Electronic Supplementary Information

Novel Microlens Arrays with Embedded Al_2O_3 Nanoparticles for Enhancing Efficiency and Stability of Flexible Polymer Light-emitting Diodes

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Experimental Method

For the photoluminescence (PL) measurement, an anode (PEDOT:PSS, Clevios PH1000), a hole-transporting layer (PEDOT:PSS, Clevios AI4083), and a blue light-emitting layer (SPB-02T, Merck) were deposited on a PEN substrate by the same preparation methods and conditions used in the fabrication of the polymer light-emitting diodes (PLED). The PL spectra were obtained by fluorospectrometer (ISS PC1 Photon Counter Meter). The samples were excited at 300 nm light generated by a xenon arc lamp attached to a monochromator. Flexible yellow PLEDs were fabricated via the same procedure used for SPB-02T-based devices except a deposition of a yellow light-emitting layer. The yellow light-emitting polymer (PDY-132, Merck) was dissolved in chlorobenzene by a concentration of 7 mg/ml. PDY-132 solution was deposited on atop of the AI4083 layer by spin-coating at 3000 rpm for 60 seconds followed by thermal annealing at 115 ^{o}C for 20 minutes. The water-vapor transmission rates (WVTR) were assessed by AQUATRAN Model 1 (MOCON) following ASTM protocol F1249.

Photoluminescence measurement

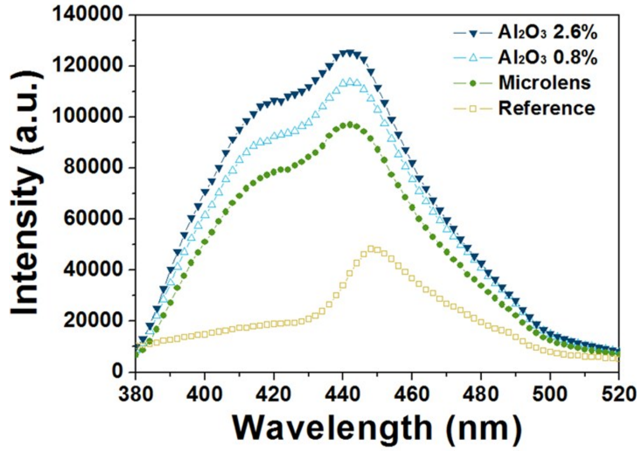

Figure S1. PL spectra of SPB-02T-based films fabricated on bare PEN, on a microlens array, and on the microlens arrays with Al_2O_3 nanoparticles.

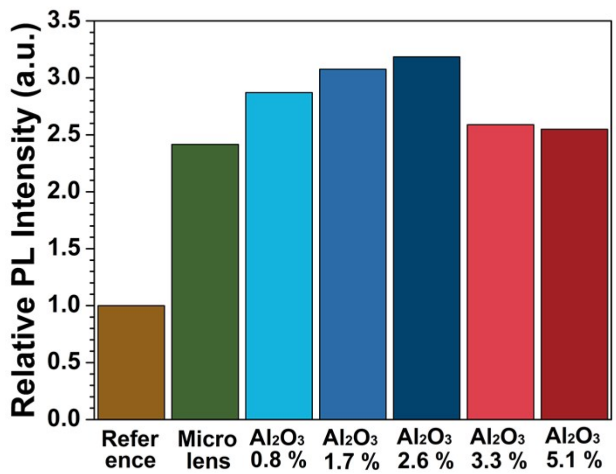

Figure S2. Relative PL intensities of samples fabricated on bared PEN, with microlens only, and microlens embedded with Al_2O_3 nanoparticles having different concentrations.

Voltage-current density curves for the SPB-02T-based devices

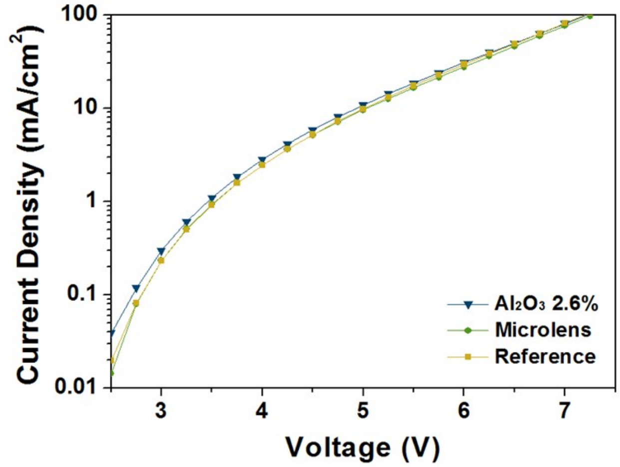

Figure S3. Current density versus applied bias for the flexible, blue PLEDs.

