Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C

Supporting Information

Novel vertical-spinning preparation of free-standing carbon nanotube/polyaniline composite films with high electrical conductivity

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1. Molecular weight measurement

The weight average molecular weight of PANI was measured by static light scattering method.[1] All samples and vials must be scrupulously free of any particulate matter and all solvents and solutions filtered through 0.22 μm Teflon™ filters before use. Absolute molecular weights were measured using a static light scattering instrument equipped with a 658 nm laser source (DAWN, HELEOS-11, Wyatt Technology Corp.) in Debye model. Solution of polyvinylpyrrolidone (PVP, M_w=58000, Alfa) dissolved in 1-methyl-2-pyrrolidinone (NMP) was used as standard solution (3 mg/ml). PANI was dissolved in NMP (7.66×10^{-6} g/ml) as test solution. All samples were injected into the light scattering instrument though 0.22 μm Teflon™ filters. Analysis was performed using ASTRA 5.3.4.14 software. Table. S1 shows the results of the PANI molecular weight measurement. The results are presented in Fig. S1 and Fig. S2. dn/dc of the PANI sample was measured to be 0.5 ml/g and the average R_z is 103.6 nm. Finally, the weight-average molecular weight of the PANI is calculated to be 9.649×10^5 g/mol.

Table. S1 The results of PANI molecular weight measurement.

Sample	Average M_w (g/mol)	dn/dc (ml/g)	Average R_z (nm)
PANI	9.649×10^5	0.5	103.6

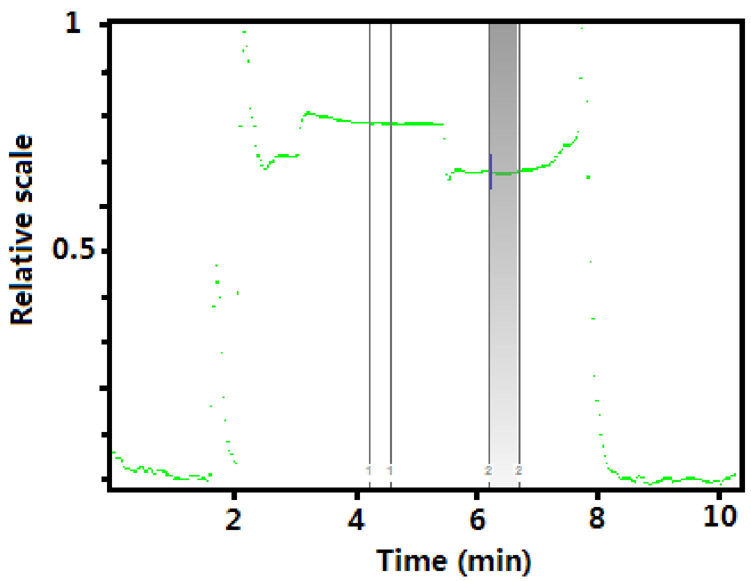

Fig. S1 Light scattering intensity of the PANI-NMP solution as a function of time.

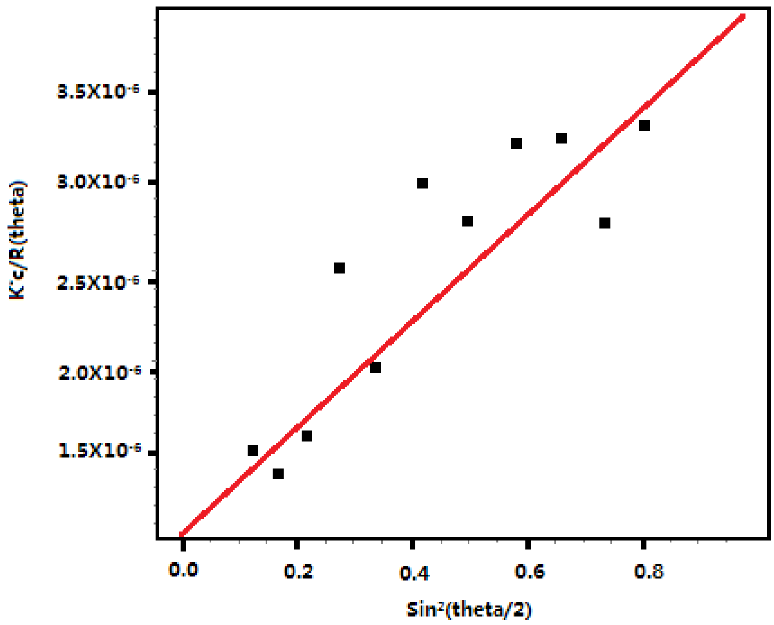

Fig. S2 Measured Debye plots of PANI.

