High-Rate Microstructured Negative Electrodes

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Many conventional lithium-ion cells use copper foils as the current collectors. However, foils only provide good electronic conductivity to the electroactive material (normally a fine carbon powder) to which they are in direct contact. Therefore conductivity additives have to be utilized. As the conductivity additives are typically carbon blacks or very fine graphite powders it is difficult to ensure a homogeneous electrode composition. Additionally, dispersants may be required to prevent agglomeration of the fine particles. Clearly the use of conductivity additives adds to the cost and complexity of electrode preparation.

Recently we have demonstrated that microstructured current collectors, prepared by metallizing woven polymeric fabrics may be used to give acceptable performance with graphitic electrodes, without the need for additional conductivity additives [1]. Copper was electroplated onto a polymeric substrate after an initial electroless plating to leave a material with uniform, pinhole-free plating. The conductivity of the plated material was of the same order of magnitude as copper foil of the same mass.

Electrodes were made from the current collectors with graphitic powders and polymeric binders. The graphite was found to be located preferentially, according to particle size, in "pockets" of different dimensions formed among the fibres of the current collector.

The work described here has extended the use of the microstructured current collectors to very fine (< 1 µm diameter) soft carbons. In this case the carbons were found to coat the metallised fibres and not to reside in the "pockets", Fig. 1

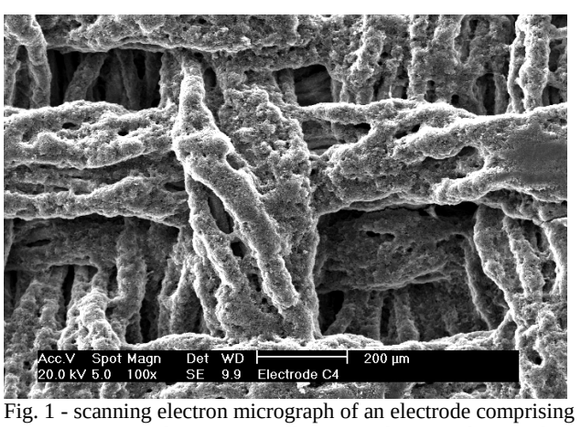

Fig. 1 - scanning electron micrograph of an electrode comprising a microstructured current collector and very fine carbon electroactive material

The electrochemical behaviour of these electrodes was examined in two electrode coin cells with a 1 M $LiPF_6$/ EC/ DEC electrolyte and a lithium metal counter electrode. The rate dependence of the cells was determined by charging at a C/10 rate (10 hr to 100% theoretical capacity) followed by galvanostatic discharge at increasing rates. For an electrode with 4.6 mg cm^{-2} carbon, the capacity decreased to 50% of its maximum value at a 20C (i.e. a current which would cause 100% discharge after 180 s). This is a considerably higher rate performance than that commonly obtained from graphitic electrodes, although the capacity was lower (0.8 mAh cm^{-2}). The dependence of the rate dependence on carbon loading was explored, from which it was found that for electrodes with lower carbon loadings a maximum discharge rate of ~75C could be obtained. A model was proposed to explain the rate dependence on loading.

Similarly the first cycle irreversible capacities were determined as a function of electrode loading.

The long-term cycle stability of the electrodes was also examined at constant charge and discharge rates of C/4. The capacity fade from cycles 100 - 400 was found to be ~ 0.03% $cycle^{-1}$. In addition the average cycle efficiency was 99.4%.

The discharge rates and capacities of the soft carbon, microstructured electrodes were found to lie between those of conventional Li-ion cells and supercapacitors. In addition the electrodes were at least as stable as conventional Li-ion electrodes. The microstructured electrodes examined here would be suitable for application in high power batteries, an area where Li-ion systems have so far proved unsuitable, especially when compared to Ni-Cd or lead acid systems.

Reference:

1. A. H. Whitehead, C. M. Hagg and M. Schreiber, "Metallised polymer current collectors for lithium-ion batteries" **in Vol. 2000-2**, Ex. Abs. No. 157, from *ECS 200th meeting*, Phoenix, AZ (2000)