One step fabrication of highly stable, durable, adhesion enhanced flexible, transparent conducting film based on silver nanowires and neutralized PEDOT:PSS

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Experimental

Materials

Silver nanowires (AgNWs) (0.5 wt.% in water) with diameter of 20~25 nm and length of 25~30 μm was received from N&B Co. Ltd, Korea. PEDOT:PSS (AGFA 1021; ratio of PEDOT to PSS, 1:2.5, 1.3 wt.% aqueous dispersion) and polysiloxane were received from Solvay chemicals Korea. 3,4-Ethylenedioxythiophene (EDOT, XZL Chemical, 99.8%) was used as received. Dimethyl sulfoxide (DMSO), isopropyl alcohol (IPA) were used as received from Daejung chemicals. Imidazole and hydroxypropyl methyl cellulose (HPMC) were received from Sigma Aldrich. Polyethylene terephthalate (SH40 (PET, a thickness of 188 μm) was purchased from SKC, Korea.

Preparation of AgNWs/N-PEDOT:PSS hybrid dispersions

Acidic PEDOT:PSS was neutralized by adjusting the pH from ~1.3 to 7.0 using aqueous imidazole solution (1 M). The neutralized PEDOT:PSS weight was adjusted to 0.5 wt.% using IPA, DMSO and distilled water. AgNWs/PEDOT:PSS hybrid dispersion was prepared by mixing of AgNWs with neutralized PEDOT:PSS solution with the different weight ratios (1:0, 1:1, 2:1, and 0:1). Then 5 wt.% of HPMC (1.0 wt.% aqueous solution) was added to the solution and thoroughly mixed for 1-2 h by roll mixer. The AgNWs hybrid dispersion was utilized for

the fabrication of TCEs and further characterizations.

Characterizations

The sheet resistance of pristine AgNWs and hybrid TCF films were measured by CMTSR1000N four-point probe measurement (A.I.T.). The surface morphology of the AgNWs hybrid films was investigated using an S-4800 field emission scanning electron microscope (FE-SEM, Hitachi). The surface topology of all the film samples was analysed from AFM (n-Tracer, NanoFocus Inc.). AFM images were taken using in tapping-mode with a silicon-mounted cantilever ($T < 10$ nm, $L = 125$ µm, $f = 200–400$ kHz, $k = 25–75$ Nm^{-1}). The transmittance and absorbance of the AgNWs hybrid film samples were recorded in the OPTIZEN 322UV spectrometer. The flexibility and durability of the AgNWs hybrid TCFs were tested by measuring the change in resistance using a computer system with a digital multimeter (Agilent 34401A) during the cyclic bending test. The cyclic bending test was performed on rectangular TCF samples. The tests were carried out using a home-made fatigue machine with a constant linear vertical movement of 10 mm at 2 Hz stroke. A cyclic bending stress was applied to the films dynamically using a moving jig.

