Synthesis and Electrochemical Performance of Soft Carbons for Potassium-Ion Batteries

Takasumi Saito [a], Hiroo Onuma [a], Shotaro Muratsubaki [a], Kei Kubota [a], Tsuyoshi Inose [b], Yuji Ito [b], Nobuaki Ishii [b], Masataka Takeuchi [b], Shinichi Komaba [a]

[a] *Tokyo University of Science, 1-3 Kagurazaka, Shinjuku, Tokyo 162-8601, Japan*

[b] *Showa Denko K.K., 8, Ebisu-cho, Kanagawa-ku, Yokohama, Kanagawa 221-8517, Japan*

Corresponding author: komaba@rs.kagu.tus.ac.jp

Recently, K-ion batteries have attracted much attention due to abundant K resources and lower standard potential of K^+/K in ester-based electrolyte than that of Li^+/Li.[1] Jian *et al.* and our group reported at almost the same time that K^+ ion is electrochemically intercalated into graphite delivering reversible capacity of ca. 250 - 270 mAh g^{-1} with formation of KC_8 in a K cell.[1,2] Mai *et al.* also reported that graphitizable carbon, so-called soft carbon (SC), shows larger reversible capacity in a K cell than graphite.[3] The structure of SC suitable for K (de)intercalation, however, has never been clarified yet. In this study, we synthesize SCs in different synthesis condition and their electrochemical properties are examined in K cells.

SC samples were prepared by heating petroleum needle coke as a starting material at 800 - 1400 ºC in Ar. Synthesized SCs are hereafter denoted as NCSC-T where T is heat-treatment temperature / ºC). 002 diffraction line was observed at 2 theta = ca. 25.6º in the XRD patterns of all the NCSC samples, and G and D bands appeared at 1575 and 1342 cm^{-1} in all the Raman spectra. Temperature dependence of the interlayer distance, d_{002} and A_G/A_D ratio for NCSCs are shown in Fig. 1. With raising heat-treatment temperature, the interlayer distance shrinks while A_G/A_D ratio increases, which suggests that NCSCs heat-treated at higher temperature are more graphitized. NCSC electrodes were prepared by mixing the NCSC powder, acetylene black, and sodium polyacrylate binder at a weight ratio of 85 : 10 : 5 and coating the slurry on Cu foil followed by drying at 80 ºC under vacuum. An electrolyte solution of 1 mol dm^{-3} KFSA / EC:DEC (1:1 v/v) was used for electrochemical test. Initial charge/discharge curves of K // NCSC cells are shown in Fig. 2. The reversible capacity somewhat decreases with raising the heat-treatment temperature, simultaneously operating potential becomes lower from the curves in the voltage region between 0.3 and 1.5 V. As revealed from XRD and Raman, difference in nano-scale structure of NCSC, like defects in lower crystallinity SC, probably influences the reversible potassiation capacity. We further examined micropores inside of NCSCs by small angle X-ray scattering and the results will be presented.

References:

[1] S. Komaba *et al. Electrochem. Commun.*, **60**, 172 (2015).
[2] Z. Jian, W. Luo and X. Ji, *J. Am. Chem. Soc.*, **137**, 11566 (2015).
[3] X. Wang, L. Mai *et al.*, *Nanoscale*, **9**, 18216 (2017).

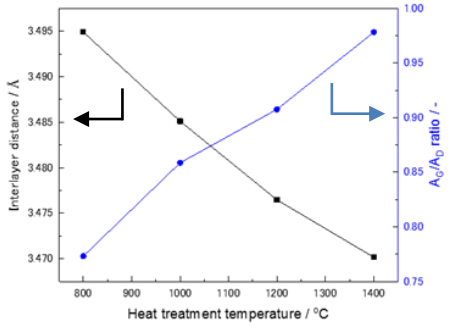

Fig. 2 Temperature dependence of d_{002} and A_G/A_D ratio for NCSCs obtained from the XRD and Raman spectra, respectively.

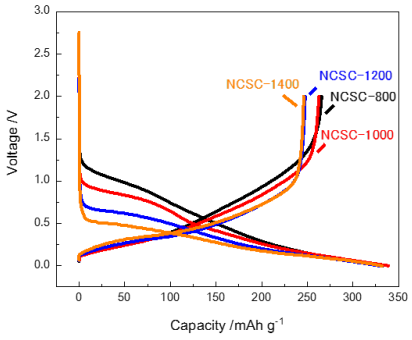

Fig. 1 First charge/discharge curves of NCSCs prepared at 800 - 1400 ºC in K cells.