Scale up of non-PGM ORR catalysts

Barr Halevi, Paul Short
Pajarito Powder LLC, Albuquerque NM 87102, USA
Alexey Serov, Plamen Atanassov
Chemical & Nuclear Engineering Department,
Center for Emerging Energy Technologies,
University of New Mexico, Albuquerque, NM 87131, USA
Selvarani Ganesan, Scott Calabrese Barton
Chemical Engineering & Materials Science,
Michigan State University, East Lansing, MI 48824, USA
Sanjeev Mukerjee
Department of Chemistry and Chemical Biology,
Northeastern University, BostonMA 0211, USA

Non-platinum group metal (non-PGM) oxygen reduction reaction (ORR) catalysts have been developed as a largely academic pursuit until recently. However, as researchers have discovered and synthesized increasingly active non-PGM ORR[1,2] catalysts, commercial interest has increased.

Pajarito Powder LLC is a venture-backed, Albuquerque-based start-up company with the goal of commercializing non-PGM ORR catalysts so as to help reduce the costs of PEM fuel cells and thus assist the fuel cell industry at this pivotal point in fuel cell development. Pajarito Powder has examined several leading non-PGM technologies and selected for commercialization metal-nitrogen-carbon (MNC) technologies generated by the groups involved with a US DOE-EERE project for developing non-PGM ORR catalysts under Northeastern University. Pajarito was therefore brought on board as the scale-up partner. Here we present scale up efforts for these catalysts, defined in terms of performance and manufacturability, and examine the challenges in commercializing a new class of catalysts.

While MNC catalysts are made in different ways, the type of active sites created are similar for all, with nitrogen-coordination of transition metals (such as iron) as the most probable active site structure. Typically, precursor mixtures are made from either metal-salts mixed with carbon-nitrogen compounds or metal-carbon-nitrogen compounds. These mixtures may require complex processing to bring all the active site components into close proximity, depending on the precursors used. The precursor mixtures are then pyrolyzed at 800-1000°C in inert or reducing atmosphere to convert the precursors and create active sites as supported on a carbon substrate or incorporated in a carbon matrix co-synthesized in the process. Excess metal is released in particles made during the synthesis are then leached out in a post-processing step. In most cases, a second pyrolysis is conducted to enhance catalyst activity and stability.

Clearly, to form the metal-nitrogen-carbon complex active sites it is necessary to bring-together the metallic, carbon, and nitrogen components so that they can react during pyrolysis. This can be done in different ways. One is to begin with metallo-macrocycle that contains the needed moieties providing for simple activation. These precursors are however costly. It has been shown that it is possible to create similar or identical types of sites from much less costly precursors. One approach relies on high pressures to force the reaction of activated nitrogen compounds with iron-functionalized carbon supports[3]. This High Pressure Pyrolysis (HPP) approach has low materials cost but is challenging because of the need for containing corrosive gasses at 30+ atmospheres at 800-1000°C. Preliminary results for scaling up this synthesis approach are promising, as evident from the MEA polarization test show below.

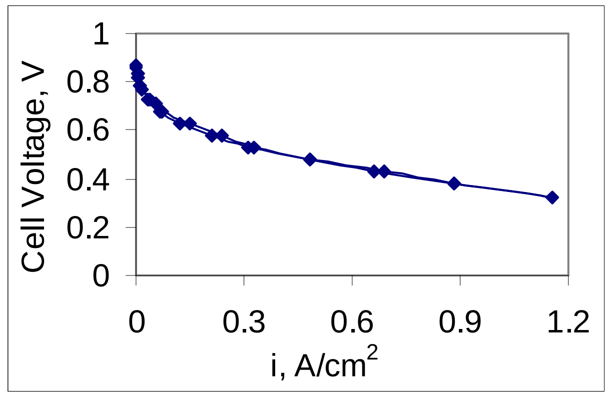

Fig. 1: MEA performance of scaled up non-PGM catalyst. 33wt% Ionomer, Nafion 211, 80°C, 30PSIg O_2, 100% RH

Another approach relies on using silica microspheres (mono-dispersed colloidal silica powder) to serve as a support during the pyrolysis of inexpensive precursors, where the silica is then etched after the high temperature treatment[4]. This Sacrificial Support Method (SSM) allows for synthesis of high-surface area open frame structure templated catalysts at atmospheric pressure, yet has higher materials costs when compared to high pressure pyrolysis. This approach is less-equipment demanding and therefore more amenable to scale-up.

The scale-up potential, challenges, and successes for these two different non-PGM catalysts illustrates that non-PGM ORR catalysts are promising in performance and scale-up potential. While there is still more need for improved performance and increased batch size of catalysts, these early results demonstrate that non-PGM catalysts offer great promise in reducing fuel-cell costs and facilitating fuel cell commercialization in general.

Acknowledgement:
We gratefully acknowledge the partial financial support from the U.S. Department of Energy (EERE), under a Non PGM Catalyst development effort (Contract no EE 0000459) lead by Northeastern University (Sanjeev Mukerjee, P.I.).

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