PTh/Co_3O_4 Nanocomposites as New Conducting Materials for Micro/Nano-Sized Electronic Devices

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This paper reports polythiophene/cobalt (II,III) oxide (PTh/Co_3O_4) nanocomposites synthesized via *in situ* polymerization of thiophene in the presence of Co_3O_4 at various molar concentrations. Samples were characterized by Fourier transform infrared spectroscopy (FT-IR), X-ray diffraction (XRD), Energy-dispersive X-ray (EDX) spectroscopy, differential scanning calorimetry (DSC), thermogravimetric analysis (TGA) and atomic force microscopy (AFM). The alternating current (ac) conductivity of the samples was studied depending on the temperature. XRD analyses indicated that the filling process decreased the $\pi - \pi$ stacking distance of PT chains. The most significant shift was observed in the C-S band of PTh depending on the filling process. Thermal stability of the PTh increased with increasing concentration of Co_3O_4. Filling process reduced the surface roughness of PTh. The ac conductivity analyses indicated that charge transport mechanism of the samples was consistent with corraleted barrier hopping (CBH) model. The conductivity of PTh increased about 18 times for maximum filling level depending on temperature and frequency. The thermal stability and controllable ac conductivity properties of PTh/Co_3O_4 nanocomposites showed that they can be used in the production of micro/nano-sized electronic circuit elements with lower cost. POLYM. ENG. SCI., 57:1168–1178, 2017. © 2017 Society of Plastics Engineers

INTRODUCTION

Over the past decade, conducting polymers have been of interest to scientists because of their wide ranging potential applications in various electrical and electronic devices such as chemical sensors, rechargeable batteries, light-emitting diodes capacitors, and organic field effect transistors [1–3]. The combination of electronic properties of conducting polymers with the properties of metal oxides has brought new prospects for various applications [4–7]. Nano metal oxides have important applications due to their interesting optic and electronic properties that can be used in photovoltaics, optoelectronics, energy storage, gas sensors and photocatalysis [8–10]. Furthermore, they also reduce the disadvantages of conducting polymers such as poor processability and stability when filled into the conducting polymers [11–14]. Hence, conducting polymers/metal oxide nanocomposites have been an intense research area in recent years. Novel composite materials with desired structural and physical properties using various methods and experimental conditions were produced [15–18].

PTh is one of the most studied conducting polymers due to its high conductivity and excellent environmental stability. PTh and its derivatives have very important applications in corrosion protection, solar cells, sensors, supercapacitors, light emitting diodes, nonlinear optics, photovoltaic cells and Schottky diodes etc. [19–21]. Interesting results have been reported on nanocomposites of PTh and its derivatives with metal oxides in recent years. Aldemir et al. [22] showed that PTh-SiO_2 polymer nanocomposite can be used as a new material for the organic electronics. Olson et al. [23] proved that P3HT/ZnO composites can be used as solar cell devices. Lu et al. [24] determined that (CuO, ZnO, TiO_2, $Fe(OH)_3$)-polythiophene composites are very sensitive materials for large-scale gas sensors.

However, no studies have yet been reported in literature on PTh/Co_3O_4 nanocomposites to the best of my knowledge. Cobalt (II,III) oxide, which is an important magnetic p-type semiconductor, has important applications in many fields, including electrochromic devices, solid-state sensors, gas sensing, solar energy absorbers and lithium ion batteries [25–27]. It is thought that the coordination between cobalt and sulfur atoms in thiophene rings may increase the conductivity by shortening the conduction paths of the charge carriers. Furthermore, considering the need for micro and nano sized electronic circuit elements and the heating problems in the small devices, it is thought that the conductivity behavior and thermal stability of PTh/Co_3O_4 nanocomposites between 300 and 400 K can be important for electronic applications.

One of the aims of this study is to produce PTh/Co_3O_4 nanocomposites with low cost, high conductivity and high thermal stability so that they can be used in various electronic applications. For instance, Li et al. [28] and Ashraf et al. [29] showed that PTh based composites with high conductivity can be used in polymeric memory devices, Li-ion battery components and microelectronics. Another probably more important aim is to determine the ideal charge transport mechanism model of the PTh and its nanocomposites, which is important for developing new materials for various applications mentioned above. For instance, Lee et al. [30] and Kreuer [31] reported that proton transport mechanism in the polymeric materials can be important for fuel cell applications. Nambiar and Yeow [32] indicated that the differences in type and transport mechanism of the charge carriers in the conducting polymer based materials can affect their sensor properties. Since the charge transport mechanism of the disordered systems such as polymer and composite materials cannot still be entirely explained, it is thought that the temperature dependent dielectric and ac conductivity analyses of the PTh/Co_3O_4 nanocomposites can make a significant contribution in these types of applications.

In this study, low cost chemical polymerization process, where the material quantity can also be adjusted was used for the synthesis of PTh and PTh/Co_3O_4 nanocomposites.

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