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Electrochemical properties of fuel cell catalysts loaded on carbon nanomaterials with different geometries

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ABSTRACT

PtRu or Pt catalysts were supported on four types of carbon nanomaterials with different shapes, sizes, and graphitic and electrical properties, and their resulting catalytic activities were evaluated by electrochemical methods. The carbon nanomaterials used included two types of particles: Arc Black (AcB) and Vulcan XC-72R (Vulcan), and two types of nanofibers: carbon nanocoils (CNC) and VGCF-X. Pt and Ru were loaded onto the nanomaterials by a reduction method using sodium borohydride. Transmission electron microscopy and X-ray diffraction (XRD) revealed the PtRu catalyst particles to be 4–6 nm in diameters. The shifts in the Pt(1 1 1) XRD peak of the catalysts on CNC and VGCF-X were larger than those on AcB and Vulcan, indicating a higher degree of alloying between Pt and Ru. The diameters of the CNC-supported Pt and PtRu catalyst particles had the narrowest distributions and were constant within the range of catalyst loadings investigated. Electrochemical studies of the catalysts during methanol oxidation were carried out using cyclic voltammetry. The catalyst particles supported on CNC and VGCF-X exhibited higher catalytic activity than those on AcB and Vulcan. The effect of the surface area of the carbon nanomaterials on the catalytic activity is discussed.

1. Introduction

Two problems preventing the commercial use of fuel cells are the efficient use of platinum (Pt) and ruthenium (Ru) catalysts and the improvement of power density. Carbon black, nanometer-size carbon particles, is commercially used as the catalyst support owing to its high surface area, porosity, electric conductivity, low density, and low cost. In previous work, we have used various carbon nanomaterials as catalyst supports for direct methanol fuel cells (DMFC) [1]. Various types of carbon nanomaterials exist because of the unique variation of carbon bonding: sp^1, sp^2, and sp^3. Many different types of carbon nanomaterials, including carbon nanohorns (CNHs) [2–4], carbon nanotubes (CNTs) [5–8], carbon nano-onions [9], graphitic spherical carbon [10], carbon aerogel [11], cryo/xerogel carbon [12,13], carbon nanocapsules [14], carbon nanofibers (CNFs) [15–20], graphitic mesoporous carbon [21], and graphene [17,22,23], have been studied for application as fuel cell catalyst supports. These results were compared with that of commercially used carbon blacks (Vulcan), and some showed better catalytic activity and resultant fuel cell performance [6–10,13,15,18–22].

In our laboratory, we have succeeded in the large-scale synthesis of carbon particles and nanocoils in gram quantities, and investigated their applications. They are expected to find use in field electron emitters [24,25], super capacitors [26,27], and fuel cells [1,28,29].

Carbon nanocoils (CNCs) are helical-shaped CNFs with coil and fiber diameters of 400–1000 nm and 120–400 nm, respectively [30,31]. We have investigated methods of increasing the purity of CNCs in synthesized materials containing CNCs and CNFs, and have achieved a CNC purity of 80% [32]. CNFs are attractive because of their negligible microporosity and crystalline structure, which provide high electrical conductivity at lower cost [16]. In fuel cell electrodes, CNFs are capable of forming mesopore geometries, allowing good accessibility to catalyst sites [17]. Additionally, CNCs are expected to form paths for fuel and resultant fluid movement

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