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Electrochemical Properties of Nanostructured Porous Carbon for Electrodes of Lithium-Ion Batteries

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Carbon materials have been used as electrodes in a lithium ion battery for use as negative electrode active materials.[1,2] The performance of lithium ion secondary batteries, such as the charge-discharge capacity, speed, voltage profile and cyclic stability depend on carbon nanostructures. The size of surface area and the dynamic behavior of the ions responsible for the characteristics of the devices are markedly influenced by material porosity.

On the other hand, from the viewpoint of the recycling of various kinds of waste, much attention has been paid to the battery application as effective use of carbon materials that are made of various wastes. One carbon material that fills the requirements mentioned above is fly ash as industrial waste. The electrochemical properties of pristine fly ash have been reported to be good for applications to lithium ion secondary batteries.[3]

In this study, the electrical and electrochemical properties of pristine fly ash and pyrolyzed fly ashes with various heat treatment temperatures (HTTs) are explored for lithium ion secondary battery application.

Fly ash was observed with a scanning electron microscope (SEM) to check the change of porosity before and after the heat treatment in Ar atmosphere. Pristine fly ash inherently has a porous structure as can be seen from the SEM images in Fig.1 (a). Even after heat treatment at 2600°C, pyrolyzed fly ash maintains its porosity and the surface of pyrolyzed one is smoother than that of pristine one.

We have been exploring the electrochemical properties of pristine fly ash and pyrolyzed one with various HTTs as electrodes in lithium ion secondary batteries. These measurements were carried out using a beaker-type cell at room temperature in an argon-filled glovebox. Figure 2 shows the third charge-discharge profiles of pristine fly ash and pyrolyzed fly ashes with HTTs of 1100°C, 1400°C, and 2800°C. The discharge capacity of pyrolyzed fly ash with a HTT of 1100°C is the highest. That is, the charge-discharge characteristic of fly ash can be improved by pyrolysis. In all cases, Coulombic efficiency is more than 90%.

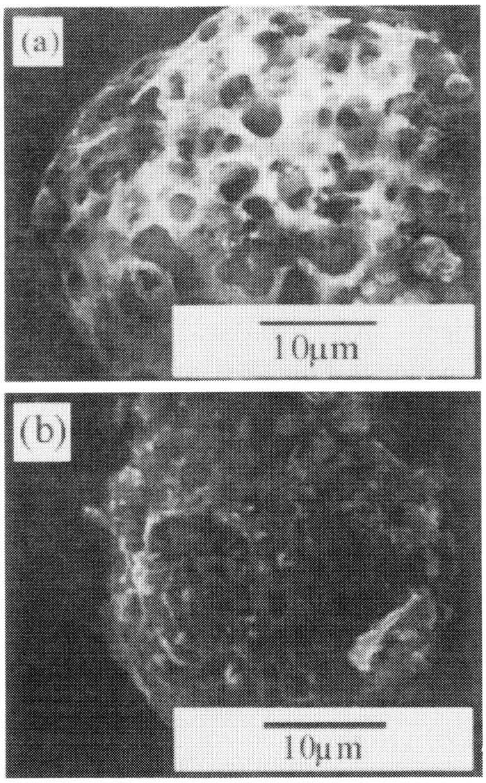

Fig.1. SEM images of (a) pristine fly ash and (b) pyrolyzed one with HTT of 2600°C

Besides, to control porous structure artificially, we have also applied the periodic porous nanostructured carbon to electrodes. In this study, these nanostructured carbons with three-dimensional periodicity at optical wavelengths were prepared using the method that the pristine products infiltrating the voids in synthetic opals by starting materials pyrolyze in a high-purity Ar or N_2 atmosphere for carbonization of samples and subsequently removing the SiO_2 spheres by immersing into the aqueous solution of hydrofluoric acid.[4] These samples were pyrolyzed at various temperatures for 1h in a high-purity Ar or N_2 atmosphere again. Figure 3 indicates SEM image of periodic porous nanostructured carbons. We have been investigated the electrochemical properties of periodic porous nanostructured carbons and it showed good stability, high Coulombic efficiencies, and high charge-discharge capacity.

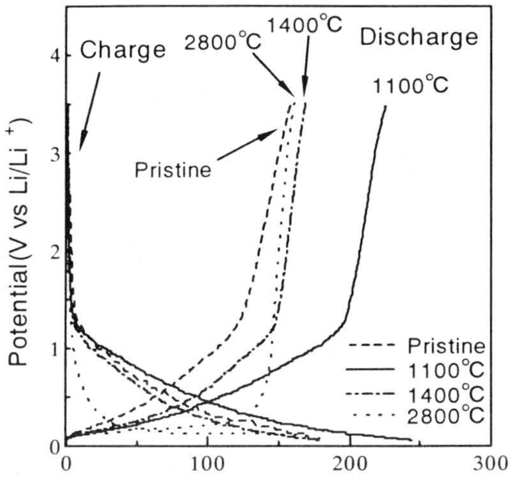

Fig.2. Charge-discharge profiles at the third cycle for pristine and pyrolyzed fly ashes with HTTs of 1100, 1400, and 2800°C.

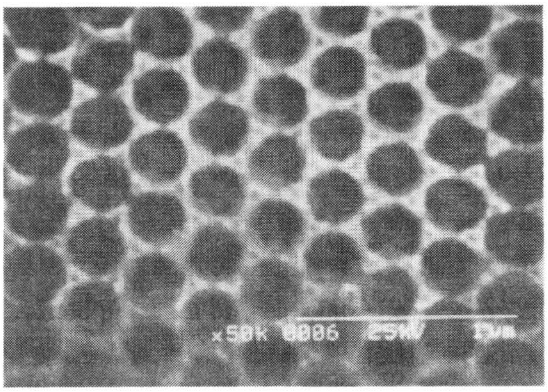

Fig.3. The SEM image of periodic porous nanostructured carbons which were made by using synthetic opal as a template.

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