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Preparation and characterization of Pt nanowire by electrospinning method for methanol oxidation

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A B S T R A C T

Pt nanowires are prepared by treating electrospun polyvinyl pyrrolidone (PVP)–Pt composite fibers at high temperatures in an air atmosphere and their activities toward a methanol oxidation reaction (MOR) are investigated. Thermogravimetric analysis (TGA) and inductively coupled plasma-atomic emission spectroscopy (ICP-AES) results indicate that the electrospun PVP–Pt composite fibers thermally decompose at 250 °C, which leads to the removal of 98 wt% of the PVP polymer and the simultaneous reduction of the Pt precursor to a Pt nanowire. The physical and electrochemical properties of Pt nanowires are found to be affected by the heat treatment conditions such as heating rate, time, temperature, and atmosphere. Furthermore, polymer fibers subjected to a pyrolization process in nitrogen followed by exposure to an air atmosphere enhance the surface area of the Pt nanowires, leading to high electrochemical activity toward a MOR. The detailed physical and electrochemical properties of the Pt nanowires are characterized by various spectroscopic and electrochemical techniques, and the possibilities of using them as electrocatalysts in a fuel cell are explored.

1. Introduction

Pt nanoparticles, which are used as catalysts in various chemical/electrochemical reactions, are generally prepared by means of chemical impregnation or reduction methods [1–3]. Recently, a series of studies on metal particles supported on graphite/carbon nanofibers and nanotubes [4–6] and the preparation of metal or metal oxide in the shape of nanotubes or nanowires [7–10] have been reported. As in other types of nanostructures, it is expected that if the diameter of a metal nanowire or nanotube shrinks, there will be a dramatic increase in the surface-area-to-volume (mass) ratio as well as the ratio of exposed atoms on the surface [11]. The use of unsupported metal nanowires/tubes as catalytic materials for fuel cells can be beneficial because of their higher electron conductivity [12,13]; moreover, the catalyst degradation that normally occurs due to corrosion of the carbon support can be avoided [11].

Metal nanowires are generally prepared by template synthesis [10,12], a wet-chemical method that employs a carbon nanosphere [14], galvanic displacement [15], and the electrospinning method [13,16–18]. Of these, electrospinning has proven to be a simple and stable method to prepare polymer fibers that have a uniform diameter in the range of a nanometer scale. The physical properties of electrospun fibers can be controlled through the maintenance of certain parameters such as polymer concentration, dissolution temperature, spinning voltage, and spinning rate [19–22].

The conventional electrospinning method that is normally used to prepare polymer fibers uses polymer solutions, whereas metal–polymer hybrid wires [23,24] or metallic nanowires are prepared by electrospinning a polymer solution blended with the metal precursors [13,16,17]. Working along these lines, Bognitzki et al. [25] prepared copper nanowires with a size of 215–270 nm using a mixture containing polyvinylbutyral (PVB) polymer and a Cu precursor. Kim et al. [13] prepared electrospun PtRh and PtRu nanowires using a Pt precursor–polyvinyl pyrrolidone (PVP) mixture and used the same for the MOR. In their study, the PVP was burnt out by means of a heat treatment carried out at 300 °C for 3 h in air, followed by treatment at 100 °C in a H_2 atmosphere in order to reduce Pt. They also prepared hybrid PtRu nanoparticles/nanowires using the electrospinning method, and used the hybrid materials as electrocatalysts in a DMFC and in a polymer electrolyte membrane fuel cell (PEMFC) [16]. They were able to achieve a power density of approximately 35 mW/cm^2 using a 2.5 mg/cm^2 hybrid catalyst in the anode and pure oxygen in the cathode of a DMFC, at an operating temperature of 70 °C. Although the above studies have explored the possibilities of using the electrospinning technique to prepare Pt and Pt alloy nanowires as

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