

## Electrochemical Properties of Graphitized Nanoparticles

Takeshi Abe, Hongyu Wang, Yasutoshi Iriyama,  
and Zempachi Ogumi

Department of Energy and Hydrocarbon Chemistry,  
Graduate School of Engineering, Kyoto University  
Nishikyo-ku, Kyoto 615-8510, Japan

High rate performances of lithium-ion batteries are required for practical use in hybrid electric vehicles (HEV). Therefore, rapid lithium-ion transport from negative to positive or vice versa is essential by considering the charge and discharge reactions of lithium-ion batteries.

Fine particles of positive and negative active materials are desirable to decrease the diffusion path of lithium-ion, leading to the enhancement of rate performance of lithium-ion batteries.

As for active materials of positive electrodes, several methods such as a sol-gel method, hydrothermal method, etc, have been employed to obtain fine particles. In contrast, it is somewhat difficult to prepare fine graphite particles for a negative electrode. For example, mechanical milling is a very convenient way to decrease the particle size of graphite. However, the crystallinity of graphite drastically decreases.

Co-intercalation of lithium-ion with propylene carbonate (PC) into graphite electrode leads to exfoliation of graphite in the PC-based electrolyte. In this work, preparation of graphite fine particles was made by use of this phenomenon, and the electrochemical properties of the resultant graphite fine particles were studied. Further, electrochemical properties of graphitized nano-carbon beads prepared by a CVD method were also studied.<sup>1,2)</sup>

Natural graphite flakes of the particle sizes ranging 1 to 2 mm were used as a starting material. Graphite fine particles were obtained in the PC-based electrolyte using the co-intercalation of lithium-ion and PC into the graphite flakes electrode. The resultant fine particles were rinsed by ultra pure water followed by heating at 673 to 1173 K under Ar atmosphere. Graphite particles were characterized by TEM, XRD and Raman spectroscopy and then the electrochemical properties of the graphite particles were studied by cyclic voltammetry and charge-discharge measurements.

From the TEM image, graphite nano-fibers are found to be obtained. The crystallinity of the graphite nano-fibers is very high from XRD patterns and Raman spectra.

Figure 1 shows cyclic voltammograms of the graphite nano-fibers heat-treated at 673 K for 10 h. As is clear from Fig.1, very sharp reduction and oxidation currents appear. From a closer look at the oxidation currents, split of the peak due to the stage transformation of lithium-graphite intercalation compound appeared. The clear stage transformation should be ascribed to the short diffusion path of lithium-ion.

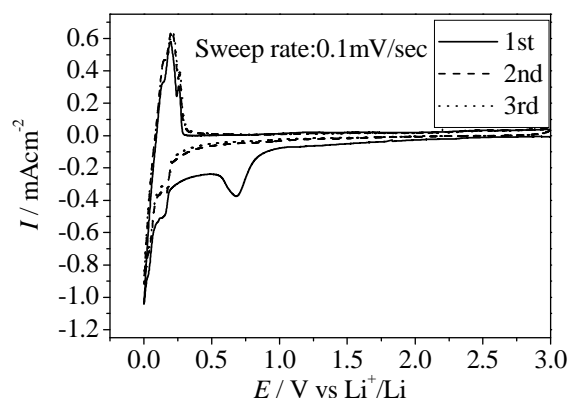
From the charge and discharge measurements, the negative electrode using the graphite nano-fibers showed high rate performance. The detail will be presented in the conference.

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## References

- [1] H. Wang et al., *Chem. Mater.* submitted.
- [2] .H. Wang et al., *Chem. Mater.* submitted.



**Fig.1** Cyclic voltammogram of the graphite sample (heated at 400°C for 10 hours in Ar) in 1M LiClO<sub>4</sub>/EC+DEC(1:1).