Nanostructural engineering of Pt/C catalyst via spray-drying for electrocatalyst applications

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The great advantages of proton exchange membrane fuel cell (PEMFC) drive us to develop industrially friendly processing techniques and technologies for the production of its components such as a fuel cell catalyst. Platinum nanoparticles supported on carbon (Pt/C) are the most widely used catalyst material. Many researchers have demonstrated intense effort in the development of Pt/C catalysts. They were concerned with not only reducing Pt consumption, but also with keeping the catalytic performance at a reasonable level by means of structural engineering of the catalyst support materials to provide a high surface area. However, the common methods have been relatively time consuming (Balgis *et* al, 2012 and Balgis *et* al, 2013). In this work, we report development of a facile in-situ synthesis route to control the morphology and atomic content of Pt/C catalyst using spray-drying technique. The prepared catalyst showed high performance catalytic activity with excellent durability. The present method, described herein, is simple and cost-effective with a short processing time, which presents high opportunity for large-scale commercialization.

A precursor containing polystyrene latex (PSL, 300 nm), carbon black (40 nm), H_2PtCl_6 solution, and Polyvinyl alcohol (PVA, Mw = 500, at a mass ratio of 16:1) was spray-dried at 180°C with an air flow of 11.1 l/min as shown in Figure 1. Ammonia solution, $(NH_3)_{aq}$, was added into the precursor to intrude Nitrogen atom to the catalyst support (carbon). As-sprayed composite particles were calcined at 700°C for 30 min, under a nitrogen atmosphere in order to decompose PSL particles, to allow for a reduction process and for the crystal growth of platinum, accomplish N-doping process, and to obtain spherical microflower architecture. Electrocatalytic activity was performed using cyclic voltammetry (CV) and rotating disc electrode (RDE) measurement.

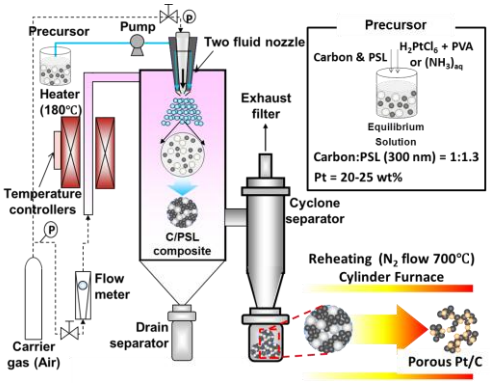

Figure 1. Schematic diagram of the experimental setup.

The prepared Pt/C catalysts have a unique porous structure that appears as a flower bunch in micrometer scale, namely spherical microflower catalyst (Pt/C_{SMF}) and Pt/C_N for sample with N-doping, as shown in Figure 2(a) and (b), respectively. Pt nanoparticles were very well dispersed on both catalysts, without any sintering, even after exposed at high temperature. The average particle size of Pt was 3.34 and 4.01 nm for Pt/C_{SMF} and Pt/C_N, respectively. The XRD pattern of both catalysts (data not shown) was indicating face-centered cubic crystal structure, which means complete reduction of H_2PtCl_6 was achieved.

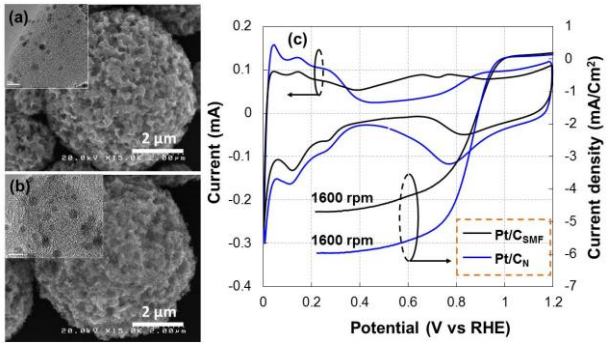

Figure 2. SEM and TEM image of: (a) Pt/C_{SMF} and (b) Pt/C_N; and (c) polarization curve of CV and ORR at 1600 rpm of Pt/C_{SMF} and Pt/C_N

The electrochemical characteristics of the prepared catalysts are presented by CV and ORR polarization curve shown in Figure 2(c). The electrochemical surface area (ECSA), mass activity (MA), and specific activity (SA) values of the catalysts summarized in Table 1. This work demonstrates an ample opportunity for the large-scale commercialization of a high-performance Pt/C catalyst with an exotic architecture.

Table 1. Catalyst characterization results.

Sample	Pt loading (wt%)	ECSA (m^2/g_{Pt})	MA (mA/mg_{Pt})	SA ($\mu A/cm^2_{Pt}$)
Pt/C_{SMF}	20.1	63.70	132.26	207.62
Pt/C_N	25.1	68.00	564.00	834.00

Balgis, R., Anilkumar, G.M., Sago, S., Ogi, T., Okuyama, K. (2012) *Fuel Cells* **12**, 665-669.
Balgis, R., Anilkumar, G.M., Sago, S., Ogi, T., Okuyama, K. (2013) *J. Power sources* **229**, 58-64.