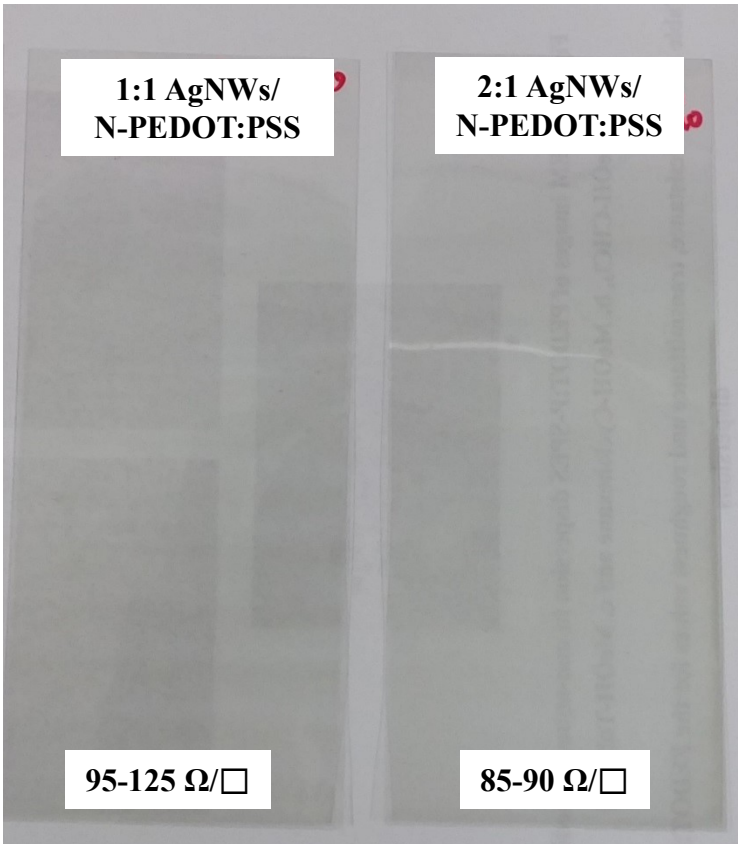

Figure S1: Photo images of hybrid AgNWs/N-PEDOT:PSS TCFs from 0.5 wt.% AgNWs and 1.3 wt. % N-PEDOT:PSS dispersion.

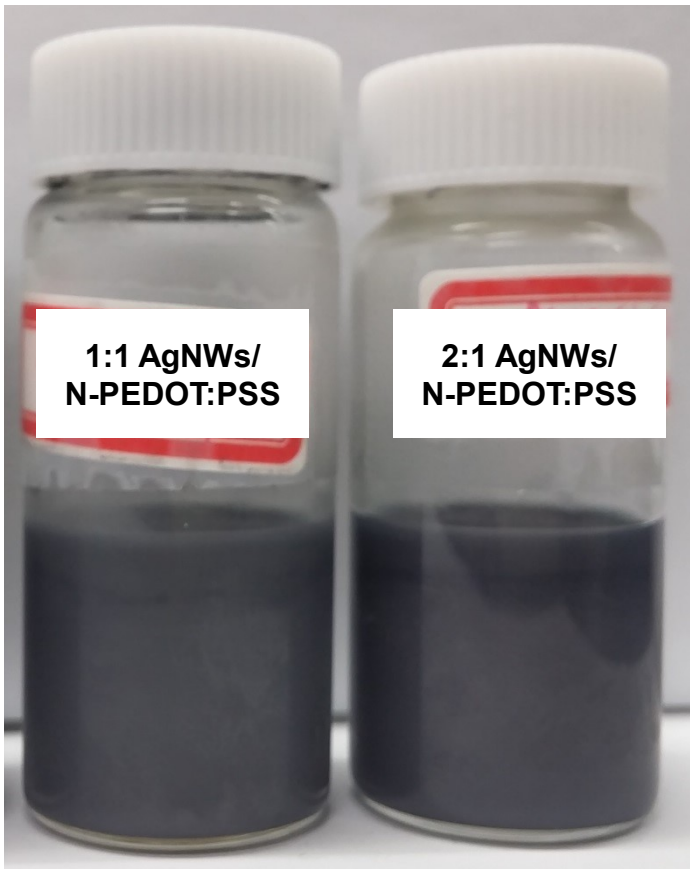

Figure S2: Photo images of hybrid AgNWs/N-PEDOT:PSS solutions from 0.5 wt.% AgNWs and 0.5 wt. % N-PEDOT:PSS dispersion.

