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Developing efficient anodic electrocatalyst: Three-dimensional interconnected network of bimetallic Pd–Ni aerogel for advanced electrocatalysis of ethanol

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A B S T R A C T

This paper introduces a valuable and easy strategy for connecting metallic nanoparticles to assemble a three-dimensional (3D) network of bimetallic palladium-nickel aerogel. This research provides several unique advantages (e.g., facile, surfactant-free, one-pot, and fast) without any chemical destabilizer compounds. The 3D metallic superstructure is formed during the reduction of Ni^{2+} and Pd^{2+} ions by adding $NaBH_4$, followed by CO_2 supercritical drying. Additionally, the gelation kinetics are explored by raising the temperature to create an efficient anisotropic atmosphere to assemble the 3D Pd-Ni hydrogels. This study demonstrated that the alteration in anisotropic conditions affects the formation of a 3D hydrogel. The production of a 3D network assembled by the extended nanowires with high porosity and plenty of open pores is confirmed by various analyses. The Pd-Ni aerogel is employed as a self-supported electrocatalyst for decomposing EtOH fuel and reflects the more prominent electrocatalytic activity relative to Pd/C. The existence of nickel will facilitate the adsorption of hydroxyl groups on the surface of the resulting aerogel. These adsorbed hydroxyls react with the generated intermediates and release the blocked active sites by carbonaceous intermediates, thereby affecting efficiently the ethanol oxidation.

1. Introduction

Energy is the main foundation of modern life in the present century. The crises caused by the excessive consumption of traditional fuels (e.g., oil, coal, etc.) to supply the required energy have created grand problems with respect to the human and ecosystem health. Hence, the achievement of clean and renewable energies has become an emergency topic worldwide. Direct organic small fuel cells (DOSFCs) have emerged as evolving young technologies to provide clean and renewable energy [1–8]. Among them, DEFCs (direct ethanol fuel cells) have attracted considerable attention from researchers due to their security, safe storage, high efficiency, and low toxicity [2–15]. In addition, DEFCs will generate the high energy density in comparison to other liquid fuel cells such as DMFCs (direct methanol fuel cells) and DFAFCs (direct formic acid fuel cells). Therefore, the studies for the development of DEFCs have become an attractive target in the scientific community. At the beginning of the new century, palladium-based electrocatalysts have been in the limelight as splendid nanocatalysts in DOSFCs and especially in DEFCs [1–8]. However, the fatal barriers such as weak sustainability and inadequate efficiency of nanocatalysts have become the grand obstacles in commercializing DEFCs [1–15]. Thus, abundant attempts have been dedicated for finding novel and fantastical nanocatalysts to remove the mentioned barriers. An overview of published literature on DEFCs corroborated that some issues (e.g., scattering, phase engineering, size effect, shape, and the components of electrocatalysts) can intensively affect the electrocatalytic efficiency [4–12]. Especially, recent studies have proven the enhanced performance of bimetallic electrocatalysts (Pd-M) by the combination of an oxophilic metal (e.g., Ag, Cu, Ni, and Co) with palladium [10–15]. The promoted efficiency originates from the modification of the electronic property of palladium (synergistic effect). Therefore, the alloyed nanostructures not only facilitate the adsorption of hydroxyl anions (OH^{-1}) on the surface of binary Pd-M electrocatalysts but also improve the decomposition process of liquid fuel.

Moreover, the construction of anodic electrocatalysts with unique morphologies can improve the electrocatalytic activity and stability. Among various kinds of morphologies, metallic aerogels (MAs) have emerged as 3D (three-dimensional) networks with unusual properties

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