Lightweight, Stable, and Rechargeable Battery with an Activated Carbon Fibre Electrode

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A type of activated carbon fibre can be used as the stable electroactive material for a lightweight, high energy density, and rechargeable battery.

Polyacetylene, $[CH]_x$,[1] and poly(p-phenylene)[2] have recently been reported to be useful as the anode and/or cathode materials in rechargeable batteries. For example, the battery, $Li|LiClO_4$ in propylene carbonate $(PC)|(CH)_x^{a+}(ClO_4^-)_a$, gave a theoretical energy density as high as 307 W h kg^{-1} under the complete discharge condition. The high energy density was assumed to be caused by the large specific surface area of polyacetylene. Polyacetylene is, however, somewhat unstable in air. Moreover, time is required to lower the electrode resistivity during the initial charging, since polyacetylene has a relatively large electrical resistivity. In a search for another electrode material which does not have these disadvantages, we noticed that a type of activated carbon fibre (ACF) made from cellulose has the following attractive properties as the electrode material:[3] (i) ACF can be obtained commercially as a paper sheet, felt, or fibre at low cost; (ii) it has a low electrical resistivity of about 0.1 Ω cm; (iii) it has a much larger specific surface area (about 1500 m^2 g^{-1}) than polyacetylene and poly(*p*-phenylene); and (iv) it is quite stable in air.

We can make an ACF battery with a high energy density, comparable with that of the polyacetylene battery, and thus suggest that ACF is a new and promising candidate as an electrode material of technological value. For example, ACF (33 mg), type KF-1600 available from Toyobo Co. Ltd., and a strip of lithium, separated by a glass filter paper of 0.25 mm thickness, were immersed together in a 1 M solution of lithium perchlorate in PC under an argon atmosphere. ACF and lithium were connected respectively to the positive and negative terminals of a power supply by platinum wires. After passing 8.16 C, the battery, $Li|LiClO_4$ in $PC|(ACF^{a+})(ClO_4^-)_a$, was constructed, and the ratio of dopant to carbon was estimated to be 0.0357 : 1 at this stage.† The open circuit voltage of 3.9 V and initial short circuit current of 203 mA which were obtained correspond to a power density of 24 kW (kg ACF)$^{-1}$. On discharging down to 38% recovery of the dopant with a 1 kΩ resistor (30 min discharge), an average voltage of 2.5 V and average current of 2.5 mA were obtained, which correspond to an energy density of 93.7 W h (kg ACF)$^{-1}$. The energy density under complete discharge conditions was estimated to be 248 W h (kg ACF)$^{-1}$. Even after 200 charge and discharge cycles, the cycles were still reproducible.

The cell composed of the electrodes, an ACF doped with p-type and an ACF doped with n-type, was found to be an electrolytic capacitor, because the plot of the stored charge (q) against the open circuit voltoge (V_{oc}) gave the relation $V_{oc} = q/c$.[4] Thus, the ACF electrode in this study is also a capacitor plate.

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† Estimated from the elemental analysis of ACF.

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