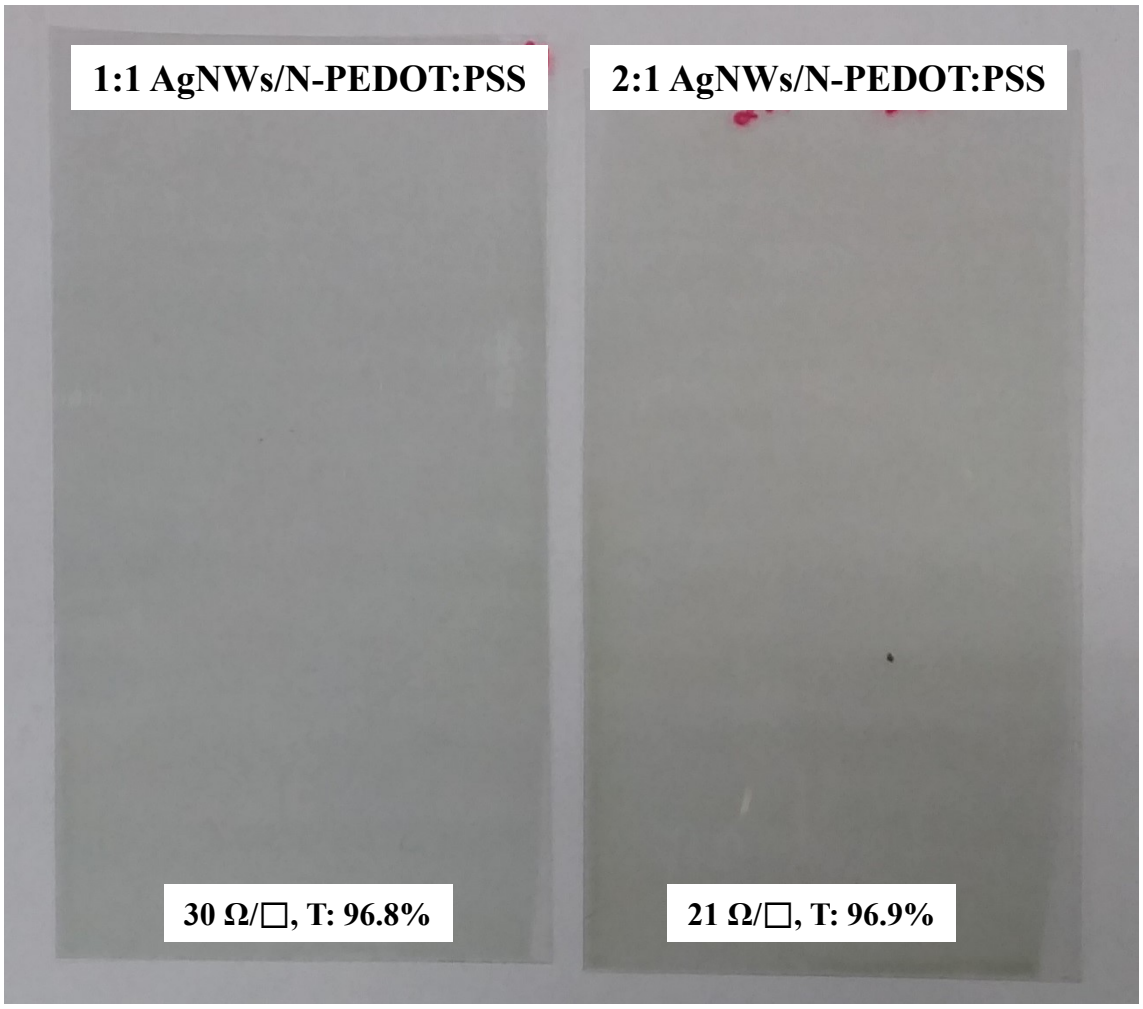

Figure S3: Photo images of hybrid AgNWs/N-PEDOT:PSS TCFs from 0.5 wt.% AgNWs and 0.5 wt. % N-PEDOT:PSS dispersion.

