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Supporting Information

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Noble Roll-to-Roll Cohesive, Coated, Flexible, High-Efficiency Polymer Light-Emitting Diodes Utilizing ITO-Free Polymer Anodes

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Table S1. The characteristic summerizations of transparent conducting materials, compared with ITO, conducting polymers, SWCNTs and silver nanowires. The data of ITO and conducting polymer were measured by our own work. SWCNTs and silver nanowires were written by references. This table shows the advantages of conducting polymers because the roughness and flexibility of conducting polymer are better than the others. In addition, electrical and optical property are comparable to ITO, SWCNTs and silver nanowires.

	Flexibility	R2R suitability	Roughness	Sheet resistance	Transparency **
ITO*	poor	poor	3.8 nm	15 Ω/\square	81.6 %
Conducting polymer*	superior	superior	1.1 nm	90 Ω/\square	83.4 %
SWCNTs ^[4-6]	superior	good	7~10 nm	150 Ω/\square	90 %
Silver nanowires ^[7-9]	good	good	10 nm	110 Ω/\square	90 %

* Our work

**At visible wavelengh (550 nm)

1. Comparison between performance of the flexible polymer-anode device and the ITO-glass device.

Figure S1 compares current density versus voltage (*J-V-L*) characteristics of flexible polymer light-emitting diodes utilizing the roll-to-roll coated PH1000 (modified by adding 5% DMSO) and commercial grade ITO-glass (less than 10 Ω/\square).

The following is a summary of the fabrication process for the ITO-glass based devices. First, the ITO-glass was subjected to a UV-ozone treatment of about 1 h. A PEDOT:PSS layer (40 nm) was then spin-coated (2000 rpm, 40 s) onto the ITO-glass. A yellow light-emitting polymer (Merck “Super Yellow” PDY-132) dissolved in toluene at 0.6 wt% was then spin-coated (thickness approximately 80 nm). The ZnO NP layer (approximately 30 nm) was spin-coated onto the emissive layer. The ZnO NPs dispersed solution, dissolved in 1-butanol at a concentration of 30 mg/mL was synthesized. The ZnO NPs appeared rather monodispersed, with an average size of approximately 5 nm. Finally, the ionic solution was spin-coated onto the ZnO NP layer. The ionic solution permeated the ZnO NP layer, which was thin and porous, as the ionic solution was spin-coated onto the ZnO NP layer.

