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Aerosol synthesis of carbon nano-onion nanoparticles and their application to fuel cells

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Various carbon nano-materials, such as graphene, carbon nanotubes and carbon black, have been used as supports for the catalyst particles in Proton exchange membrane fuel cells (PEMFCs) on account of conductivity and low cost. Due to the extremely high cost of widely employed Pt catalyst particles in PEMFCs, it is desirable to load these particles on a robust support material such that the degradation of the support does not render the noble metal useless. Among the various forms of carbon, carbon nano-onions (CNOs) draw particular attention due to their concentric shells with high degree of graphitization. CNOs can be continuously synthesized by laser pyrolysis of hydrocarbon source (such as acetylyene and ethylene), and therefore has the advantage over other forms of carbon nano-materials due to the scalability of the production method [1].

Here, we present a CO_2 laser induced pyrolysis of gaseous hydrocarbons to produce CNOs, and explore the parameter space toward the goal of producing CNOs over other carbon particles (such as amorphous soot). We demonstrate that the size, morphology and the number of graphitic shells are easily controlled by adjusting the experimental parameters. Owing to the high degree of graphitization, the CNOs show enhanced durability against oxidative potentials to commonly used commercial carbon materials such as Vulcan XC-72 [2]. Platinum-decorated CNOs have been used to fabricate PEMFCs and they are shown to have comparable performance to conventional cells, and the accelerated stress test reveals that the durability of the cells improved.

Furthermore, a method of improving catalytic activity was applied on the carbon nano-onions particles by doping heteroatoms (nitrogen and boron) with keeping the crystallinity of the carbon particles. The electrochemical measurements indicated that the co-existence of nitrogen and boron enhance the ORR kinetic performance by reducing the overpotential and increasing the current density. The results from the kinetic studies indicated that the nitrogen and boron induced an oxygen adsorption mechanism and a four-electron-dominated reaction pathway for the as-prepared catalyst that was very similar to those induced by Pt/C. Using the N-, B-codoped CNO, it was synthesized with Pt nanoparticles at low loading 2wt%, and we confirmed that the performance of the N-, B-codoped CNO catalyst has better oxygen reduction reaction (ORR) kinetics and catalytic durability than the commercial 40wt% Pt/C catalyst. Our work provides a large-scale continuous method for improved catalytic activity and durability, and we expect the codoped CNO catalyst to help accelerate commercialization of fuel cells as a fuel cell catalyst.

참고문헌

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