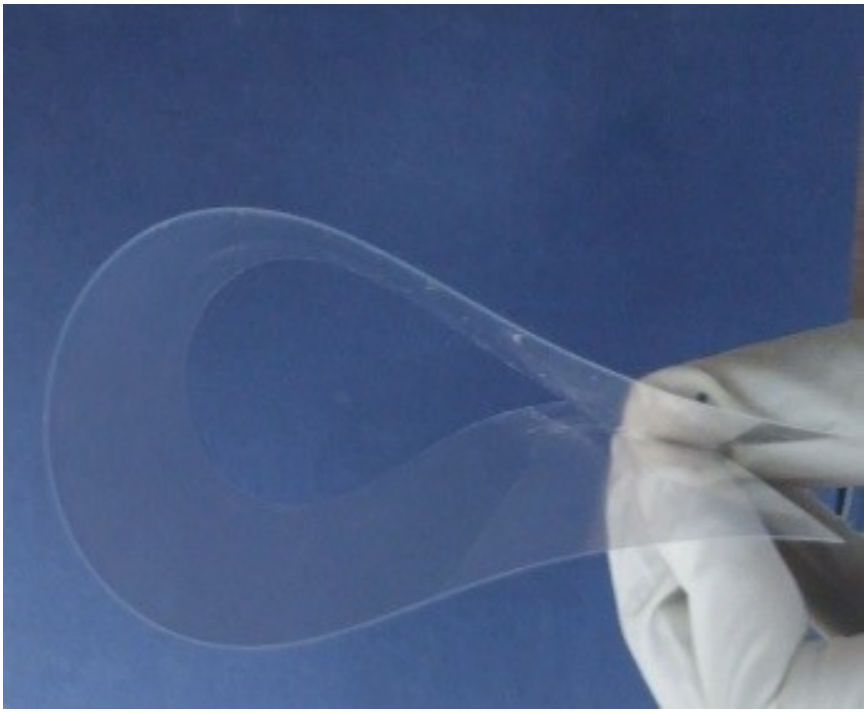

Figure S4: Photo image of hybrid AgNWs/N-PEDOT:PSS dispersion coated on flexible PET substrate.

