

## Supplementary Materials for RSC Advances

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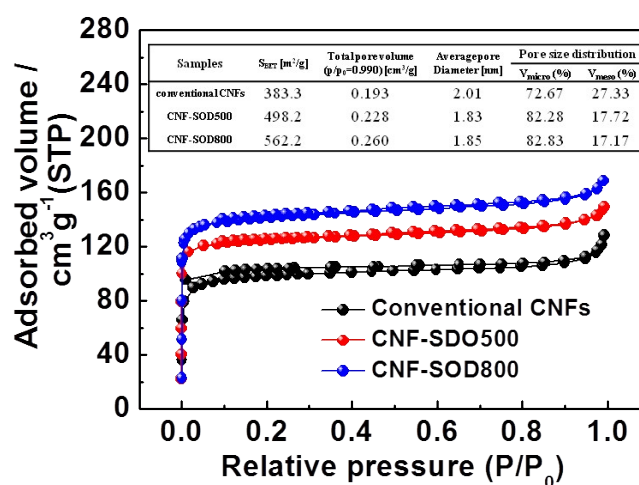
### Enhanced electrochemical performances of phosphorus incorporated carbon nanofibers by the spin-on dopant method

Dong-Yo Sin, Il-Kyu Park\*, and Hyo-Jin Ahn\*

*Department of Materials Science and Engineering, Seoul National University of Science and Technology, Seoul 139-743, South Korea*

#### 1. Adsorption and desorption results of carbon nanofibers (CNFs)

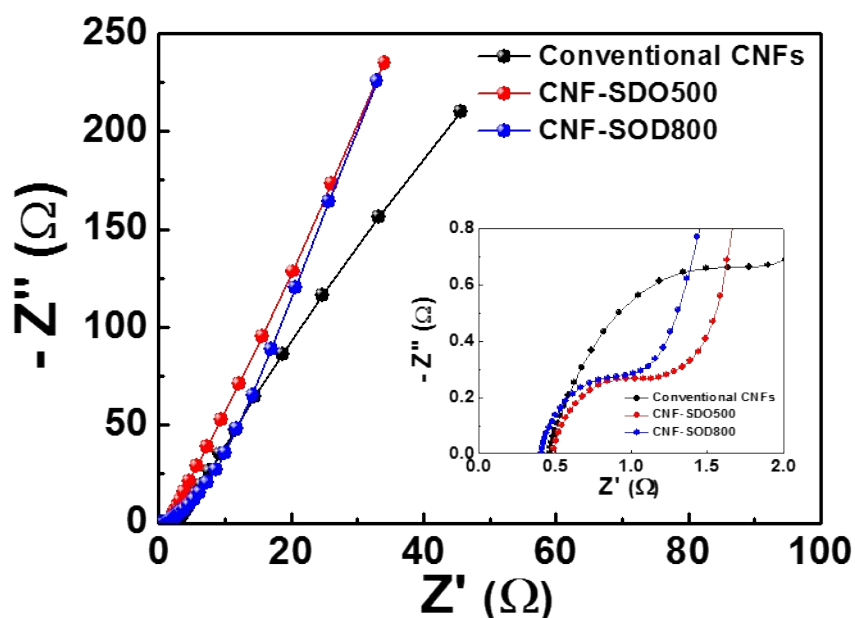
Adsorption and desorption results were measured by Brunauer-Emmet-Teller analysis (BET, Micromeritics ASAP2010) for the conventional CNFs, CNF-SOD500, and CNF-SOD800 using N<sub>2</sub> gas at 350 °C. The specific surface area and total pore volume increased after the SOD treatment. And the P incorporated CNFs showed reduced ratio of mesopore to micropore. It should be noted that this ratio do not imply the absolute content of the mesopore is reduced in the SOD treated CNFs because the total volume of pore has been increased for the SOD treated CNFs.



**Figure S1.** Adsorption and desorption results for the CNFs, CNF-SOD500, and CNF-SOD800.

## 2. Electrochemical impedance spectroscopy (EIS) results

Electrochemical impedance spectroscopy (EIS, PGST302N by Eco Chemie, Netherlands) was measured for the conventional CNFs, CNF-SOD500, and CNF-SOD800 in the frequency range of 100 kHz to 10 MHz before the charge-discharge test. All samples show typical EIS spectra corresponding to the electrochemical cells with initial incomplete semicircle and linearly increasing region. The initial semicircle indicates charge transfer impedance ( $R_{ct}$ ) between electrode and electrolyte interface. And the slope of linearly increasing region implies the diffusion rate of ions into the electrodes and is regarded as Warburg impedance. As shown in the Fig. S1, after P-incorporation into the CNFs, both of the charge transfer impedance and Warburg impedance were greatly reduced compared with the conventional CNF.



