Study of a High-Power Lithium-ion Battery

Kyoichi Watanabe, Mori Nagayama, Yasuhiko Ohsawa, Kouichi Nemoto, Takamitsu Saito, Takaaki Abe, Tomaru Ogawa, Hideaki Horie, Mikio Kawai, and Hiroshi Sugawara

Nissan Research Center, Nissan Motor Co., Ltd., 1, Natsushima-cho, Yokosuka, Kanagawa 237-8523, Japan
Tel: +81-46-867-5192, Fax: +81-46-865-5796, E-mail: kyoichi-w@mail.nissan.co.jp

1. Introduction

We have been developing a high specific power lithium-ion battery for hybrid electric vehicles (HEVs). In order to improve the specific power of a lithium-ion battery, it is necessary to analyze lithium-ion transport phenomena in the cell. In our previous study concerning the high-rate discharge capability of $LiMn_2O_4$ cathodes [1], it was demonstrated that depletion of the electrolyte (Li^+ and PF_6^-) in the electrode layer was the limiting factor and that diffusion of the electrolyte from the outside solution phase was important when a cathode active material with very small particles was used. In this study, the high-rate discharge capability of the anode was examined by changing the particle size of the anode active material and the electrode thickness.

2. Experimental procedure

The anode active material was hard carbon (Carbotron P, average diameter of 20 μm; Kureha Chemicals), and smaller hard carbon samples with an average diameter of 7.1 μm, 2.4 μm, and 0.7 μm were prepared from the 20 μm sample by mechanical ball milling. The electrode samples were prepared from hard carbon powders, PVdF binder (mass ratio of 90:10), and copper foil current collector by using a bar-coater. All measurements were carried out in the potential range of 0 to 2.0 V vs. Li/Li^+ at room temperature by using a sandwich-type three-electrode cell in which the reference and counter electrodes were made of lithium metal. The electrolyte solution used was 1 M $LiPF_6$/EC-DMC (1:1).

3. Results and Discussion

The dependence of the discharge capacity on the particle size and the electrode thickness is shown in Figs. 1 and 2, respectively. As expected from our previous results for cathodes [1], the discharge rate capability of a hard carbon anode was improved substantially by reducing the particle size and electrode thickness. To understand this tendency better, the current rates at which the capacity decreased to 35% are compared as follows. As seen in Fig. 1, the current rate increased from 200 to 500 C when the particle size was reduced from 20 to 2.4 μm. As shown in Fig. 2, the current rate increased from 100 to 1000 C when the electrode thickness was reduced from 50 to 14 μm. This implies that the electrode thickness is more effective than the anode particle size in improving the performance of a hard carbon anode. Furthermore, as shown in Fig. 3, since the observed diffusion coefficient showed almost the same value for every specification, it can be presumed that this transportation is an obstacle. From the results obtained in this study, it appears that the diffusion of Li^+ in hard carbon particles is comparatively rapid and the transportation of the electrolyte in the solution phase is the obstacle to the high-rate discharge capability of an anode.

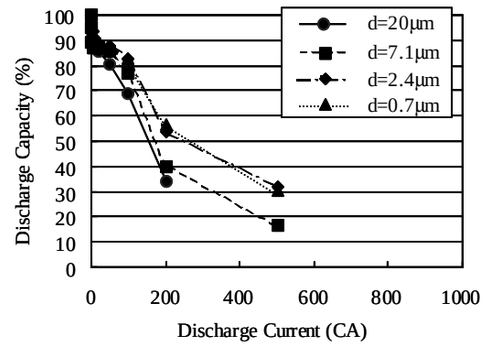

Fig. 1. Discharge capacity vs. current rate for hard carbon electrodes of various diameters.

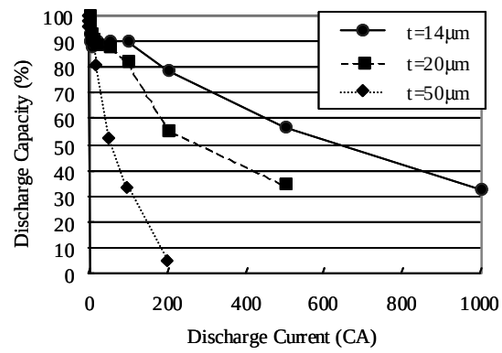

Fig. 2. Discharge capacity vs. current rate for hard carbon electrodes of various thicknesses.

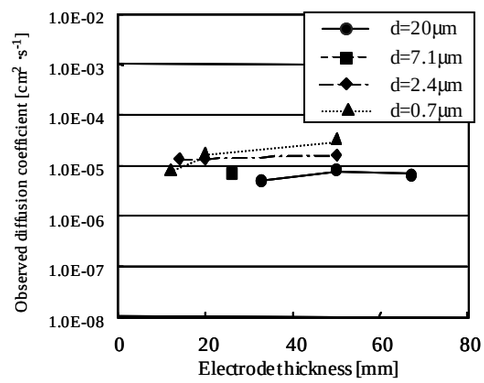

Fig. 3. Observed diffusion coefficient vs. electrode thickness plots for hard carbon electrodes of various diameters.

Reference

1. Y. Ohsawa, et al., The 41st Battery Symposium in Japan, p. 358 (2000).