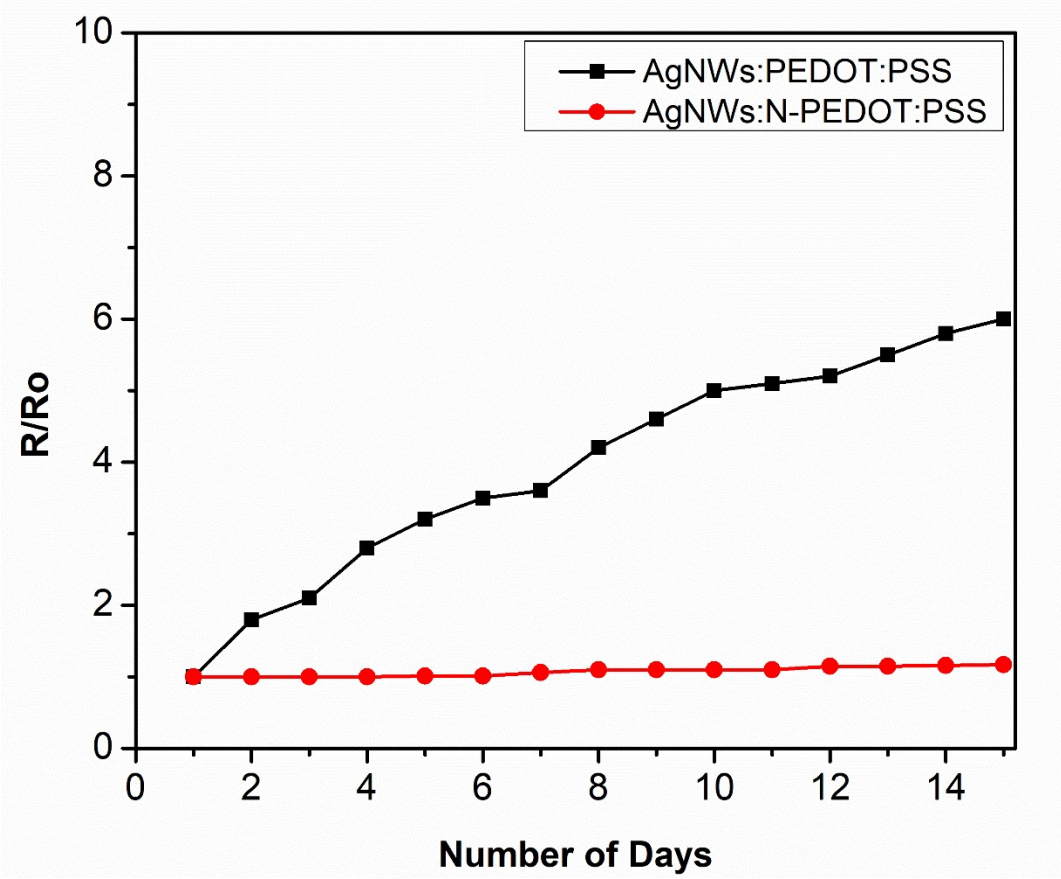

Figure S5: Sheet resistance vs time plot of AgNWs/PEDOT:PSS (un-neutral) and AgNWs/N-PEDOT:PSS (neutral) TCFs.

Table S1. Sheet resistance, transmittance, haze and roughness of the pristine AgNWs, AgNWs/N-PEDOT:PSS hybrid TCF films in comparison with already reported TCFs

Samples (W/W)	Sheet Resistance (Rs) Ω/□	Transmittance (%)	Haze (%)	Roughness (nm)	References
AgNWs:N-PEDOT:PSS (1:1)	**29.7 30.0***	**94.91 96.89***	**0.96 0.76***	**9.4**	**This work**
AgNWs:N-PEDOT:PSS (2:1)	**22.0 21***	**94.59 96.99***	**1.28 1.04***	**11.2**	**This work**
AgNWs:N-PEDOT:PSS (0:1)	**700**	**94.2**	**-**	**0.3**	**This work**
AgNWs	79.2	98.6	4.18	31.1	56
AgNWs/PEDOT:PSS	~75	>90	1.21	17.9	56
AgNWs Cross aligned	18.8-42.3	93.5-97.0	-	-	5
AgNWs Random aligned	15.9-88.6	88.2-97.0	-	-	5
Ultra-long AgNWs	24-109	94-97	3.4-1.6		76
AgNWs/Silica sol/PEDOT:PSS	12	87.5	-	-	77
AgNWs	8.2	82.7			78
Nb_2O_5/AgNWs/Nb_2O_5	9.61	84.3			79
AgNWs embedded HPMC	15-260	65-88	6-0.2	4.8±0.5	80
AgNWs coated HPMC	15-270	55-83	9-0.7	56.6±2	80
AgNWs	30-480	82.8-93	8-2	>20	63
AgNWs/PEDOT:PSS	15	90	1	-	81
AgNWs/CA	28.62-81.68	88.21-89.86			82
AgNWs/PEDOT:PSS	23	86	-	-	11
AgNWs/PEDOT:PSS	22-43.4	90.8-92.9	2-3.8	19.6-31.3	54
AgNWs/PEDOT:PSS	16	90.4	-	-	62
AgNWs/PEDOT:PSS/PVA Silane	20	95.4	1.6	-	57
AgNWs/PEDOT:PSS	17	83	-	20-30	4
AgNWs/PEDOT:PSS	25-54	85-90	-	-	21, 50
AgNWs/PEDOT:PSS	10.76	84.3		51.8	75
MPS-AgNW/PEDOT:PSS	22.6	81.4			24
AgNWs/Graphene	33	94			22
AgNWs/Single layer Graphene	22	88			37

DWCNT	35	90		10.5	28
AgNWs/SWCNT	8.7	66.4	11.0		83
AgNWs/SWCNT	20.87-81.76	95.33-98.45	1.8-0.21	-	84

*Overcoat with polysiloxane