Supporting Information

Quantification of SWNT fraction in the LBL assembled composites. Thermal gravimetric analysis (TGA) is commonly used to determine the nanoparticle content inside a LBL assembled film. In the SWNT nanocomposite with SPEEK, the TGA analysis is complicated due to the multiple components and high temperature resilience of several of them.[1,2] We had to use a different quantification procedure based on a combination of QCM and EDAX results.

According to QCM results (Figure 6B), HOCS has a mass deposition increment of $0.100\pm0.047\mu g/cm^2$ in comparison to $0.476\pm0.082\mu g/cm^2$ for SPEEK stabilized P2 SWNT per layer. HOCS can thus to be determined to have a mass fraction of 17.36%, which can be slightly underestimated due to the dissolution of SPEEK during the deposition process. EDAX is a useful technique to quantify elements, and penetration depth is 1.2μm on bulky carbon under 10kV electron beam.[3, 4] An EDAX analysis (Figure S5A) on SPEEK shows the element atomic ratio C:O:S= 16.93:7.05:1, which correlates well with the assumed SPEEK unit of $[C_{19}O_6SH_{12}]$ shown in Figure 1. Elements of the LBL assembled film can also be easily determined accordingly, with C:O:S=142.32:20.61:1. SPEEK is the only component inside film with sulfur element, so that its content can be easily determined to be as 17.02%. The last component SWNT can thus be calculated to be 65.62%.

Unlike the previously studied systems, mass fraction can be easily estimated from TGA curves (Figure S5B). Only SWNT leaves traces of residue after burning until 950^0C, so the content of SWNT can be determined by analyzing the residue of the film after burning. Estimated from this method, the fraction of SWNT is 73.91%, quite agreeable with the previous analysis.

In the P3 composite, C:O:S has a atomic ratio of 222:54:1, corresponding to a weight percentage of 0.91% of S. Weight fraction of SPEEK can thus be determined to be 10.05%.

Complete reference of (24): Bae, S.; Kim, H.; Lee, Y.; Xu, X. F.; Park, J. S.; Zheng, Y.; Balakrishnan, J.; Lei, T.; Kim, H. R.; Song, Y. I.; Kim, Y. J.; Kim, K. S.; Ozyilmaz, B.; Ahn, J. H.; Hong, B. H.; Iijima, S. Nat. Nanotechnol. 2010, 5, 574.

Cumulative Figure of Merit (Π_{TC}) calculation of ITO: In our previous publication, we estimated Π_{TC} of ITO is 0.07 ohms-1 by using the best property of ITO reported on **glass**: **6 ohms/sq at 90%** [Ref: Gordon, R.G. Mrs Bulletin 25, 52 (2000)], and critical strain of **1.7%** [Ref: Chen, Z., et al. Thin Solid Films 394, 201-205 (2001).] . (The transmittance T and visible absorption coefficient α can be converted by $\alpha=-lgT$.) When drafting this paper, we realized that the performance of ITO on plastic substrate, such as PET, can be much worse due to the low processing temperature required for polymer substrate. Thus in this paper, we quoted the best results of ITO on PET substrate, and tested the commercially available ITO in our lab. We believe this data can more accurately reflect the real performance of ITO on PET.

	Density(g/cm^3)
HOCS	1.5
PEEK	1.32
SWNT	2.11
Buckypaper	0.28~0.42

Table S1 Density of materials.

Diameter	**1.48**	**nm**
Length	2.5	nm
Number of atoms	456	
Mass	9.09×10^{-21}	g
Volume	4.30	nm^3
Density	2.11	g/cm^3

Table S2 Intrinsic density of an individual SWNT(19, 0).

