PREPARATION AND CHARACTERIZATION OF ELECTROSPUN SILVER/PAN-BASED CARBON NANOFIBER WEBS

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Introduction

Recently, many kinds of electronic machines for communication are a small-sized, a lightweight, and an advanced tendency (cellular-phone, camera). So demand of the EDLCs (electric double layer capacitors) is demanded by sources of electricity of an electronic device. EDLCs are a new equipment to produce high power. The electrode materials of the EDLCs used are normally carbon alloy, aerogel carbons, and activated carbons. More recently, conductive polymers and polyacenic semiconductor (PAS) are started to be used. Electrospinning has shown to be a powerful and effective method for the preparation of fibers with nano size diameters. And it is a process to prepare non-woven web with nano size of fibers through introducing instability into a polymeric solution or melt by applying high direct current (DC) voltage with opposite charges at spinneret and at ground. Initially, the polymer solution is held by its surface tension in the form of droplet at the tip of spinneret. As the voltage increased, the charge is introduced on the surface of the droplet, and then, the droplet is distorted. At above a critical voltage, single jet is ejected from the tip of the spinneret, commonly termed as Taylor cone. The silver is one of the most scientific interests in nanotechnology and nanodevices because of their thermal and electrical performance. Incorporation of silver into nanofiber webs has been demonstrated to enhance electrical conductivity in electrospun nanofiber webs. The PAN-based carbon nanofiber webs could be used directly for supercapacitor electrodes. The power density was poor due to high electrical resistivity of the PAN-based carbon nanofiber webs. Higher electrical conductivity was always desired to have high capacitance and high power density in EDLCs. For this reason, silver/PAN-based nanofiber webs had been introduced recently.

In this work, the silver sol embedded polyacrylonitrile solutions in *N,N*-dimethylformamide (DMF) were electrospun to be webs consisting of nanofibers, which were used to produce a series of carbon nanofibers with developed high electrical conductivity through stabilization and carbonization processes. The surface characteristics of silver/PAN-based carbon nanofiber webs were evaluated by fourier transform infrared spectroscopy, X-ray photoelectron spectroscopy and X-ray diffraction measurements. Morphologys and silver particles distribution of the nanofiber webs were studied by scanning electron microscope, transmission electron microscope analyses. The electrochemical behaviors of the nanofiber webs were observed by cyclic voltammetry test.

Experimental

PAN and DMF were purchased from Aldrich Co. The silver sol used in this study was purchased from ABC nanotech. The silver of 0, 1, 3, and 5wt.% were immersed DMF and sonicated for 5 h in a bath-type sonicator. All reagents were used without further purification PAN with an average molecular weight of Mw = 86,200 g/mol was dissolved in slightly stirred silver-dispersed DMF to yield an 10 wt.% solution. The electrospinning technique is based on electrostatic forces drawing a jet of the polymer solution, which experiences high extension due to an electrostatically driven bending instability forming nanofibers. The solutions were electrospun from a 5 ml syringe with a MN-22G needle (negative). An aluminum wheel was used as the collector (positive). The distance between the needle tip and collect wheel (TCD) was 10 cm. and the apply voltage was 15 kV. The electrospun silver/PAN-based nanofiber webs were collected on aluminum foil that was attached on the edge of the collector. The 10×10 cm sized web was stabilized in air-circulating furnace with supplying 30 ml/min air, raising the temperature from room temperature to 250°C at 1 °C/min and holding for 2 h at the final temperature, then carbonized for 2 h in nitrogen at 1,000°C at 1 °C/min at given temperature previously set. The samples were stored in a desiccator until they are used for analysis.

Results and discussion

Fig. 1 shows the SEM micrographs of silver/PAN-based nanofibers. Fig. 1 (A) illustrates the PAN nanofiber webs by electrospinning. Fig. 1 (B), (C), and (D) are shown the nanofiber webs as a function of silver/PAN solution ratio. It is found that the average diameter of silver/PAN-based nanofiber webs was in the range of 250~500 nm. In comparison with electrospun fibers, these fibers slightly decreased and increase in size after immersed silver.