**Figure S2.** EIS results of the conventional CNFs, CNF-SOD500, and CNF-SOD800.

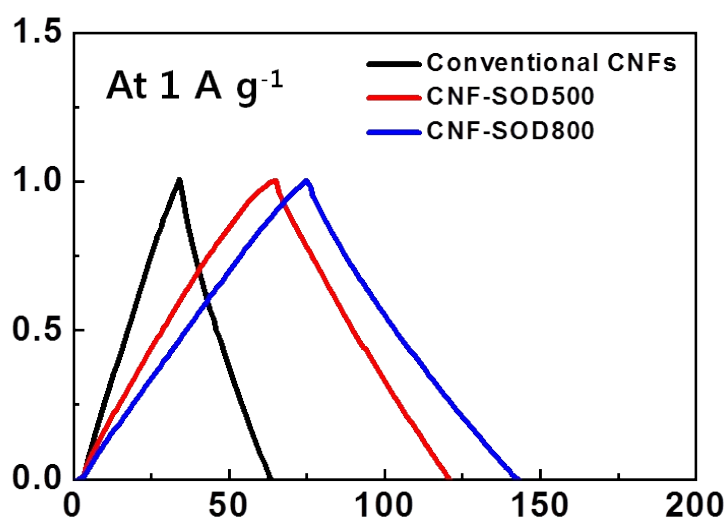
## 3. Galvanostatic charge-discharge results

Galvanostatic charge-discharge curves were obtained from the conventional CNFs, CNF-SOD500, and CNF-SOD800 using symmetric two-electrode cells in 6 M KOH at 1 A/g. The charge-discharge curve shows bilateral symmetry and linear slopes, implying ideal capacitance. The discharge time for conventional CNFs, CNF-SOD500, and CNF-SOD800 were 32, 61, and

71 sec, respectively. And the estimated discharge time was used for the specific capacitance of the capacitors in the manuscript by using the following equation;

$$C_{sp} = 4I/(mdV / dt)$$

where  $C_{sp}$  is the specific capacitance,  $t$  is the discharging time (s),  $dV/dt$  is the scan rate,  $m$  is the total mass of the active material (g), and  $I$  is the current (A). The specific capacitances of conventional CNFs, CNF-SOD500, and CNF-SOD800 at a current density of  $0.1 \text{ A}\cdot\text{g}^{-1}$  are 76, 160, and  $188 \text{ F}\cdot\text{g}^{-1}$ , respectively.



**Figure S3.** Charge-discharge curve at  $1 \text{ A g}^{-1}$  obtained from conventional CNFs, CNF-SOD500, and CNF-SOD800.

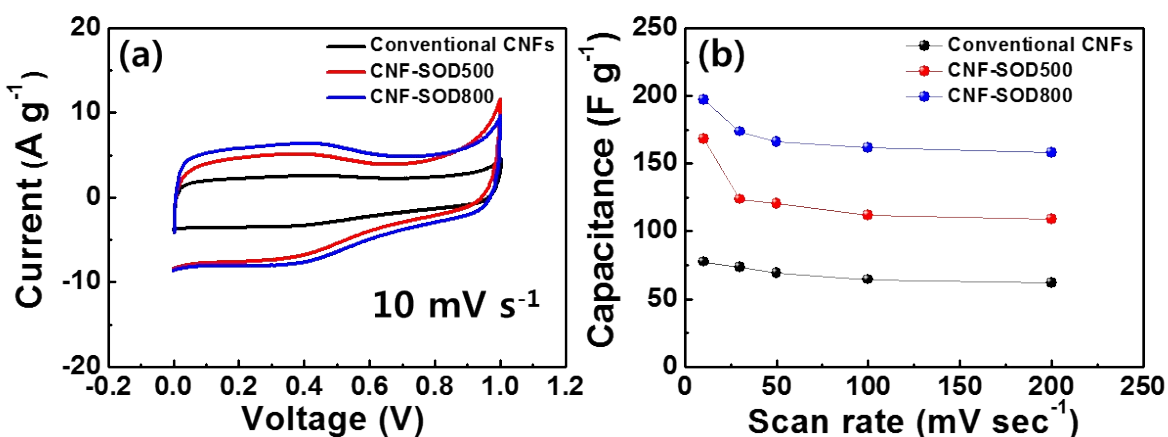
#### 4. Cycle voltammogram and specific capacitance measurement by three electrodes system

Electrochemical performance was measured using a potentiostat/galvanostat (PGST302N by Eco Chemie, Netherlands) with three-electrode system. Ink consisting of the prepared samples was fabricated by acetylene black and a polyvinylidene fluoride (PVDF) binder with mass ratio of 7:2:1 in N-methyl-2-pyrrolidinone (NMP). The inks were loaded on the glassy carbon (55 mm length, 6.35 mm diameter,  $7.06 \text{ mm}^2$  surface area; CH Instruments) as the working electrodes. Working electrode consisting of ink was dried at  $70 \text{ }^\circ\text{C}$  for 0.5 h. the reference and counter electrodes were used by Ag/AgCl and Pt wire, respectively. Cycle voltammogram (CV) were measured in electrolyte of  $0.5 \text{ M H}_2\text{SO}_4$  solution at scan rates of 10, 30, 50, 100, and  $200 \text{ mV/s}$ .

And capacitance of all samples was calculated by following equation;

$$C = (q_a + q_c) / (2m\Delta V)$$

where  $q_a$ ,  $q_c$ ,  $m$ , and  $\Delta V$  are the charge of the anodic region, charge of the cathodic region, mass of active materials (g), and potential range of the CV, respectively. CNF-SOD500 and CNF-SOD800 exhibits electric double layer capacitance and pseudocapacitance behaviour owing to functional groups, which is formed. [U. B. Nasini, V. G. Bairi, S. K. Ramasahayam, S. E. Bourdo, T. Viswanathan, and A. U. Shaikh, Journal of Power Sources 250 (2014) 257-265.]



**Figure S4.** (a) C-V curves obtained for the electrode of conventional CNFs, CNF-SOD500, and CNF-SOD800 at a scan rate of 10 mV·s<sup>-1</sup> in the voltage range 0.0–1.0 V by three electrode system. (b) Specific capacitance results obtained for the ECs with CNF electrodes by three electrode system.