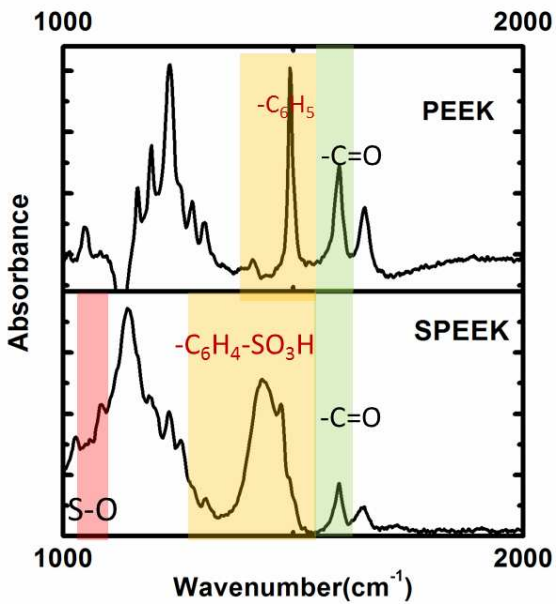

Figure S1. Fourier transform infrared (FTIR) spectra of PEEK and SPEEK.

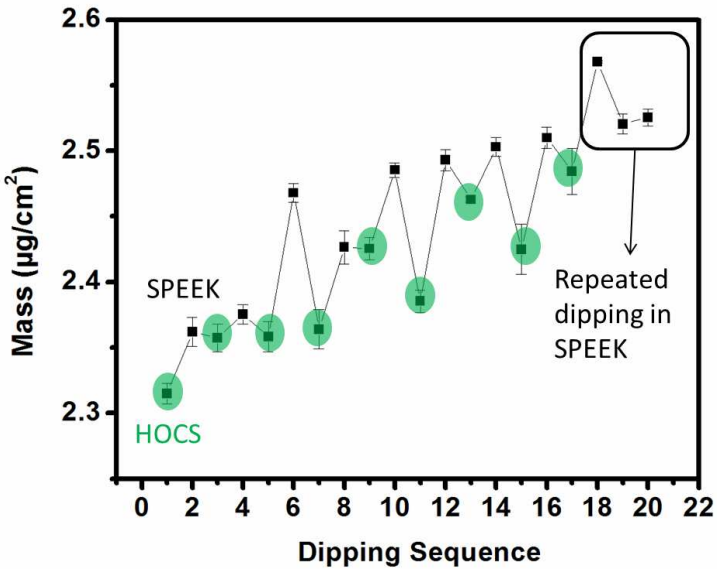

Figure S2. Mass deposition with the increasing dipping sequence for $[HOCS/SPEEK]_n$ multilayers. A layer of [polyethyleneimine/polystyrene sulfonate] was initially deposited onto the quartz crystal.

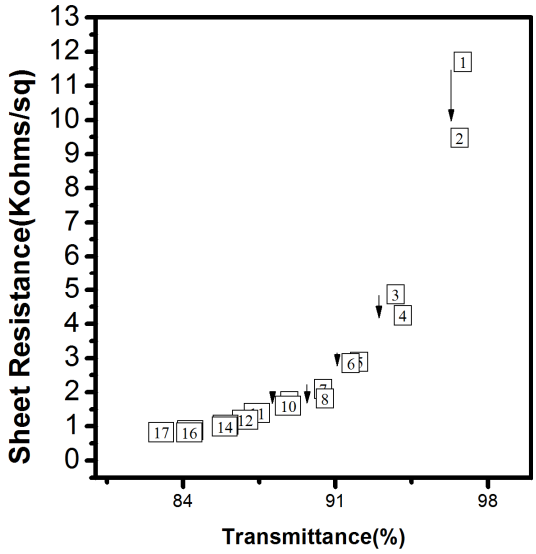

Figure S3. Sheet resistance vs. transmittance@550nm for $[HOCS/SPEEK\text{-}P2]_n$. The number marked on each point indicates the LBL deposition cycle, with odd number for SWNT layer and even number for HOCS adsorption layers. The enumeration starts from the first SWNT layer.