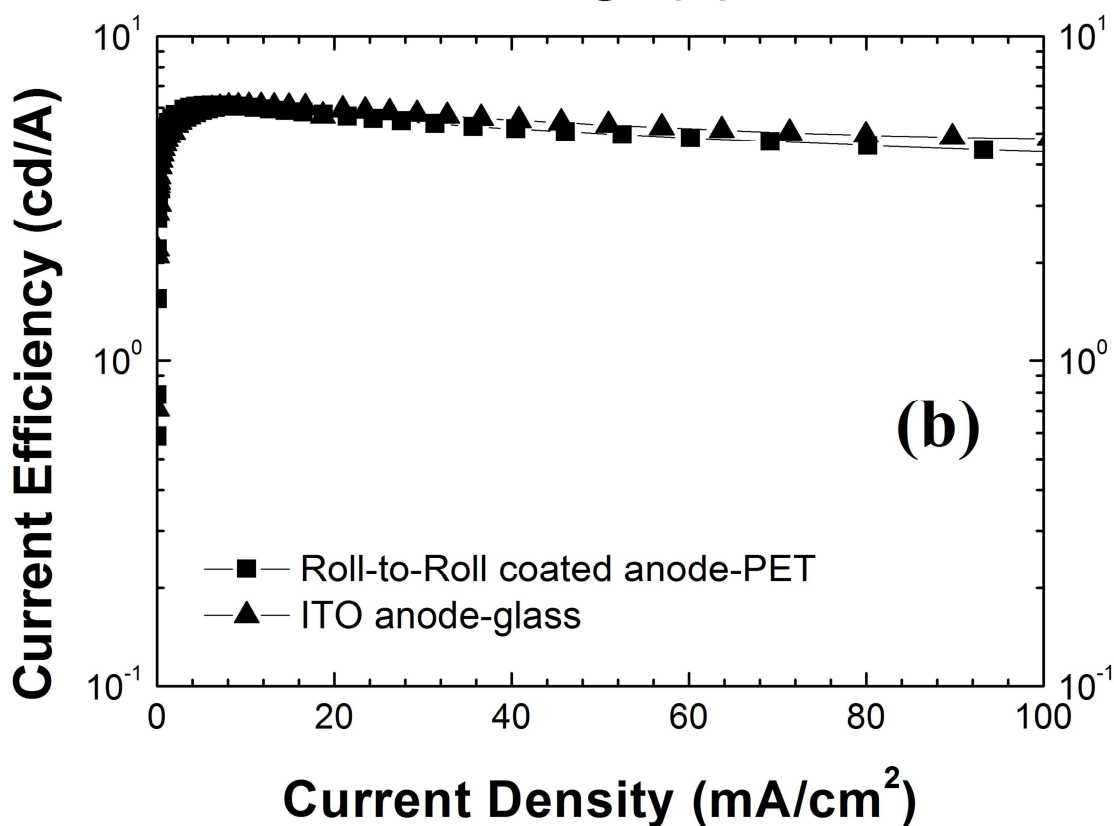
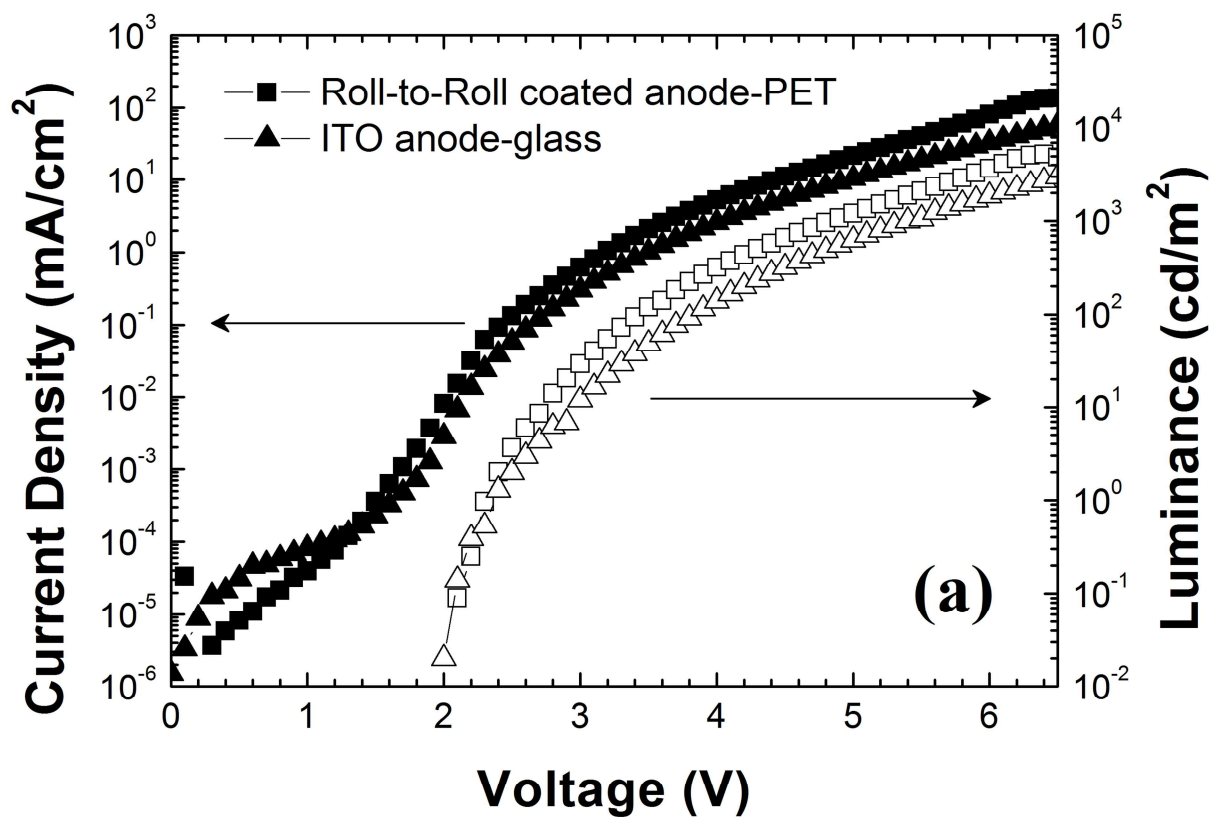


Figure S1. Comparison between the performances of spin-coated polymer-anode PLEDs and the roll-to-roll-coated polymer-anode PLEDs on PET substrate and ITO-glass. (a) Current density, voltage, and luminance (J-V-L) characteristics. (b) Current efficiency of the roll-to-roll cohesive coated device on PET substrate and the spin-coated device on ITO-glass substrate.