Water-vapor transmission rates of PEN films

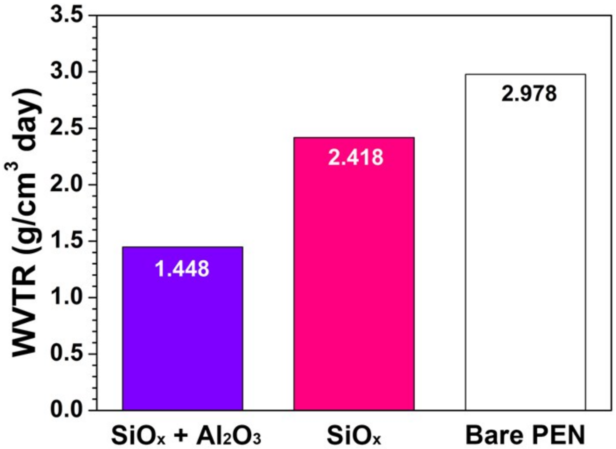

Figure S4. Water-vapor transmission rates of PEN films without and with silica hybrid sol

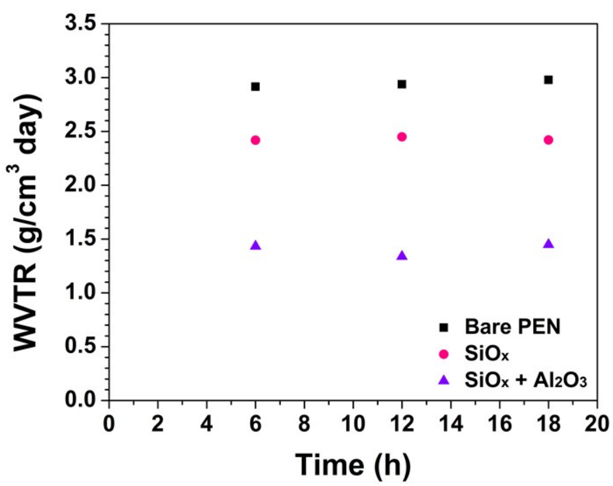

Figure S5. Water-vapor transmission rate of the samples over time.

Performances of yellow PLEDs with and without microlens array

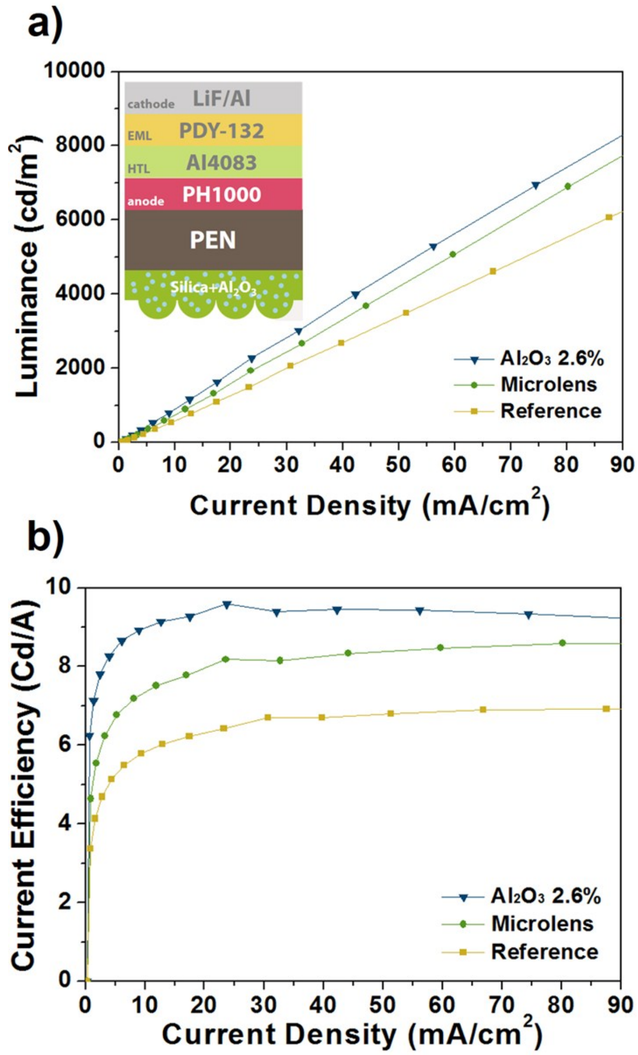

Figure S6. a) Luminance and b) current efficiency of devices as a function of current density. The structure of PLED fabricated in this experiment is shown in the inset image.

Table S1. Luminance and efficiencies of PDY-132-based devices with and without a microlens array

	$L^{‡}$ (cd/m^2)	Max. PE‡ (lm/W)	Max. CE‡ (cd/A)	$R_{Max.CE}{}^{‡}$
Reference	1265	4.61	6.93	1
Regular microlens array	1599	6.08	8.60	1.24
Regular microlens array + Al_2O_3 2.6 %	1885	7.54	9.59	1.38

‡ L: Luminance at 20 mA/cm^2, Max. PE: Maximum power efficiency, Max. CE: Maximum current efficiency, $R_{Max.CE}$: Relative maximum current efficiency