Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information

Improved Stability of Transparent PEDOT:PSS/Ag Nanowire Hybrid Electrodes by Using Non-ionic Surfactant

Sunghee Kim,‡[a,c] Su Jeong Lee,‡[a] Sunghwan Cho,[a] Sangbaie Shin,[b] Unyong Jeong*[b]

and Jae-Min Myoung*[a]

[a]Department of Materials Science and Engineering, Yonsei University, 50 Yonsei-ro, Seodaemun-gu, Seoul 03722, Republic of Korea. E-mail: jmmyoung@yonsei.ac.kr

[b]Department of Materials Science and Engineering, Pohang University of Science and Technology (POSTECH), 77 Cheongam-Ro, Nam-Gu, Pohang 37673, Republic of Korea. E-mail: ujeong@postech.ac.kr

[c]Research and Development Center, LG Display, 245 Lg-ro, Wollong-myeon, Paju-si, Gyeonggi-do 10845, Republic of Korea

*E-mail address: ujeong@postech.ac.kr, jmmyoung@yonsei.ac.kr

Experimental procedures

Materials.

Ag NWs were obtained from Nanopyxis. Poly(3,4-ethylene dioxythiophene):poly(styrene sulfonate) (PEDOT:PSS, Clevious P) was purchased from Heraeus. Triton X-100 (C14H22O(C2H4O)n); polymethyl methacrylate (PMMA, Mw = 996000); tris(2,2′-bipyridine)ruthenium(II) hexafluorophosphate ($Ru(bpy)_3(PF_6)_2$,); and 1-ethyl-3-methylimidazolium bis(trifluoromethylsulfonyl)imide ([EMIM][TFSI]) were purchased from Sigma-Aldrich. Acetonitrile and toluene were supplied from Duksan Pure Chemical Co. Ltd. Polydimethylsiloxane (PDMS, Sylgard 184) was purchased from Dow Corning.

Preparation and characterization of T-PEDOT:PSS/Ag NW hybrid films.

T-PEDOT:PSS/Ag NW hybrid films were fabricated by vacuum filtration and spin-coating at room temperature under ambient conditions. Ag NWs were dispersed in isopropyl alcohol (0.05 wt%) by ultrasonication for 30 min. Then, the Ag NWs were filtered onto a polytetrafluoroethylene (PTFE) membrane (0.2 μm pore size, 47 mm diameter, Millipore) by vacuum filtration to form a uniform Ag NW film. Subsequently, the Ag NW film was transferred to a 188 μm-thick polyethylene terephthalate (PET) substrate. A Triton X-100 aqueous solution (0.7 wt%) was dispersed in PEDOT:PSS solution to improve the viscoelasticity of a PEDOT:PSS. After that, the mixture was spin-coated onto the Ag NW film on PET at 4000 rpm for 30 s, and then dried at 120 °C for 5 min under ambient conditions.