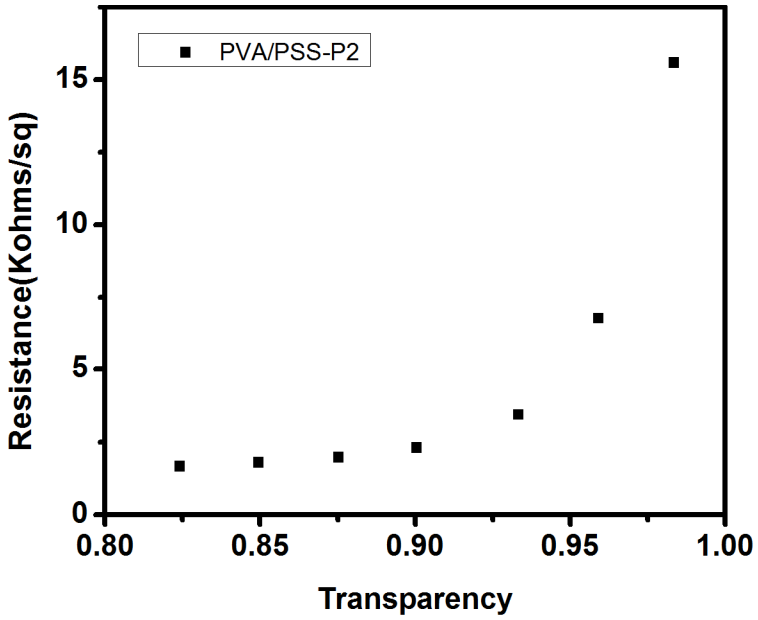

Figure S4. Sheet resistance vs. transmittance@550nm for [PVA/PSS-P2]. The preparation of the film follows the optimized recipe and procedure in Reference 5.

