Oriented Electrode Based on TiO_2 Nanotube Arrays

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Polymer exchange membrane fuel cells (PEMFCs) have received considerable attention as a promising energy conversion device for both stationary and mobile application. However, there are several issues hindering the commercialization of PEMFCs such as high cost, low reliability and poor long term durability.

Carbon materials, i.e. XC72, are the common support due to their large surface area, good electronic conductivity and proper pore structure. However, carbon oxidation during fuel cell operation leads to significant degradation due to aggregation and dissolution of Pt particles. Metal oxides with high stability under fuel cells work conditions, is beneficial to improve catalytic performance of catalysts because of the strong metal-support interaction (SMSI) between metals and metal oxides, which might alert absorption properties of oxygen or fuel on the catalyst surface. In particular, TiO_2 has been considered as one of the most studied compounds due to its good physical, chemical properties and high stability in acidic and alkaline solutions.

High oriented nano-structured electrode with lower Pt loading and higher electrochemical surface area has attracted much attention. To design oriented meso-structure, TiO_2 nanotubes (TNTs) arrays which have high stability and unique oriented structure hold promise as support in fuel cell.

By using Ni as the precursor, Pt nanoparticles were deposited onto the TNTs. The prepared Ni nanoparticles with diameter of about 30 nm were advantageous to the deposition and dispersion of Pt catalysts within TNTs support. The modified electrode exhibited high activity in half cell test. The electrochemical surface area of this electrode had reduced by 28% after an accelerated durability test compared to 57% for commercial Pt/C (JM 20%) after 600 potential cycles between 0-1.2 V vs.NHE. In this work, the TNTs as catalyst support in was tested under single cell test condition. The maximum power density reached 557 mW cm^{-2} when this novel electrode was used as the anode of fuel cells.

Furthermore, the hydrogen-treated TiO_2 nanotube (H-TNTs) arrays served as highly-oriented nanostructured electrode support significantly improve the electrochemical performance and durability of fuel cells. The electrical conductivity of H-TNTs increases by about one order of magnitude in comparison to the Air-TNTs. Meanwhile, the increased oxygen vacancies and hydroxyl groups on the H-TNTs also anchor more Pt atoms during Pt electrodeposition. The H-TNTs pre-treated by a novel successive ion adsorption and reaction method enhances the loading and dispersion of Pt catalysts. The fabricated Pt nanoparticles with smaller diameter of 3.4 nm are located uniformly around the pre-treated H-TNTs support. The as-prepared highly-oriented electrode exhibits much excellent durability during accelerated durability test especially for the H-TNTs loaded Pt catalyst annealed in ultrahigh purity H_2 for second time. There is little decrease for the electrochemical surface area of the as-prepared electrode after 1000 cycles compared to 68% for JM 20% Pt/C after 800 cycles. After the H-TNTs loaded Pt catalyst were annealed in H_2 again, the strong metal-support interaction between TNTs and Pt catalyst enhance the electrochemical stability of electrodes. In a full fuel cell testing, the maximum power density got 500 mW cm^{-2} when this novel highly oriented electrode was used as the anode. When it is used as the cathode in a fuel cell, the new electrode generated power as 2.68 kW g^{-1}_{Pt}.