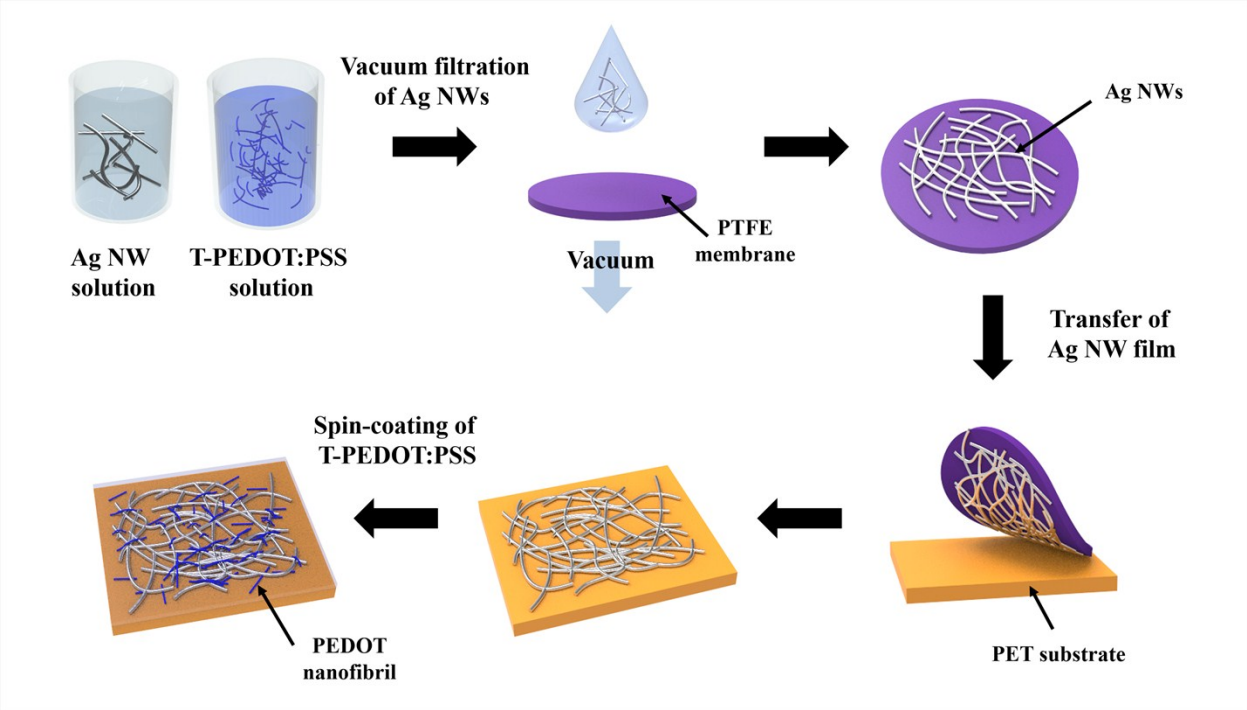

Fig. S1. Schematic illustration of the experimental procedure for the T-PEDOT:PSS/Ag NW hybrid electrode.

Device fabrication.

First, the bottom electrode consisting of an IZO–Ag–IZO (OMO) multilayer was deposited on a PET substrate at room temperature by in-situ sputtering. The 40 nm-thick bottom IZO layer was sputtered using an IZO target (90 wt% In_2O_3 + 10 wt% ZnO) at an RF power of 200 W, Ar flow rate of 50 sccm, and working pressure of 10 mTorr. Subsequently, a 12 nm-thick Ag layer was continuously deposited on the bottom IZO layer by sputtering at a DC power of 150 W, Ar flow rate of 50 sccm, and working pressure of 10 mTorr. Then, a 40 nm-thick IZO top layer was deposited on the Ag layer under identical conditions as the bottom IZO layer deposition.

The Ru complex was prepared by mixing 40 mg/mL $Ru(bpy)_3(PF_6)_2$ in acetonitrile, 60 mg/mL PMMA in toluene, and [EMIM][TFSI] with a ratio of 2:1:0.1 (v:v). Then, the 3.2 μm-thick Ru complex emissive layer was spin-coated over the OMO multilayer electrode on PET (1500 rpm for 30 s, repeated 3 times). Afterwards, it was dried in a vacuum oven at 120 °C for 24 h. Finally, a T-PEDOT:PSS/Ag NW hybrid electrode was deposited on a PDMS substrate (base resin to curing agent ratio of 10:1 (v:v)) and transferred on the Ru complex/OMO multilayer/PET substrate using a dry transfer printing method.[1]

Characterization.

The surface morphologies and the thicknesses of the films were observed by field-emission scanning electron microscopy (FE-SEM, S-5200, HITACHI). Surface roughness values, characterized by the root mean square (RMS) roughness, were evaluated using an atomic force microscope (AFM, Asylum Research system). The optical transmittances of the films were analyzed using an ultraviolet-visible-near infrared spectrophotometer (UV-vis-NIR, V-670,

JASCO). The electrical properties of the films were measured under ambient atmospheric conditions using a four-point probe (CMT-SR1000N, AiT). The ECL characteristics of the displays were studied with a function and arbitrary waveform generator (Agilent 33521A, Agilent Technologies). The electroluminescence (EL) spectra from these ECL displays were obtained by using Andor SOLIS simulation software. The mechanical stabilities of the films and ECL displays were evaluated with a bending machine (Flexible Materials Tester, Hansung Systems Inc.).

---

1. M. A. Meitl, Y. Zhou, A. Gaur, S. Jeon, M. L. Usrey, M. S. Strano and J. A. Rogers, *Nano Lett.*, 2004, **4**, 1643.

Table S1. Physical properties of Triton X series.

	EO unit[a]	molecular weight	HLB	CLC[b]	Protein extraction[c]
Triton X-45	4.5	427	9.8	136	15%
Triton X-114	7.5	537	12.3	120	62%
Triton X-100	9.5	625	13.4	189	70%
Triton X-102	12	757	14.4	267	54%
Triton X-165	16	911	15.5	570	40%
Triton X-305	30	1,527	17.3	1916	4%

[a] Average number of ethylene oxide (EO) units
[b] Critical Micelle Concentration: ppm at 25°C
[c] Protein extraction values for Triton-X series are from Ref. 2.