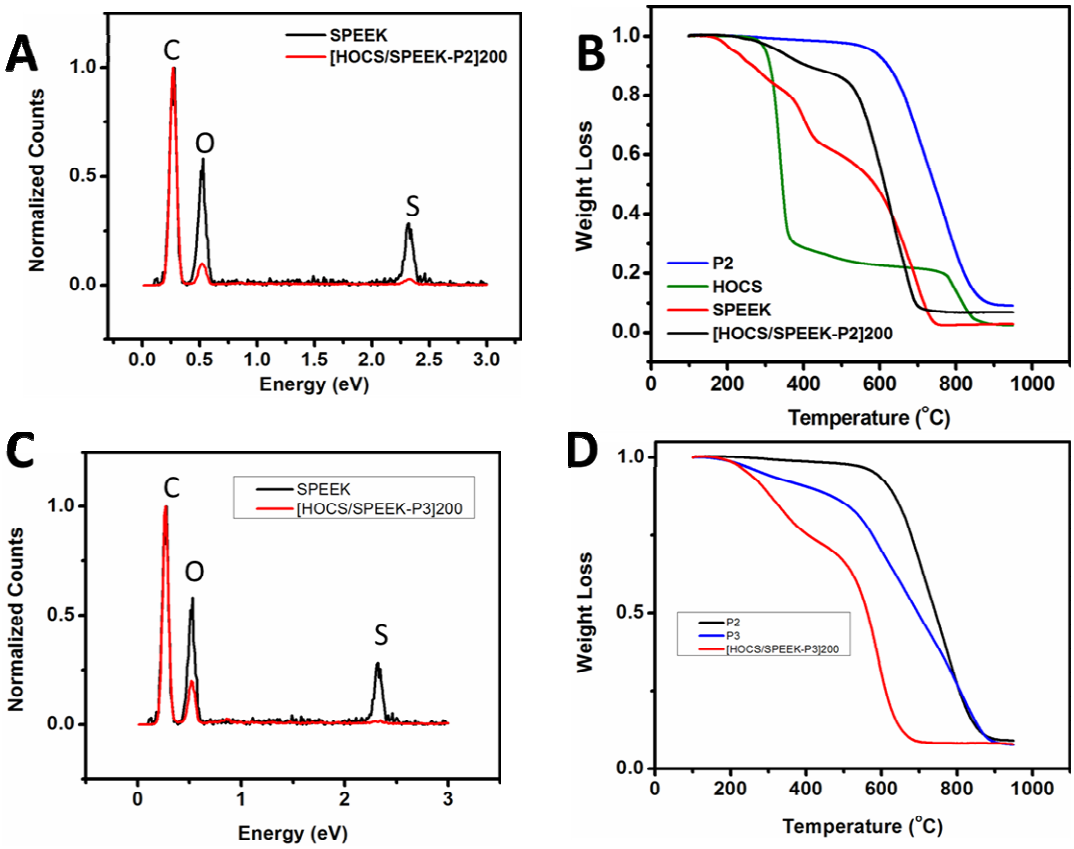

Figure S5. (A) EDAX analysis of SPEEK and $[HOCS/SPEEK\text{-}P2]_{200}$ (B) TGA analysis of P2 SWNT, HOCS, SPEEK and $[HOCS/SPEEK\text{-}P2]_{200}$ (C) EDAX analysis of SPEEK and $[HOCS/SPEEK\text{-}P3]_{200}$ (D) TGA analysis of P2 SWNT, HOCS, SPEEK and $[HOCS/SPEEK\text{-}P3]_{200}$.

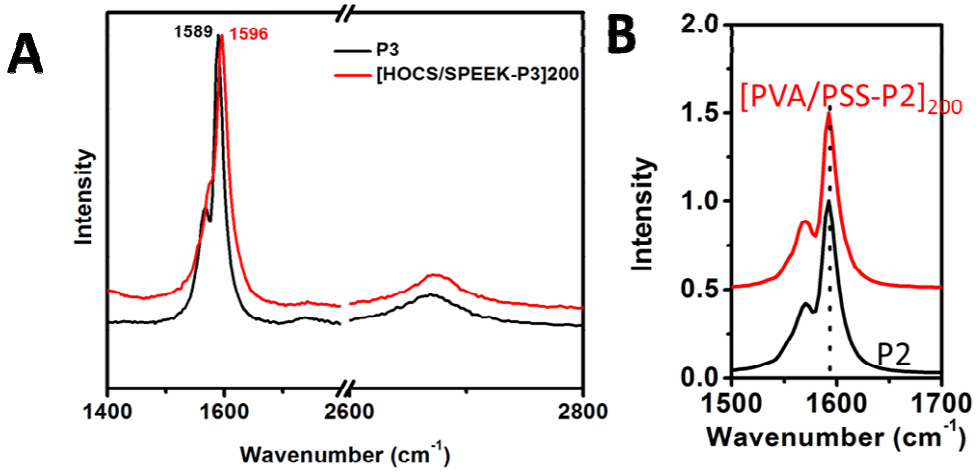

Figure S6. (A) Raman spectra of P3 SWNT and $[HOCS/SPEEK\text{-}P3]_{200}$. (B) *G* band in Raman spectra of P2 SWNT and $[PVA/PSS\text{-}P2]_{200}$. No significant shift can be seen.