2. Surface morphology of the ITO-glass measured by atomic force microscopy

The Figure S2 shows the surface-roughness analysis result from atomic force microscopy (AFM). The morphology image of the ITO-glass was acquired by the AFM tapping mode (XE-100, PSIA).

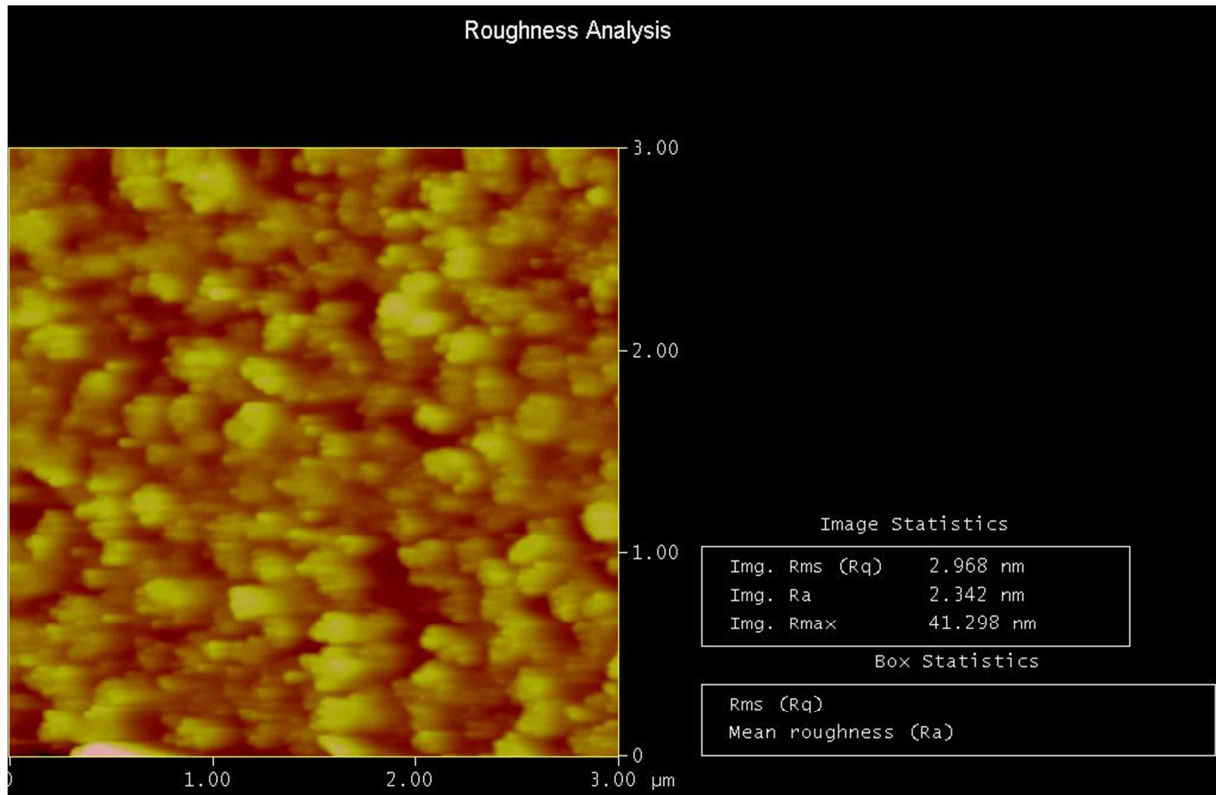


Figure S2. Atomic force microscopic images of ITO-glass anode was acquired by AFM tapping mode. The morphology of the commercialized ITO-glass (less than 10 Ω/\square) film is shown. The typical thickness of the ITO layer is 180 nm. The scan size of the ITO-glass was 3 \times 3 μm .

3. Comparison between life-time of Polymer-anode glass device and ITO-anode glass device

The Figure S3 shows the life-time of polymer-anode device and ITO-anode device. Each device was fabricated by same experiment conditions in ambient air. Two devices were fabricated on glass substrates. That is because our life-time measurement system was not applicable to flexible device. Therefore, ITO based device were also measured using ITO-glass based device. For an exact measurement, the devices were encapsulated by cover glass with a desiccant in glove box, before the life-time measurement. The criterion of life-time is a half-life (luminance intensity, 50 %) in particular luminance. The driving current was 1.5 mA, and the initial voltage was 5.7 V in case of polymer-anode. The ITO-anode was 0.4 mA and 4.7 V, respectively. The differences of reference current and voltage were caused by sheet resistance difference and the light-emitting area difference between polymer-anode and ITO-anode devices, 24 mm² and 6 mm², respectively. The active area was decided by patterning limitation.

