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Electrochemical composite formation of thiophene and *N*-methylpyrrole polymers on carbon fiber microelectrodes: Morphology, characterization by surface spectroscopy, and electrochemical impedance spectroscopy

A. Sezai Sarac [a,*], Hülya Geyik [a], Elif Alturk Parlak [a], Marina Serantoni [b]

[a] *Department of Chemistry, Istanbul Technical University, Polymer Science and Technology, Maslak 34469, Istanbul, Turkey*
[b] *Materials and Surface Science Institute, University of Limerick, Limerick, Ireland*

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Abstract

Electrochemical composite thin film formation (∼0.6–0.7 μm) of thiophene and *N*-methylpyrrole on carbon fiber microelectrodes (diameter ∼7 μm) was carried out by cyclic voltammetry in order to understand and improve the surface properties and capacitance behaviour of carbon fibers. Carbon fiber microelectrodes were coated with polythiophene and *N*-methylpyrrole was electrografted onto the thiophene electrode. The electrocoated carbon fiber surface mophology was characterized by scanning electron microscopy and atomic force microscopy and by FTIR-reflectance spectroscopy for their composition. The effect of monomer concentration and scan number on electropolymerization has also been investigated. The impedance behaviour of composite electrodes was characterized by electrochemical impedance spectroscopy. The composite of polythiophene and poly-*N*-methylpyrrole exhibits better charge storage properties than polythiophene coated carbon fiber microelectrodes.

Keywords: Carbon fiber microelectrodes; Electrochemical composites; Polythiophene; Poly-*N*-methylpyrrole; Electropolymerization

1. Introduction

Electrically conducting polymers and their composites attract much attention because of their high charge storage ability. Conducting polymers possess several advantages as electrode materials in batteries. First, the electrochemical properties can be controlled at the molecular level by manipulating monomer structure [1] or by doping [2]. Second, surface area can be controlled by the conditions used for polymerization and/or by the substrate onto which the polymer is coated.

Carbon fibers (CF), which are a new breed of high-strength materials, are mainly used as reinforcements in composite materials such as CF-reinforced plastics, carbon–carbon composites, carbon fiber reinforced materials, and carbon fiber reinforced cement. Carbon fiber composites are ideally suited to applications where strength, stiffness, lower weight, and outstanding fatigue characteristics are critical requirements. They also find applications where high temperature, chemical inertness, and high damping are important in addition to having good electrical conductivity, thermal conductivity, and low linear coefficient of thermal expansion [3].

There has been much interest in supercapacitors because of their practical applications as energy storage devices for memory backup of computers and for electric vehicles [4–6].

Polypyrrole is one of the most extensively studied conducting polymers due to the ease of synthesis, good redox properties, stability in the oxidized form, ability to give high electrical conductivity and useful electrical and optical properties [7–10]. Poly-*N*-methylpyrrole (PNMPy) has attracted attention as a possible alternative to polypyrrole for technological applications in spite of its lower conductivity [11].

Polythiophenes (PTh) have shown considerable promise for materials applications due to exceptional electrical properties and their environmental stability [11–14]. On the other hand, the high oxidation potential of thiophene compared to the polymer causes some degradation of the polymeric film, which has been the subject of a wide variety of studies.

Polythiophene and polypyrrole (PPy) have good electrical properties, however, PNMPy exhibits poor environmental stability, also PTh suffers from brittleness, low elongation, and poor processibility. In order to solve these problems, methods of preparing composites and copolymers, reforming

* Corresponding author. Tel.: +90 212 285 31 53; fax: +90 212 285 63 86.
E-mail address: sarac@itu.edu.tr (A.S. Sarac).

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