

Carbon for Batteries and Fuel Cell

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Introduction

Graphitic carbons have played an important role in electrochemical technologies. These carbons have a hexagonal structure, with the carbon atoms arranged in layer planes. A more exotic form of carbon is the so-called “buckyball”, which has a structure that resembles a soccer ball. A typical structure of a buckyball contains 60 carbon atoms (C_{60}) in a spherical structure consisting of 20 hexagons and 12 pentagons arranged on the surface.

The attractive features of carbon in electrochemical applications include its high electrical conductivity, acceptable chemical stability and low cost. These characteristics are important for the widespread acceptance of carbon in electrochemistry. The type of carbon plays a major role in improving the performance of electrodes used in batteries and fuel cells. Of practical importance is the contribution that is made by carbonaceous materials as an additive to enhance the electronic conductivity of electrodes. In other electrode applications, carbon serves as the electrocatalyst for electrochemical reactions and/or the substrate on which an electrocatalyst is located. In addition, carbonaceous materials are fabricated into solid structures that serve as the bipolar separator or current collector. Clearly, carbon is an important material for batteries and fuel cells.

The aim of this presentation is to review the important roles that carbonaceous materials play in batteries in particularly Li-ion cell. The most important. Low-temperature fuel cells and batteries are other electrochemical applications where carbonaceous materials are important components. In these applications, alternatives to carbon in the electrodes are not readily apparent.

Batteries

Lithiated carbons, in which the Li species are intercalated between the layer planes (*i.e.*, in graphite) or associated with other sites (*i.e.*, in disordered carbons), serve as the negative electrode in Li-ion batteries. The commercialization of lithium-ion cells in the early 1990's by Sony Corporation has spurred a major expansion in the efforts on manufacturing and analyzing the optimum properties of carbonaceous materials as Li insertion electrodes. Currently, graphitic carbon is most widely used in the negative electrodes in commercial Li-ion cells. Two electrochemical parameters that play a significant role in the viability of negative electrode materials for Li-ion batteries are reversible capacity (Q_{rev}) and irreversible capacity loss (ICL). The crystallographic parameter, particle size and shape of graphitized carbon have a strong influence on Q_{rev} and ICL (1). There is a strong relationship between the $d(002)$ spacing of carbon and its reversible capacity. A parabolic relationship with a minimum in Q_{rev} at a $d(002)$ spacing of 0.344 nm is evident. The reversible capacity of carbon is dependent on the amount of Li^+ -ions that are stored in its bulk structure. For graphitized carbon, the ions are intercalated between the layer planes, whereas in amorphous carbons, Li may be present in microcavities or other sites. In any case, the amount of Li^+ ions that are stored is a function of the rate at

which the charge-discharge rate is applied to the carbon electrode. Here again, the carbon shape and particle size plays an important role in Q . Electrolyte decomposition on graphitized carbon occurs during the first cycle when the potential is lowered to close to 0 V (*vs.* Li). Because the decomposition reaction is a surface process, the significant parameter is the carbon surface area. Experimental studies with a series of flaky (Fig.1) and spherical natural graphite (Fig.2) from HQ indicated a linear relationship between ICL and graphite surface area ranging from 2 to 12 m^2/g . Finally, activated carbon is widely used in double layer capacitors because it is available with high surface area and suitable electronic conductivity. It is difficult to identify a practical alternative to carbon-based materials in many commercial battery and capacitor applications.

Fuel Cells

The phosphoric acid fuel cell (PAFC) and polymer electrolyte membrane fuel cell (PEMFC) rely heavily on carbon, usually in the form of graphitized carbon. The bipolar plate in these fuel cells may be a thin structure of machined graphite or molded graphite composite. The electrochemical reactions that occur between the fuel (hydrogen) and oxidant (oxygen) to generate electricity occur on the surface of Pt electrocatalysts that are usually supported on carbon. Consequently, to minimize the amount of electrocatalyst that is required, small Pt particles (usually <4 nm) are dispersed on the carbon surface. Preparing such high surface area supported electrocatalysts and maintaining the small particle size during fuel cell operation are major technical challenges. Carbon corrosion of the electrocatalyst support is another problem that has not been resolved completely.

Although carbonaceous materials have their share of technical problems in fuel cells and batteries, a viable alternative has not been identified. Without the availability of carbon as a reasonably stable and electronically conductive electrode component, commercialization of PAFCs and PEMFCs would be problematic.

References

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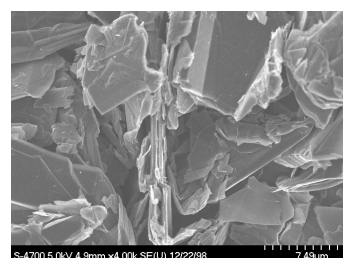


Fig. 1: HQ Flaky graphite



Fig. 1: HQ spherical graphite