2. Mechanical property measurement

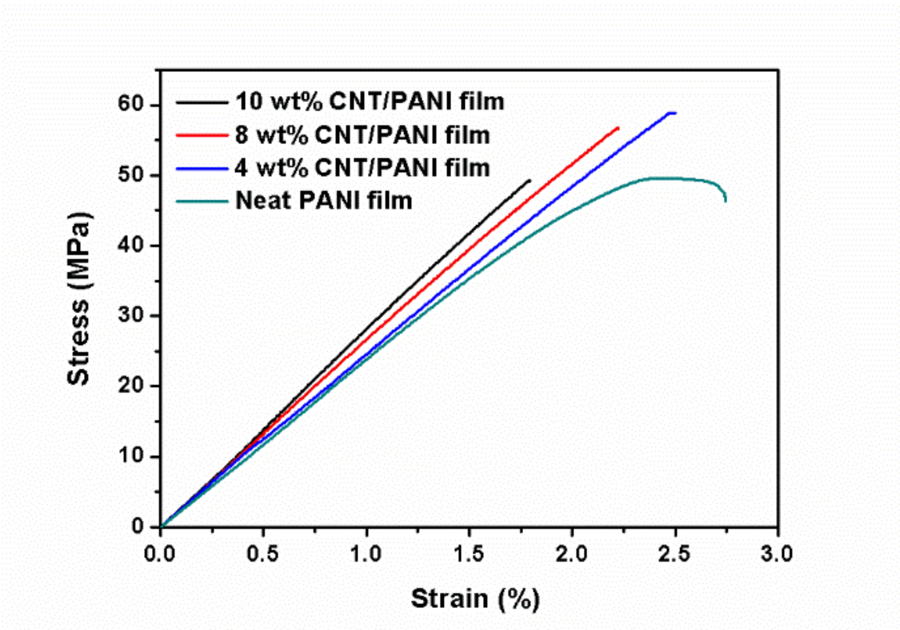

Fig. S3 Tensile stress-strain curves of neat PANI film and the CNT/PANI composite films with different CNT contents.

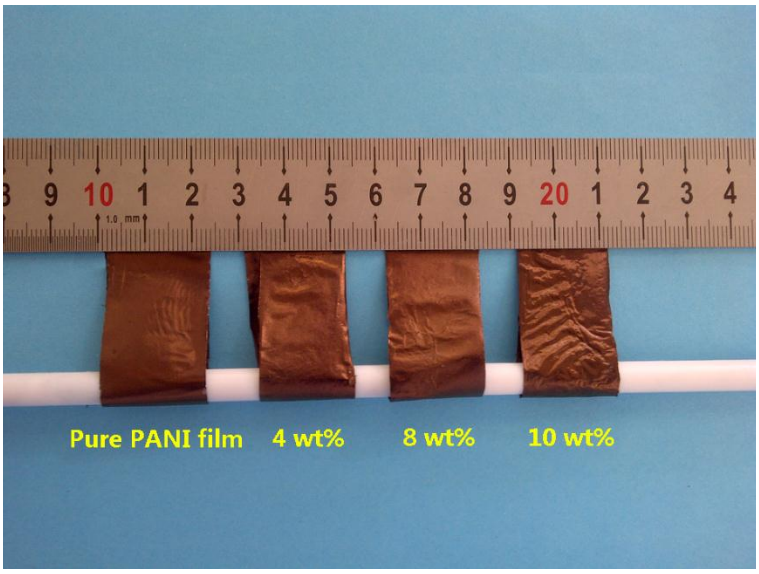

Fig. S4 Digital photograph of the pure PANI film, the vertically spun 4, 8 and 10 wt% CNT/PANI composite films coiled over a rod with a radius =2.5 mm.

