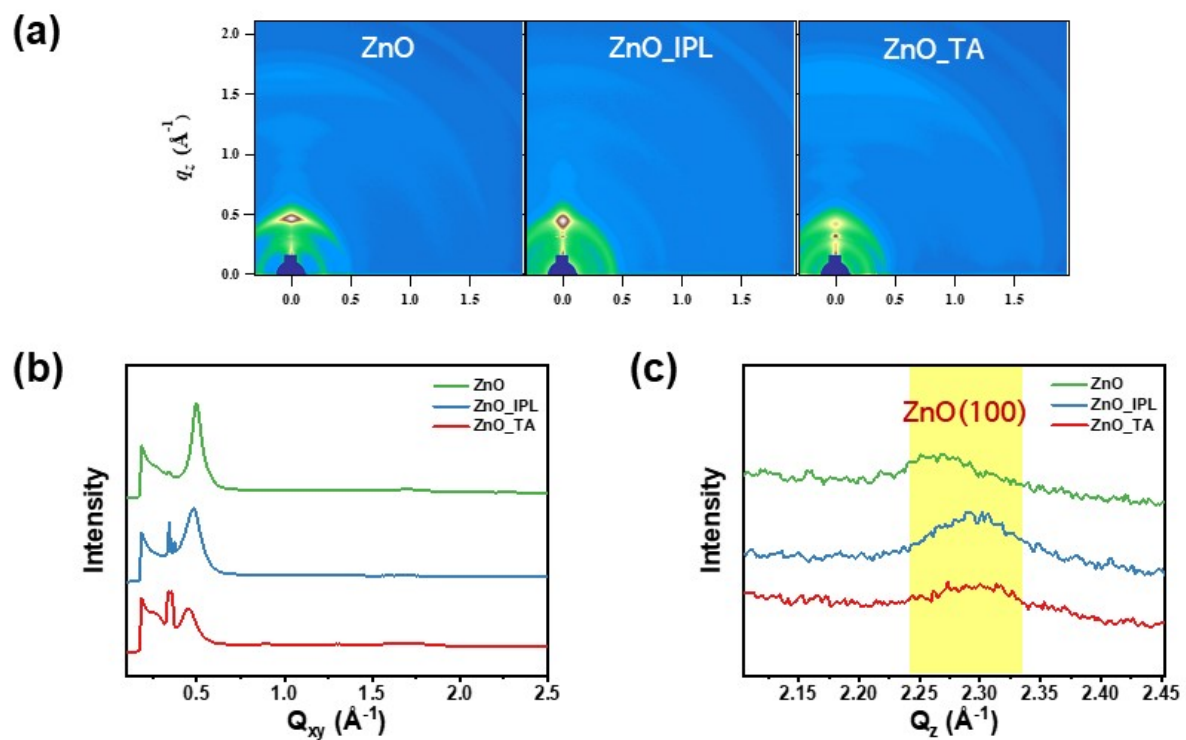


Fig. S5 (a) 2D-GIWAXS patterns of ZnO/PM6:Y6 films with and without IPL and TA treatments. The corresponding line cuts of (b) in-plane and (c) out-of-plane direction patterns.

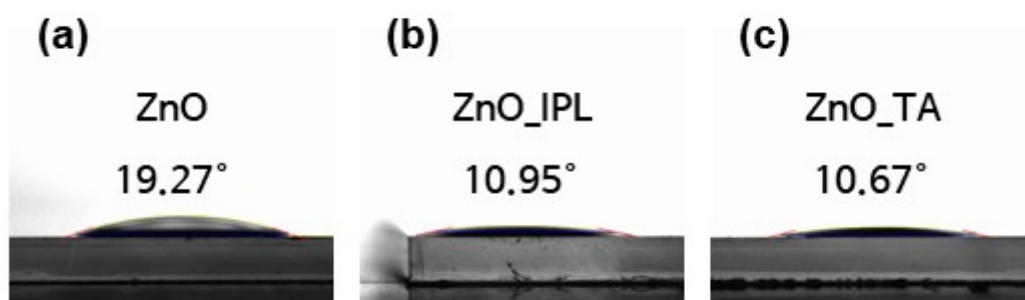


Fig. S6 (a-c) Water contact angle (WCA) images of ZnO films (a) without and with (b) IPL and (c) TA treatments.

