

ORR Enhancement Using Core-Shell CoPt Magnetic Nanoparticles In Cathode Electrode Of Pemfcs

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Extended Abstract

Polymer electrolyte membrane fuel cells (PEMFCs) have attracted great attention as a power source for automotive industry owing to their eco-friendly characteristics and high energy efficiency. The most important issues for the commercialization of PEMFCs are the high cost of Pt which is used as catalysts in PEMFCs and the slow oxygen reduction reaction (ORR) speed in a cathode catalyst layer. Platinum group metals (PGMs) contribute to 21–45% of the total cost in a PEMFC stack [1]. Pt-M alloys have been studied to solve the issues by reducing Pt loading and enhancing PEMFC performance. Especially, among the alloys, a core-shell CoPt has very high surface reactivity which increases reaction speed [2]. Meanwhile, the application of a magnetic field to ORR catalysts has been investigated to increase ORR speed. Enhancement of catalyst reactivity in a magnetic field was due to paramagnetic oxygen which is attracted to magnetic poles. Catalyst reactivity was enhanced in a magnetic field regardless of the pole direction. Okada et al. [3] reported that a PEMFC with magnetized Nd-Fe-B microparticles in a catalyst layer showed better performance than that with not magnetized Nd-Fe-B microparticles. Therefore, magnetized core-shell CoPt nanoparticles have a great potential for the performance improvement of PEMFCs, but related research is very limited. In this study, the effect of magnetization on the PEMFC performance of core-shell CoPt nanoparticles was explored.

A wet reduction method was adopted for the preparation of core-shell CoPt nanoparticles supported by carbon (Vulcan xc-72). First, 28 nm Co nanoparticles in ethanol were sonicated for 1 h. Then, sonicated Co nanoparticles were mixed with Polyvinylpyrrolidone (PVP) and H₂PtCl₆·6H₂O for 10 min. The Pt precursor was reduced by adding hydrazine hydrate dropwise to form core-shell CoPt. After CoPt preparation, CoPt nanoparticles and Vulcan xc-72 in ethanol were sonicated respectively by probe sonicator for 1 h. Then, they were sonicated together in an ice bath by bath sonicator for 1 h to form core-shell CoPt/C. The CoPt/C solution was dried in an oven at 80°C overnight. After the sample preparation, characterizations were conducted by a high-resolution transmission electron microscope (HRTEM), energy dispersive X-ray spectroscopy (EDX). Performance tests of the catalyst were conducted by running a unit PEMFC at 0.1–1.0 A cm⁻² and 0.1–0.8 V. Durability tests were conducted referring to a United States Department of Energy (U.S. D.O.E.) protocol [4] by running a PEMFC alternately at 0.6 V for 3 s and 0.95 V for 3 s as one cycle up to 30,000 cycles, which can accelerate Pt dissolution.

As a result, a PEMFC using 28 nm Co particles with magnetization as a cathode catalyst showed better performance than that without magnetization. It showed 4.76%, 7.62%, 10.77%, and 16.19% enhancement at 0.3 V, 0.4 V, 0.5 V, and 0.6 V, respectively, compared to without magnetization. This result comes from the paramagnetic characteristics of oxygen which was attracted to the magnetized CoPt nanoparticles enhancing ORR speed. In addition, diamagnetic water was repelled by magnetized CoPt and created a room in a gas diffusion layer for the oxygen to get to the catalyst layer. Consequently, PEMFCs with magnetized core-shell CoPt/C have a great potential for future PEMFC lowering cost and enhancing performance.

References

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