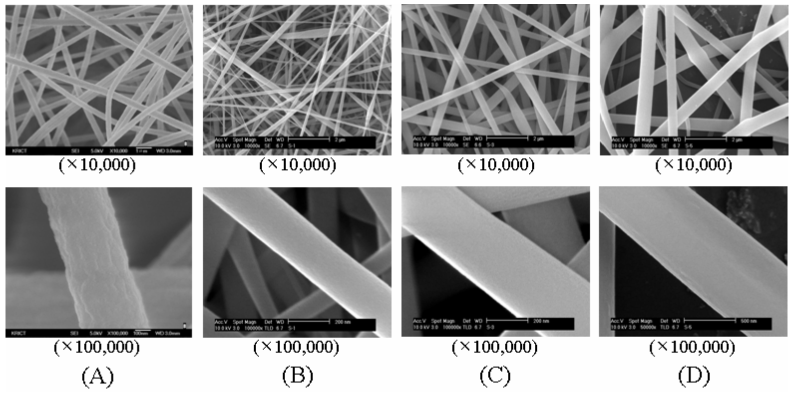

FIGURE 1: SEM micrographs of silver/PAN-based electrospun nanofiber webs with different ratio: (A) PAN/silver=100/0, (B) PAN/silver =99/1, (C) PAN/silver =97/3, and (D) PAN/silver =95/5.

Fig. 2 shows specific capacitance of the silver/PAN-based nanofiber webs with different silver ratio. The capacitance of carbonized nanofiber webs was in the range of 170~250 F/g showing an increase in the value with an increase in the concentration of silver.

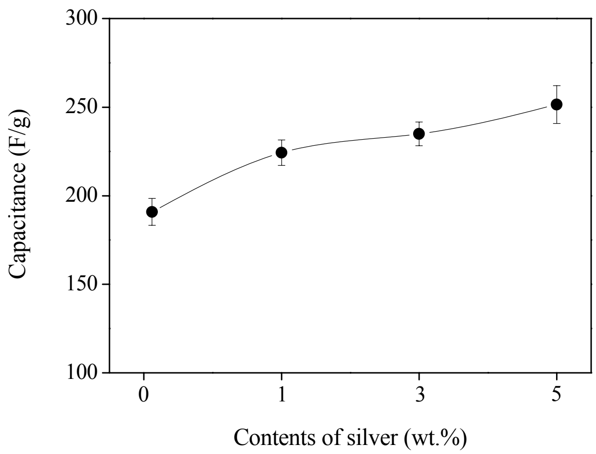

FIGURE 2: Specific capacitance of the silver/PAN-based electrospun nanofiber webs with different silver ratio.

From the results, the diameter of electrospun nanofiber webs was influenced by concentration of silver and carbonization process. It was found that the value of electrochemical property of silver/PAN-based carbonized nanofiber webs slightly increased in the concentration of silver.

References

Doshi, J. and Reneker, D. H. (1995). Electrospinning process and applications of electrospun fibers. *J. Electrost.*, 35, [2-3], 151-160.

Ge, J.J., Hou, H., Li, Q., Graham, M.J., Greiner, A., Reneker, D.H., Harris, F.W., and Cheng, S.Z.D. (2004). Assembly of well-aligned multiwalled carbon nanotubes in confined polyacrylonitrile environments: Electrospun composite nanofiber sheets. *J. Am. Chem. Soc.*, 126, [48], 15754 - 15761.

Kang, Y.S., Kim, H.Y., Ryu, Y.J., Lee, D.R., and Park, S.J. (2002). The effect of processing parameters on the diameter of electrospun polyacrylonitrile (PAN) nano fibers. *Polymer (Korea)*, 26, [3], 360- 366.

Seoul, C., Kim, Y.T., and Baek, C.K. (2003). Electrospinning of poly(vinylidene fluoride/dimethylformamide solutions with carbon nanotubes. *J. Polym. Sci. B: Polym. Phys.* 41, 1572-1577.

Reneker, D.H., Yarin, A. L., Fong, H., and Koombhongse, S. (2000). Bending instability of electrically charged liquid jets of polymer solutions in electrospinning. *J. Appl. Phys.,*87, [9], 4531-4547.

Ryu, Z., Zheng, J., Wang, M., and Zhang, B. (2000). Nitrogen adsorption studies of PAN-based activated carbon fibers prepared by different activation methods. *J. Colloid Interface Sci.*, 230, [2], 312-319.

Park, S.J. and Kim, B.J. (2005). Carbon materials for electrochemical capacitors. *Carbon Sci.*, 6, [4], 257-268.