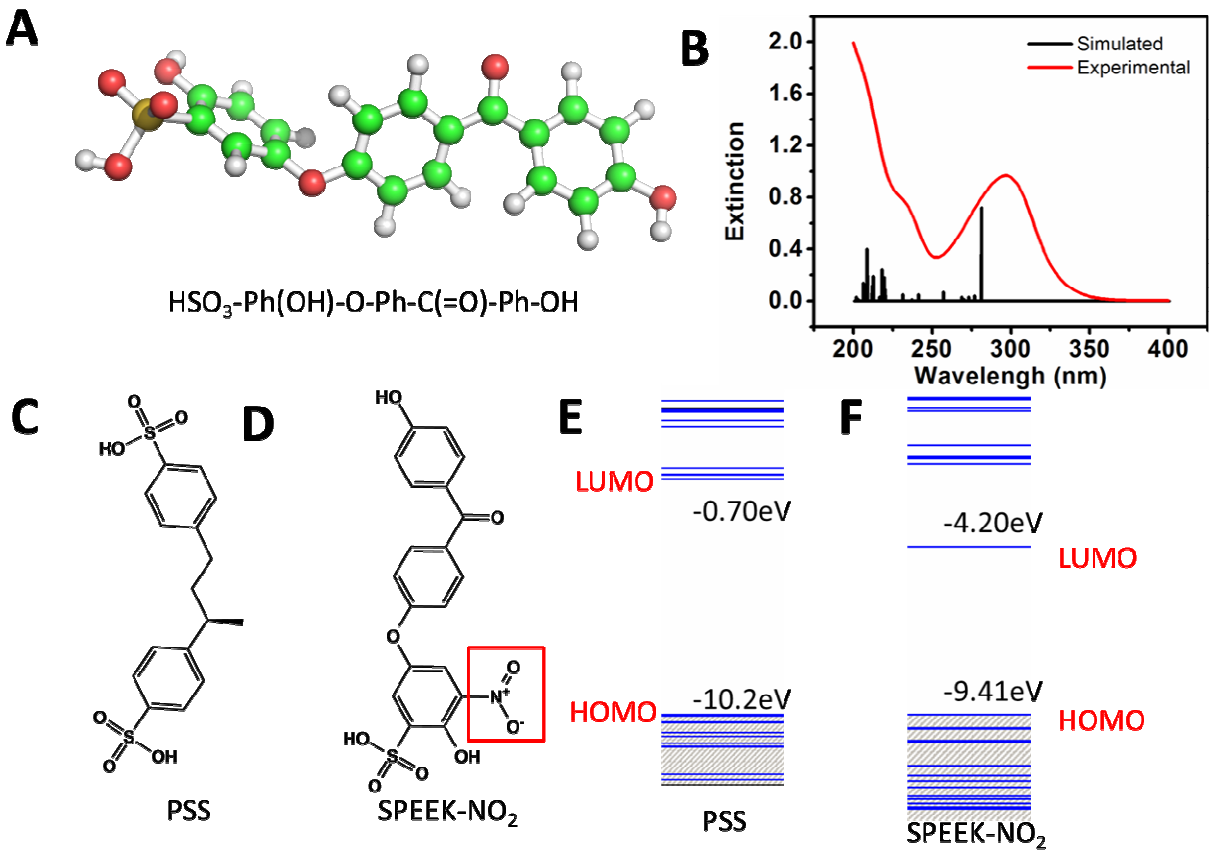

Figure S7. (A) 3D model of SPEEK unit used for calculation of energy levels. (B) Comparison between simulated and experimental UV spectra of SPEEK. (C) PSS unit used for calculation of energy levels. (D) SPEEK unit with $-NO_2$ substituting into phenyl ring. (E, F) Energy levels of PSS and SPEEK-NO_2.

