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Enhanced activity and durability of the oxygen reduction catalysts supported on the surface expanded tubular-type carbon nanofiber

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ABSTRACT

Tubular type carbon nanofibers (TCNFs) are prepared and used as a catalyst support material for a cathode electrode of low temperature fuel cells through structural modification. The pristine TCNF is treated by graphitization and makes partially torn-tube shape through the surface expansion by rapid thermal treatment of the oxidized graphitized TCNF. Physical properties of the TCNF group are examined, and it is confirmed that the unique ripped texture along fiber axis with graphitic structure is obtained by the surface expansion. Platinum catalysts supported on these TCNF group are prepared and evaluated. Electrochemical properties are examined via cyclic voltammograms and polarization curves for oxygen reduction reaction activity. The platinum catalyst on the surface expanded TCNF has the enhanced activity at initial and the stable performance even after accelerated durability test due to their unique structure.

1. Introduction

Carbon nanofibers (CNFs) have attracted great attention as unique nanomaterials having a potential for industrial applications such as functional composites, electrochemical electrodes, semiconductor devices, electron emitters, catalysts and catalyst supports [1–6]. A number of studies on selective synthesis and structural analysis have been performed to attain uniform and controlled structure of the CNFs [7–9]. The most important factor to determine the properties of the CNF is a stacking configuration of graphene layer. The CNFs are classified into three groups as platelet (PCNF), herringbone (HCNF) and tubular (TCNF) types [10]. The graphene layers of the PCNF are stacked in the direction of perpendicular to the growth axis, so the PCNF has relatively large diameter and plenty of exposure of edge sites. The HCNF has tilted graphene layers based on the structure of the PCNF, and it leads to thinner diameter and larger specific surface area than the PCNF. The TCNF (is also known as CNT), which the graphene layers locate the same direction of fiber axis, forms the exposure of stable basal planes on the carbon surface. The TCNF has been used as a catalyst support material due to relatively high surface area, excellent electronic conductivity, and high chemical stability. Many studies about the synthesis and application of the TCNF as a support material of platinum electro-catalyst for fuel cells, especially focusing on cathode electrode with high durability were conducted [11–13]. As mentioned above, the TCNF dominantly wrapped by stable basal plane typically has a good electrical conductivity and a robust structure caused by higher graphitic degree. Without the surface modification, however, lack of sufficient binding sites for anchoring precursor metal ions or metal nanoparticles is happened. This usually leads to poor dispersion and agglomeration of metal nanoparticles. It has a significant impact on the catalyst activity and durability. Therefore, the introduction of proper functionality onto the TCNF or structural modification is the essential ingredient for future applications.

In this presenting study, we first prepared the iron-nickel (Fe-Ni) binary catalyst and synthesized the TCNFs over the Fe-Ni catalyst from a mixture of carbon monoxide (CO) and hydrogen gases. The TCNFs were heat-treated at the temperature of graphitization to retain their robust original structure against further harsh procedure. The graphitized TCNFs were conducted additional surface modification through the expansion of graphene layer induced

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