

Supporting Information

Heating and Acid Doping Thin Film Carbon Nanotube Assemblies for High Transparency and Low Sheet Resistance

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UV-vis Analysis. Figure S1 shows the absorbance and transmittance spectra of the $[\text{PDDA}/(\text{SWNT}+\text{DOC})]_n$ films between 300 and 850 nm, up to 20 bilayers, as well as those after post treatments (heating and doping). The $\text{PDDA}/(\text{SWNT}+\text{DOC})$ system has over 82% transmittance with 20 bilayers and over 98% with only two bilayers at 550 nm wavelength.

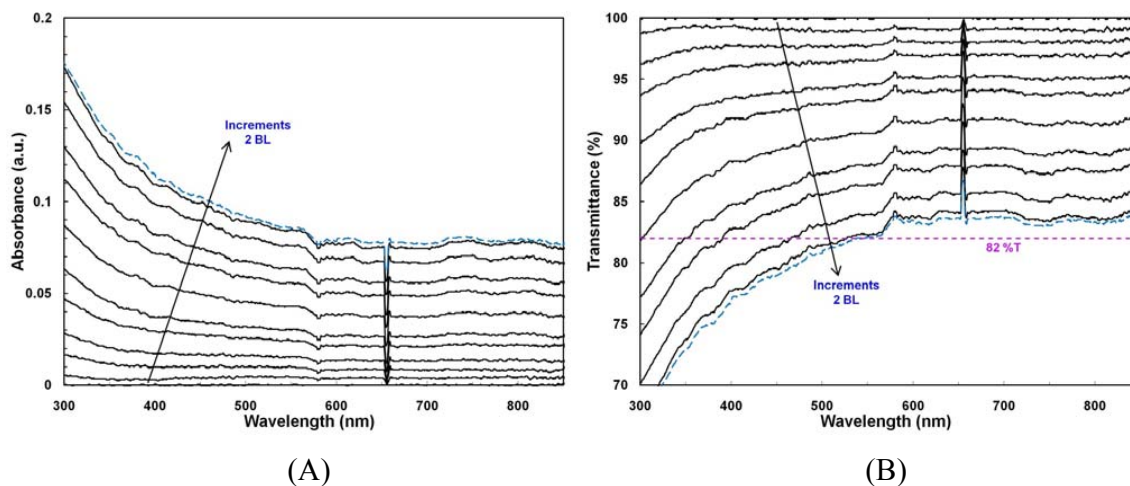


Fig. S1 Absorbance (A) and Transmittance (B) spectra of $[\text{PDDA}/(\text{SWNT}+\text{DOC})]_n$ thin films, measured in 2 BL step up to 20 BLs by the UV-vis spectrometer. The dot line is absorbance of $[\text{PDDA}/(\text{SWNT}+\text{DOC})]_{20}$ after 300 °C heating for 5 min and acid doping.

Thermogravimetric Analysis (TGA). Uncertainty remains about how to accurately measure the nanotube concentration in these nanocomposite thin films, but TGA provides a reasonable method.¹ The first step in this process is to obtain characteristic peaks for each component (PDDA, SWNT, and DOC) and the assembled films, obtained by subtracting the curve obtained under nitrogen from the curve obtained under an air environment. Figure S2 shows these curves and the corresponding characteristic peaks. These peaks are the result of differences in the degradation rate between the two gas environments. As shown in Table S1, SWNT has a characteristic peak at 620 °C (T_{C_SWNT}), which does not overlap with the characteristic peaks of PDDA and DOC. Commercial SWNTs are generally composed of ‘crystalline’ and amorphous carbons and some metallic catalyst. The catalyst has the same high temperature behavior under the air and nitrogen gas. Amorphous carbon has a lower degradation temperature than the crystalline carbon (i.e., the carbon nanotube itself), suggesting that the SWNT

concentration (C_{SWNT}) can be estimated from the height of its own characteristic peak, which is only the result of nanotube and catalyst. Therefore, the SWNT concentration in a given assembly is calculated by taking the characteristic peak wt% from TGA of the assembly, multiplying by 88 – 100, and finally dividing by the characteristic peak wt% from TGA of the neat nanotube, where 88 % stands for the carbon concentration ($C \geq 88 \text{ wt } \%$) of commercial SWNTs used in this study and 100 % assumes the LbL film possesses only the crystalline carbon. For example, the SWNT-based LbL assembly contains 10.8 – 12.3 wt% nanotube (plus some catalyst impurity), which was obtained by dividing 686.4 – 780 by 63.5.

