High Surface Area Conducting Paper Materials composed of Polypyrrole and Cladophora Cellulose

Albert Mihranyan[1], Aamir Razaq[1], Gustav Nyström[1], Maria Strømme[1] and Leif Nyholm[2]
Uppsala University
[1]Nanotechnology and Functional Materials, Department of Engineering Sciences, The Ångström Laboratory, Box 534, 75121 Uppsala, Sweden. [2]Department of Materials Chemistry, The Ångström Laboratory, Box 538, 75121 Uppsala, Sweden

During the last two decades, electronically conductive polymers, such as polyaniline (PANI), polypyrrole (PPy) and polythiophene, have found use in a number of applications including batteries, sensors, biomedical engineering, drug delivery, electrochromic devices, actuators and solid-phase microextraction [1-4]. Many of these applications are based on the fact that ions are included and excluded from the conducting polymer when the polymer undergoes oxidation or reduction. Upon the oxidation of the polymer, it has been shown [1,4] that anions enter into the polymer as charge compensating ions when the anions are sufficiently small and mobile within the polymer. In the presence of significantly larger anions, the charge compensation is instead mainly taken care of by the movement of cations [1,4]. It is also known that the ion exchange properties of the polymer depend strongly on the polymerization conditions.

Although the ion exchange capacity of conducting polymers can be altered by varying the thickness of the polymer, this approach is generally difficult to employ in practice due to mass transport limitations within the polymer for thick films [4]. There is thus a need for alternative approaches to increase the capacity of the films.

As electrochemical deposition of the polymer films requires the presence of a conducting substrate, it is likewise interesting to explore the possibilities of preparing electrochemically controlled ion exchange materials based on nonconducting high surface area substrate materials.

One potentially interesting substrate for the manufacturing of inexpensive electronically conducting ion exchange materials is cellulose. The interest in this substrate is emphasized by the fact that cellulose is a material of significant industrial importance. Electronically conducting paper is highly interesting for a range of applications particularly if the surface area of the cellulose is high enough to yield high ion exchange capacities.

In the present communication, a novel conducting polypyrrole based high surface area composite material [5-8], obtained by polymerization of pyrrole in the presence of iron (III) chloride on a cellulose substrate derived from the Cladophora sp. algae will be described. The material, which was doped with chloride ions, was molded into paper sheets and characterized using SEM (see Fig. 1) and TEM (see Fig. 2) as well as by N_2 gas adsorption analysis, cyclic voltammetry, chronoamperometry, chronopotentiometry and conductivity measurements. It will be shown that the material can be used as a potential controlled high surface area solid phase material for the extraction and desorption of anions. The influence of the polymerization conditions on the pore size of the polymer and the ion exchange capacity of the polymer with respect to different anions will be discussed as well as the possibilities of employing the material for energy storage [9].

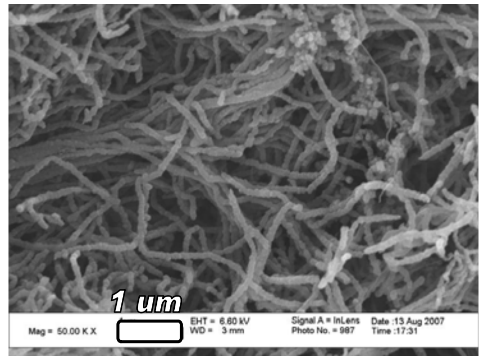

Figure 1. SEM micrograph of polypyrrole functionalized Cladophora cellulose fibers [5].

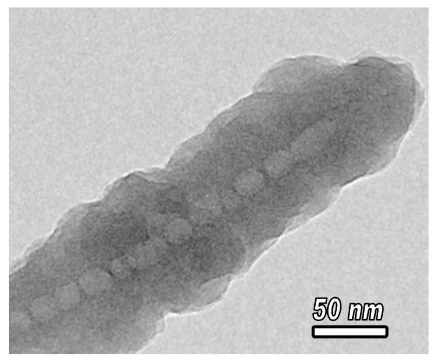

Figure 2. TEM image of a polypyrrole coated cellulose fiber showing the formation of a spine-like structure with PPy *strands* of ~6 nm thickness running perpendicular to the fiber *c*-axis direction. Lighter contrast seen in the centre of the fiber is associated with a single cellulose fibril, estimated to be ~20 nm in diameter, consistent with a PPy coating of ~50 nm in thickness [5].

References

1. J. Heinze, Organic Electrochemistry, Marcel Dekker, New York, 2001.
2. U. Lange, N. V. Roznyatouskaya, V. M. Mirsky, Anal. Chim. Acta, 614 (2008) 1.
3. S. Cosnier, Anal. Lett., 40 (2007) 1260.
4. G. Liljegren, J. Pettersson, K. E. Markides, L. Nyholm, Analyst 127 (2002), 591.
5. A. Mihranyan, L. Nyholm, A. Garcia-Bennett, M. Strømme, J. Phys. Chem. B, 112 (2008) 12249.
6. A. Razaq, A. Mihranyan, K. Welch, L. Nyholm, M. Strømme, J. Phys. Chem. B, 113 (2009) 426.
7. M. Strømme, G. Frenning, A. Razaq, K. Gelin, L. Nyholm, A. Mihranyan, J. Phys. Chem. B, 113 (2009) 4582.
8. K. Gelin, A. Mihranyan, A. Razaq, L. Nyholm, M. Strømme, Electrochim. Acta, 54 (2009), 3394.
9. G. Nyström, A. Razaq, M. Strømme, L. Nyholm, A. Mihranyan, in preparation.