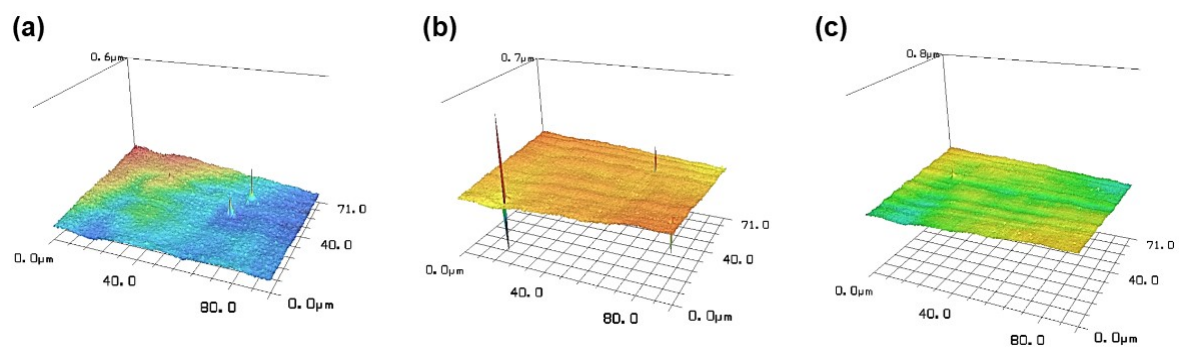


Fig. S7 3D optical microscopic images of (a) pristine ZnO, (b) ZnO_IPL, and (c) ZnO_TA films.

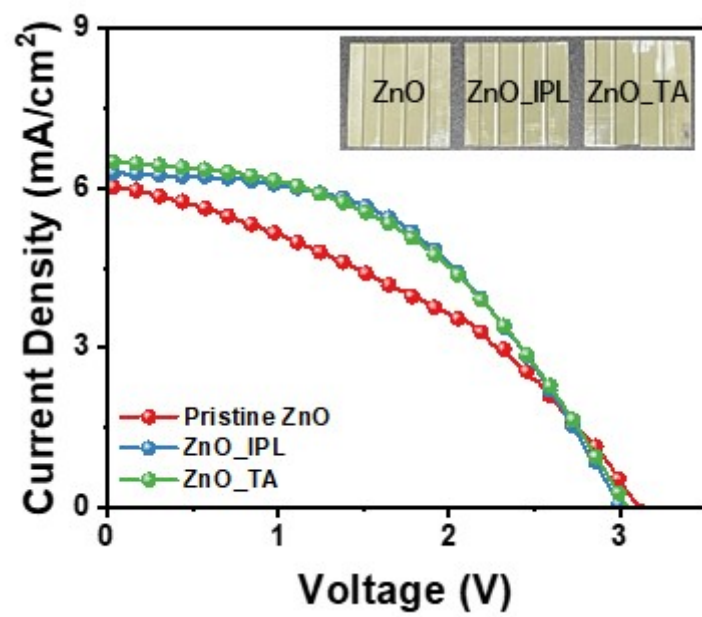


Fig. S8 J - V characteristics for large-area flexible organic photovoltaic modules with pristine ZnO, ZnO_IPL, and ZnO_TA.

Table S3 Photovoltaic parameters of flexible OPMs (4 sub-cells, total active area: 20 cm²) with pristine ZnO, ZnO_IPL, and ZnO_TA

ZnO layer	V_{oc} (V)	J_{sc} (mA/cm²)	FF (%)	PCE (%)
Pristine ZnO	3.10	6.01	39.06	7.29
ZnO_IPL	3.00	6.29	49.10	9.27
ZnO_TA	3.03	6.48	46.20	9.10