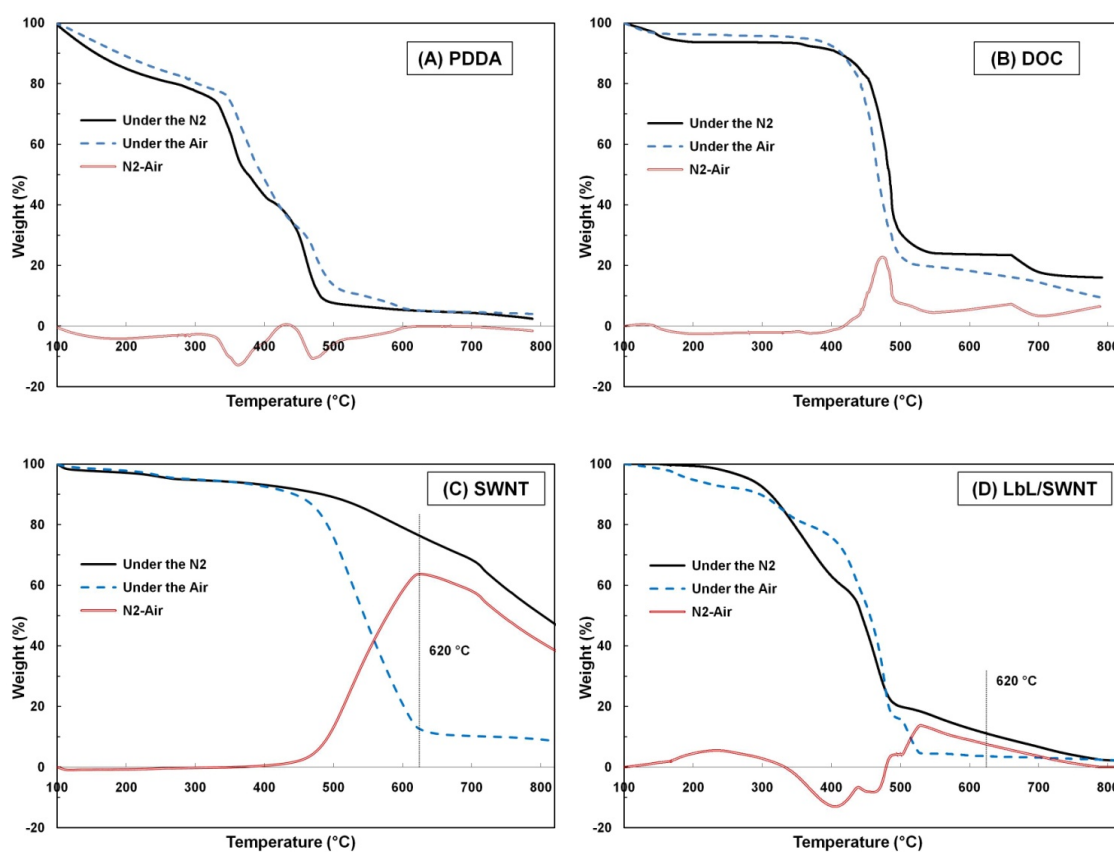


Fig. S2 Thermogravimetry of each component of CNT-based LbL films and three types of LbL films (PDDA (A), DOC (B), SWNT (C), and [PDDA/(SWNT+DOC)] (D)) under dried air and nitrogen gas, respectively. The difference between the air and nitrogen curves is also plotted to reveal the characteristic peak for a given material.

