

Nano-scale Conducting Polymers as Ion Exchangers and Electrocatalyst Support

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Conducting polymers have been widely explored as electroactive material for various applications. Electrochemical processes involve charge transfer at the interface between an electrode and an electrolyte solution. Increasing the surface area improves the reaction rate, the degree of conversion, the space time yield and other figures. This has been the motivation to develop conducting polymers with high surface area and structures down to the nano-meter scale [1-3]. Fig. 1 shows chemically prepared polypyrrole particles (PPy-PSS) with and without poly(styrenesulfonate) (PSS) as matrix and charge compensating counterion. Today similar nano-scale material based on poly(3,4-ethylene-dioxythiophene) is commercially available (trade name PEDOT-PSS) from Bayer AG, Germany.

At the molecular level these materials exhibit three dimensional structures of mixed electronic and ionic conductivity, depending on the composition and the degree of oxidation, which can be modified and dynamically controlled.

The present investigations consider technical applications of PPy-PSS as ion exchanger for water softening. Fig. 2 shows an EQCM measurement of a PPy-PSS film on GC in CaCl_2 solution demonstrating the reversible absorption of Ca^{2+} ion during the reduction and its desorption during the oxidation of the polymer. For electrochemical characterization and technical applications, the nano-scale PPy-PSS particles were fixed on fibers of a porous carbon felt. The absorption capacity and the regeneration of the 3-D electrode structure was studied in dependence on the preparation of the polymer and the loading of the carbon felt. Fig. 3 shows schematically the principle of water de-ionization using electrochemical ion exchangers based on PPy-PSS [4].

In further investigations the catalytic behaviour of PPy/Pt composites was studied using different methods of synthesis including anodic PPy film formation as well as nano-scale powder mixtures prepared from nano-dispersed PPy-PSS/Pt solutions[5]. The Pt distribution within the film electrodes and the electrochemical activity of the electrodes for the oxidation of hydrogen H_2 and methanol MeOH were studied. Fig. 4. Shows current transients of methanol oxidation at different catalyst electrodes for comparison. The catalytic activity of the PPy-Pt composite electrodes exceeds that of Pt and the glassy carbon GC-Pt electrode at comparable Pt load. Also the stability of the catalyst and resistivity against CO poisoning was found to be improved.

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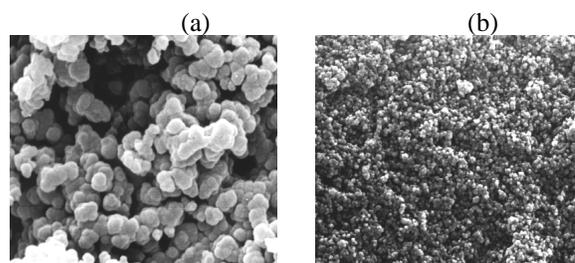


Fig. 1 Polypyrrole particles of nanometer scale with (b) and without (a) poly(styrenesulfonate) PSS as polymer matrix and charge compensating counterion.

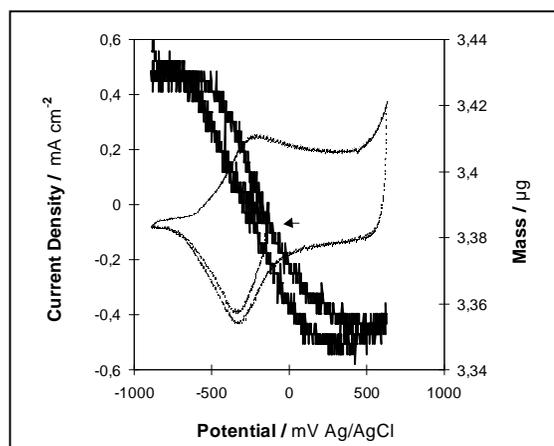


Fig. 2 EQCM measurement of PPy-PSS in 0.1M CaCl_2 to demonstrate reversible Ca^{2+} exchange on oxidation-reduction of the polymer

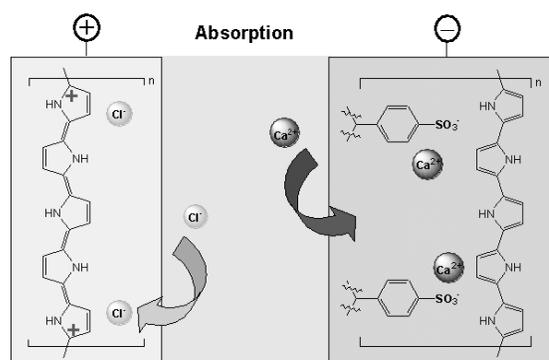


Fig. 3 Principle of water softening with 3-D PPy-PSS matrix electrode as electrochemical cation exchanger

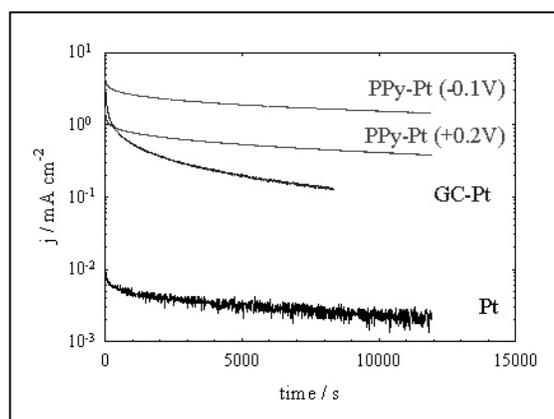


Fig. 4 MeOH oxidation on PPy-Pt catalyst ($0.3\text{mg}/\text{cm}^2$) compared to Pt disk and GC-Pt electrode at $E_{\text{SCE}} = 0,5\text{ V}$; System: $0,5\text{M H}_2\text{SO}_4 + 1\text{M MeOH (N}_2)$; RDE 100RPM