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Nanostructured Pd-Based Electrocatalyst and Membrane Electrode Assembly Behavior in a Passive Direct Glycerol Fuel Cell

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Abstract

The aim of this study was to synthesize, characterize, and observe the catalytic activity of Pd_1Au_1 supported by vapor-grown carbon nanofiber (VGCNF) anode catalyst prepared via the chemical reduction method. The formation of the single-phase compounds was confirmed by X-ray diffraction (XRD) and Rietveld refinement analysis, which showed single peaks corresponding to the (111) plane of the cubic crystal structure. Further analysis was carried out by field emission scanning emission microscopy (FESEM), energy dispersive X-ray analysis (EDX), nitrogen adsorption/desorption measurements, and X-ray photoelectron spectroscopy (XPS). The electrochemical performance was examined by cyclic voltammetry tests. The presence of mesoporous VGCNF as support enables the use of a relatively small amount of metal catalyst that still produces an excellent current density (66.33 mA cm^{-2}). Furthermore, the assessment of the kinetic activity of the nanocatalyst using the Tafel plot suggests that Pd_1Au_1/VGCNF exerts a strong electrocatalytic effect in glycerol oxidation reactions. The engineering challenges are apparent from the fact that the application of the homemade anode catalyst to the passive direct glycerol fuel cell shows the power density of only 3.9 mW cm^{-2}. To understand the low performance, FESEM observation of the membrane electrode assembly (MEA) was carried out, examining several morphological defects that play a crucial role and affect the performance of the direct glycerol fuel cell.

Keywords: Palladium, Catalyst, Membrane, Carbon nanofiber, Glycerol oxidation

Introduction

Glycerol might exceed demand as it is formed as a by-product from biodiesel production [1]. However, the good properties of glycerol which are high-energy density with three hydroxyl group, non-toxic, and non-flammable make it emerge as a worthy chemical that can be converted into value-added products. After pretreatment, for instance, using electrodialysis [2], glycerol can be applied as fuel to fuel cells [3]. Fuel cells are among the most efficient ways to harvest energy from glycerol oxidation with various types of anode materials and also catalysts.

Palladium began to receive attention and fame among researchers worldwide in 2010, when Richard Heck, Ei-ichi Negishi, and Akira Suzuki received the Nobel Prize in recognition of their success in the discovery and development of palladium-catalyzed carbon-carbon bond formation [4]. Their study had a significant impact in the field of catalysis. Furthermore, it has become a source of inspiration for researchers to apply palladium metal catalysts in various areas ranging from industrial materials and pharmaceuticals to the harnessing of energy through fuel cells. Palladium is one of the metals in the platinum group. The similar chemical properties with platinum make palladium a very appropriate match for replacing the more expensive platinum [5, 6]. Palladium has a unique electronic configuration with the $4d^{10}5s^0$ ground-state electronic configuration, making it the only transition metal that combines a filled d orbital with an

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