



Development of hollow bimetallic catalysts supported on nanostructured carbons for sustainable PEM fuel cell electrodes

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Proton Exchange Membrane (PEM) fuel cells offer an efficient method to convert hydrogen and oxygen into electricity and water, making them a promising solution for clean energy production. The catalytic layers of a PEM fuel cell are typically composed of Pt nanoparticles (NPs, ~3 nm in size) supported on carbon black and mixed with a polymer ionomer (Nafion®) [1]. However, upon operation, both the carbon support and the Pt nanoparticles degrade [2]: carbon undergoes oxidation, while Pt particles coalesce or dissolve and redeposit elsewhere (e.g., in the membrane), resulting in performance decay. To address these issues, current research focuses on improving both the Pt catalysts and the catalyst supports.

To enhance catalyst efficiency and lifetime, our research has focused on developing hollow PtM nanoparticles, as their voided architecture increases Pt utilization, provides more accessible active surface area, and can reduce the extent of Pt coalescence compared to solid nanoparticles. In particular, large (10–50 nm) hollow PtCo nanoparticles degrade more slowly, which helps maintain catalytic activity over time [3]. Alloying Pt with transition metals such as Co or Ni contracts the Pt lattice, which leads to widening the d-band and lowering the reaction activation energy. This modification reduces the binding energy of oxygen reduction intermediates, which accelerates the reaction [4]. In addition, as a support material, carbon xerogels (CXs) offer an interesting alternative to carbon black, as their tunable pore texture can reduce diffusion-induced voltage losses (η_{diff}) [5]. The stability of CX supports can be further improved by applying a thin graphitic coating via Chemical Vapor Deposition (CVD) [6], which could increase their resistance to corrosion.

PtCo/CX catalysts have been synthesized in previous work [3], but the 14-step procedure is too complex and requires simplification. The main goal of this work is to rationalize and optimize the synthesis route for hollow PtCo/CX catalysts. Several synthesis parameters were systematically investigated to identify which variables influence the nanoparticle size, morphology, and composition, and which steps can be simplified to improve the manufacturing procedure. Catalysts were prepared on CX supports with controlled mesopore size (50–100 nm) and subsequently coated with a graphitic carbon layer via CVD. Hollow PtCo nanoparticles supported on CXs were characterized using various physico-chemical methods to evaluate their structural, morphological, and compositional properties.

The electrochemical performance of the hollow PtCo/CX catalysts was assessed in 0.1 M HClO₄ on a rotating disk electrode. The catalysts exhibited higher mass and specific activities than the commercial Vulcan Pt/C material, confirming the beneficial effect of alloying and hollow nanostructuring on ORR performance. In the next phase, complete Membrane–Electrodes Assemblies will be fabricated for further electrochemical testing and Accelerated Stress Tests.

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