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# Synthesis, electrochemical characterization and impedance studies on novel thiophene-nonylbithiazole-thiophene comonomer

Fevzi Ç. Cebeci, Hülya Geyik, Esma Sezer, A. Sezai Sarac *

*Istanbul Technical University, Department of Chemistry, 34469 Maslak, Istanbul, Turkey*

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**Abstract**

In this contribution, synthesis and characterization of a novel donor acceptor donor type bis(thiophene)-(4,4′-dinonyl-2,2′-bithiazole) comonomer (TNBTT) were performed and the electrochemical characterization of redox properties and electrochemical impedance spectroscopy studies of its polymer on carbon fiber microelectrode (CFME) were reported. The comonomer oxidation onto bare carbon fiber microelectrode starts ($E_{onset}$ of the TNBTT) at 1.1 V vs. Ag/AgCl. Cyclic voltammetry of the polymer in monomer free electrolyte solution exhibits a well-defined oxidation and reduction peaks, and a linear increase in current densities was monitored. PTNBTT film shows the stability to overoxidation without any electroactivity loss up to +1.6 V vs. Ag/AgCl. Electrochemical impedance studies were performed on CFME/PTNBTT/electrolyte system. An equivalent electrical circuit for this composition was proposed and experimental data were simulated to obtain numerical values of the circuit components. Field emission scanning electron microscopy (FE-SEM) measurements were confirmed that the polymer film was deposited very well onto the surface of the carbon fiber microelectrode.


*Keywords:* Thiophene and nonylbithiazole comonomer; Carbon fiber; Electropolymerization; Spectroelectrochemistry; Conducting polymer; Impedance spectroscopy; Equivalent circuit; Low frequency capacitance; Supercapacitor

## 1. Introduction

Electronically conducting polymers [1–3] are still a very popular research field among the scientists due to their use in a wide range of marketable applications such as electrochromic devices [4–6], polymer light-emitting diodes (LEDs) [7], thin film transistors [8], sensors, and conducting polymer electrodes in charge storage devices [9–12]. Among the great number of conducting polymers, thiophene and its derivatives unquestionably are one of the most studied monomers due to their structural versatility, high environmental stability of its doped and undoped states and suitability to applications like electrode materials and conductors [13].

Recently, considerable research effort has focused on stacking of π-conjugated polymers [14–21]. Polymers with a structure of the repeating five membered heteroatomic rings readily constitute stacked structure. Polyalkylbithiazoles are very well known for their stacking properties, n-doping capability and usage in light-emitting diode construction. This new class of conjugated polymer exhibits interesting thermochromic and electrochemical behavior especially nonyl-derivative shows unusual optical properties as a result of its crystallinity and π–π stacking behavior [15,17,18,22,23].

Because of their good polarization, high surface area, processability, low cost, chemical inertness, good thermal and mechanical stability, carbon fibers constitute a class of electrode materials for several applications [24,25]. Surface modification of carbon fiber electrodes were performed recently by electropolymerizing 3-methyl-thiophene [26], ter-thiophene [27], pyrrole, 3,4-ethylene-dioxythiophene (EDOT) and their copolymers [28]; by electrocopolymerizing acrylamide, carbazole [29], thiophene, carbazole, pyrrole [30], carbazole, indole [31] and by electrochemical coating of

* Corresponding author. Tel.: +90 212 285 3153; fax: +90 212 285 6386.
*E-mail address:* sarac@itu.edu.tr (A. Sezai Sarac).

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