The typical tensile stress-strain curves of the pure PANI film and the CNT/PANI composite films are shown in Fig. S3. It exhibits that the pure PANI film possesses a high mechanical strength with a value of greater than 50 MPa while the tensile strength is enhanced by introduction of CNTs at proper contents of 4 and 8 wt% into the PANI matrix. Meanwhile, the high elongation of above 2% is maintained for the composite films. These indicate that the composite films will keep the good stretchability of the pure PANI film. Moreover, Fig. S4 shows the digital image of the pure PANI film, the vertically spun 4, 8 and 10 wt% CNT/PANI composite films coiled over a rod with a radius = 2.5 mm. These films can be easily bended to such a small radius without any visible damage, demonstrating their good flexibility.

3. Applications of CNT/PANI composite film.

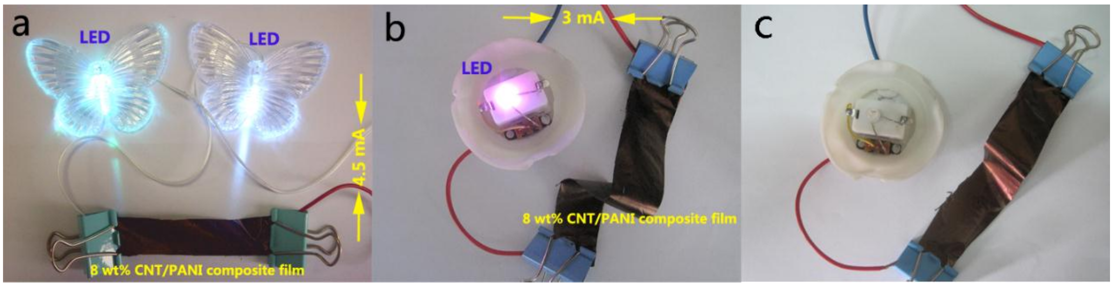

Fig. S5 (a-b) The vertically spun free-standing 8 wt% CNT/PANI composite film as a part of the electric circuits to light the colorful LEDs by respectively applying the electric current of (a) 4.5 mA and (b) 3 mA with Keithley Source Meter 2400; (c) the plane-casted 10 wt% CNT/PANI composite film is used as a part of the electric circuits to light the 3 mA LED under the same condition as for the vertically spun composite film but the LED light cannot be lit due to a relatively low electric current (1.6 mA) than the rated current needed for lighting the LED.

The 8 wt% CNT/PANI composite film is chosen because it has a higher mechanical strength and a better mechanical stretchability than the 10 wt% composite film as shown in Fig. S3 while its conductivity is close to 10 wt% film. 4.5 mA and 3 mA electric currents are applied on the circuits in Fig. S5a and Fig. S5b, respectively. The colourful LEDs are well lit using the flexible composite films as one part of the circuits as shown in Fig. S5. The composite film after cutting has the dimensions of 10 cm×2 cm×10 μm in length×width×thickness and the resistance is calculated to be about 33 Ω from its conductivity (149 S/cm) in terms of the resistance law. The low resistance results in a relatively low component voltage for the composite film in the circuits. This will keep the input voltages of the circuits around the rated voltage of the LEDs (4.5 V and 3 V respectively in Fig. S5a and S5b), which could be easily provided by the commonly used dry cells. By contrast, the plane-casted composite film (10 wt% of CNTs) is used as a part of the electric circuits to light an LED under the same condition as for the vertically spun film, however the LED cannot be lit as shown in Fig. S5c since the relatively high resistance of the plane-casted composite film will lead to a relatively low electrical current (1.6 mA) in the circuit, which is lower than the rated current (3 mA) needed for successfully lighting the LED.

REFERENCE

1 H. S. Kolla, S. P. Surwade, X. Y. Zhang, A. G. MacDiarmid and S. K. Manohar, *Journal of the American Chemical Society*, 2005, 127, 16770-16771.