The life-time of polymer-anode device was 400 hours and ITO-anode device was 515 hours [Figure S3].

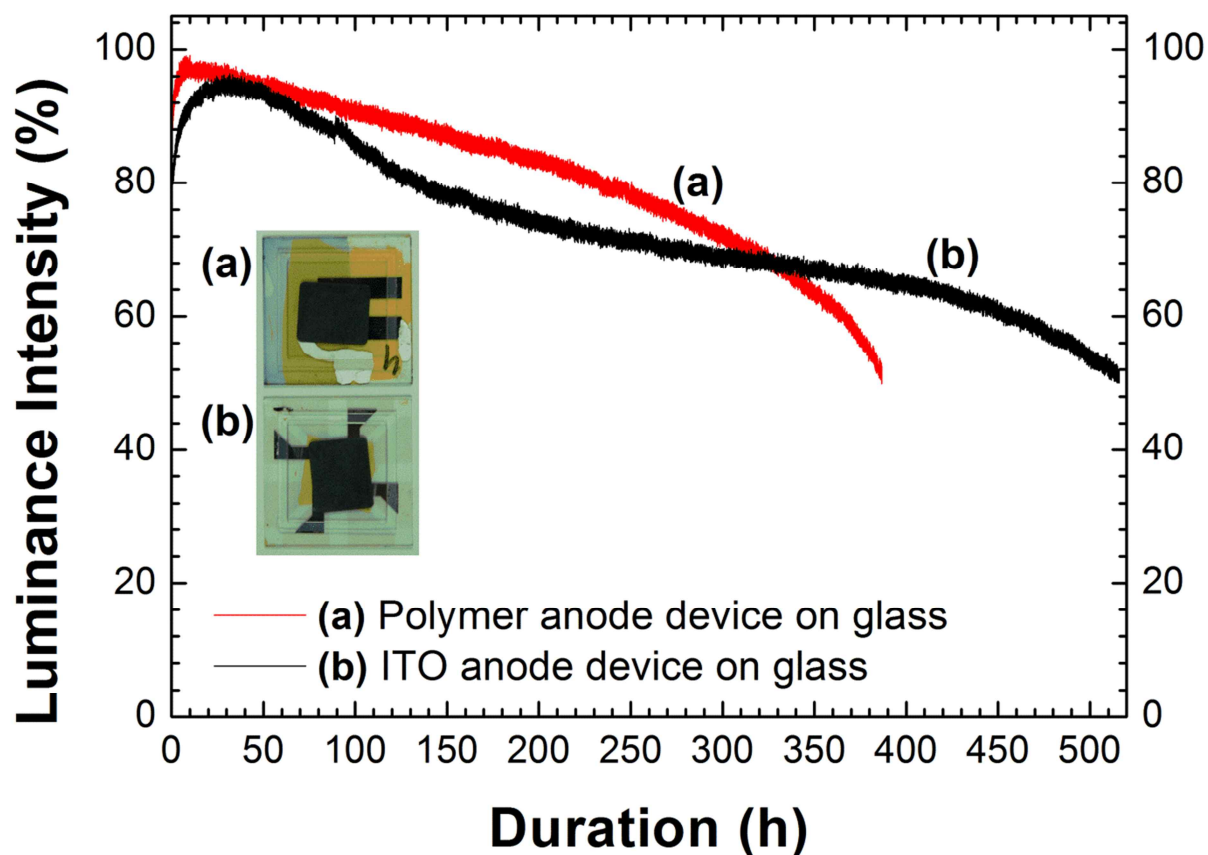


Figure S3. The life-time of the polymer-anode device and ITO-anode device on glass. (a) Red line represents the life-time of polymer-anode PLEDs, 387 h. (b) Black line represents the life-time of ITO-anode PLEDs, 515 h. Two PLEDs were fabricated on glass substrate due to the limitation of measurement system. Inset figure represents encapsulated devices using cover glass and desiccant in glove box. In the inset figure, (a) is polymer-anode PLEDs and (b) is ITO-anode PLEDs.