TABLE S1: Characteristic temperature of each CNT and CNT composition in PDDA/(SWNT+DOC) assemblies

T _{C_SWNT}	W _{C_SWNT}	W _{C_LbL/SWNT}	C _{SWNT}
620 °C	63.5 %	7.8 %	10.8 – 12.3 %

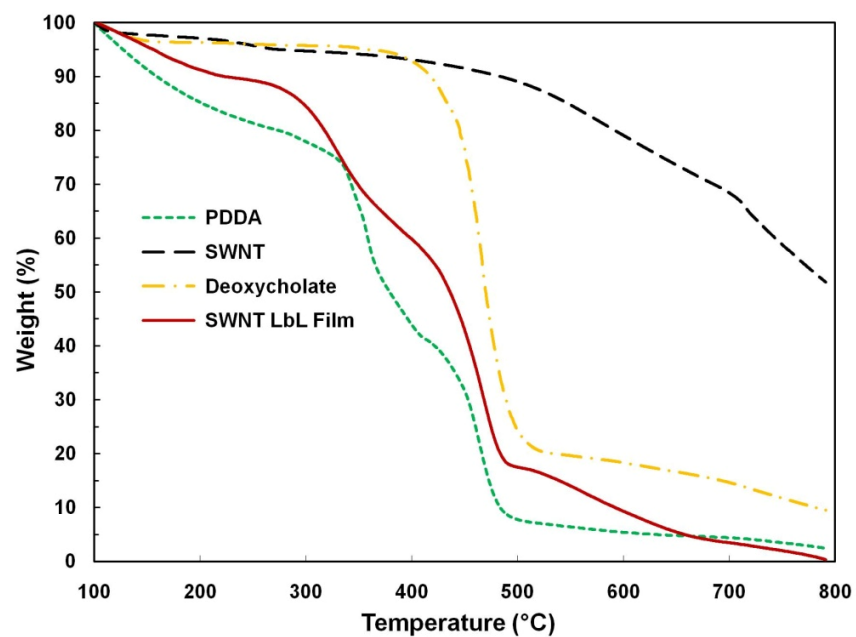


Fig. S3 Thermogravimetry of the components of the PDDA/(SWNT+DOC) system and a fully assembled film, under a nitrogen atmosphere.

Acid doping. For nitric acid vapor treatment, the SWNT LbL films were kept in an acid vapor saturated environment and held there at 70 °C for 30 min, followed by rinsing in DI water and drying with filtered air. Figure S4 shows the schematic of the acid doping apparatus, comprised of a hot plate, cover, two petri dishes (smaller one for acid and larger one for heated water), 60 ml nitric acid, sample holder and SWNT-based LbL film.

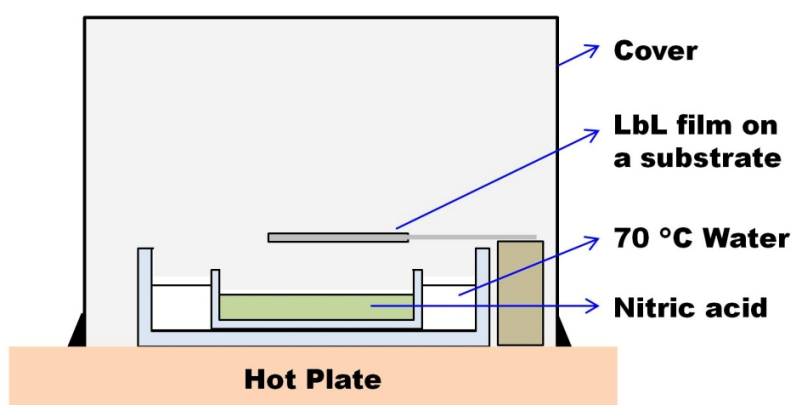


Fig. S4 Schematic of acid doping apparatus.

Reference

- 1 B. S. Shim, Z. Y. Tang, M. P. Morabito, A. Agarwal, H. P. Hong and N. A. Kotov, *Chem. Mater.*, 2007, **19**, 5467.