---

2. R. W. Egan, M. A. Jones and A. L. Lehninger, *J. Biol. Chem.*, 1976, **251**, 4442.

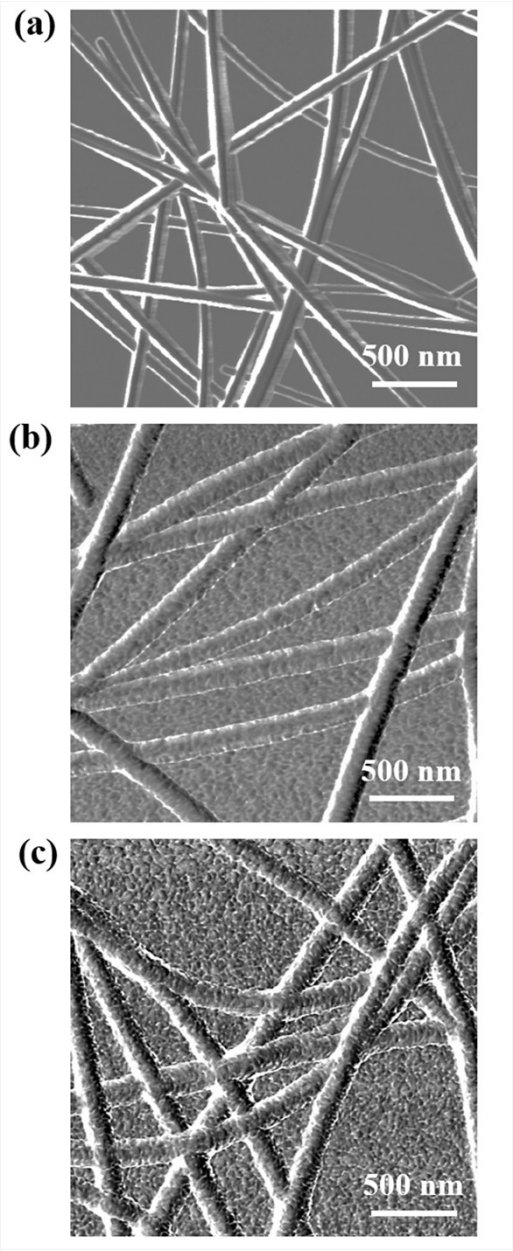

Fig. S2 Phase mode AFM images of (a) pristine Ag NW film, (b) PEDOT:PSS/Ag NW hybrid film, and (c) T-PEDOT:PSS/Ag NW hybrid film.

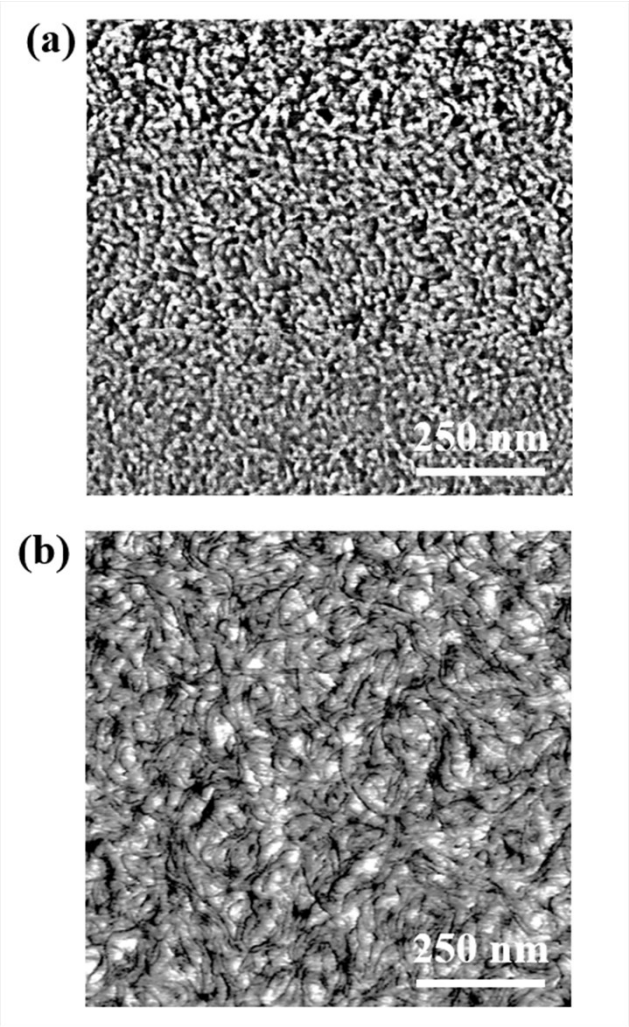

Fig. S3 AFM images of (a) pristine PEDOT:PSS film and (b) T-PEDOT:PSS film.