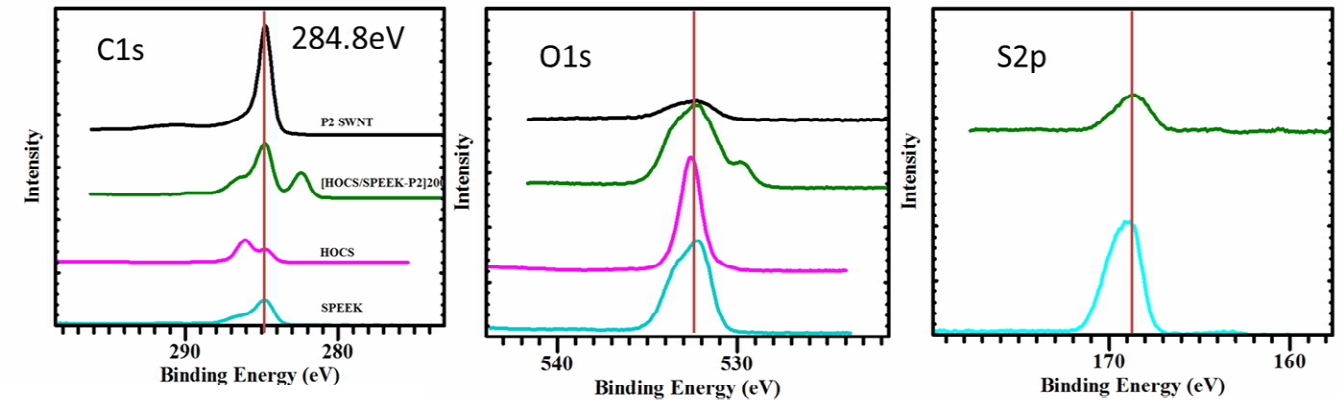

Figure S8. XPS spectra of $[HOCS/SPEEK\text{-}P2]_{200}$, HOCS, P2 SWNT and SPEEK.

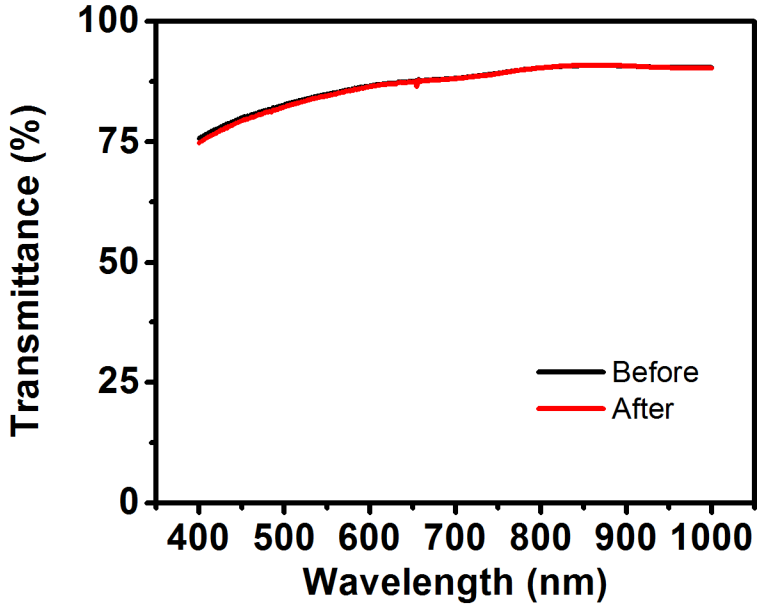

Figure S9. Transmittance of $[HOCS/SPEEK\text{-}P2]_{10}$ across visible wavelength range before and after keeping the film in the air at 100°C for a week.

Reference for Supporting Information:

(1) Shim, B. S.; Tang, Z. Y.; Morabito, M. P.; Agarwal, A.; Hong, H. P.; Kotov, N. A., *Chem. Mater.* **2007,** 19, 5467-5474.
(2) Shim, B. S.; Zhu, J.; Jan, E.; Critchley, K.; Ho, S. S.; Podsiadlo, P.; Sun, K.; Kotov, N. A., *ACS Nano* **2009,** 3(7), 1711-1722.
(3) Lee, S.; Hua, Y.; Zhao, S.; Mo, Z. In *Studies on Electron Penetration Versus Beam Acceleration Voltage in Energy-Dispersive X-Ray Microanalysis*, Semiconductor Electronics, 2006. ICSE '06. IEEE International Conference, 2006; 2006; pp 610-613.
(4) Somani, P. R.; Yoshida, A.; Afre, R. A.; Adhikary, S.; Soga, T.; Umeno, M., *physica status solidi (a)* **2006,** 203(8), 1982-1991.
(5) Shim, B. S.; Zhu, J.; Jan, E.; Critchley, K.; Kotov, N. A., *ACS Nano* **2010,** 4(7), 3725-34.