One Step Synthesis of Iron Deposited Nitrogen Doped Graphene as a Highly Active Electrocatalyst for Oxygen Reduction Reaction

Baejung Kim, Aiping Yu, Zhongwei Chen*

Department of Chemical Engineering
Waterloo Institute of Nanotechnology
Waterloo Institute of Sustainable Energy
University of Waterloo
200 University Avenue West, Waterloo, Ontario, Canada N2L3G1
*Email: zhwchen@uwaterloo.ca

Alkaline fuel cells and metal air battery technologies based on the electrochemical conversion between oxygen and water will play important roles in sustainable society. However, the commercialization of these technologies has been hampered by the sluggish kinetics of oxygen reduction reaction (ORR). At the current state of technology, precious metals and alloys, such as Pt, Pt-Au and Pt-Pd, have been studied and developed as the best performance ORR catalysts [1]. However, insufficient performance coupled with the limited availability and high cost of these precious metal based catalysts limit their long term practical application in fuel cells and metal-air batteries. Therefore, materials abundant in nature and active for the ORR are highly expected.

With increasing interest in graphene application in electrochemistry, a variety of graphene based electro-catalysts are being explored. As a monolayer of carbon atoms boned into a hexagonal lattice, graphene possesses favourable properties that allow it to be employed with various conductive metals to enhance ORR. In addition to graphene metal nanocomposites, dopant heteroatoms, such as nitrogen, show fascinating catalytic activity towards ORR [1].

Herein, the study focuses on methods of synthesis harnessing iron as electro-catalysts, with the aid of nitrogen doped graphene as the substrate through simple pyrolysis. The method uses thermally exfoliated graphene as a starting material, and it is mechanically mixed with urea and iron acetate. The mixture is pyrolyzed at a high temperature. The synthesized catalyst is observed to be a well exfoliated nitrogen doped graphene with iron nanoparticles deposited on the carbon (Fe-N-G) (Figure 1).

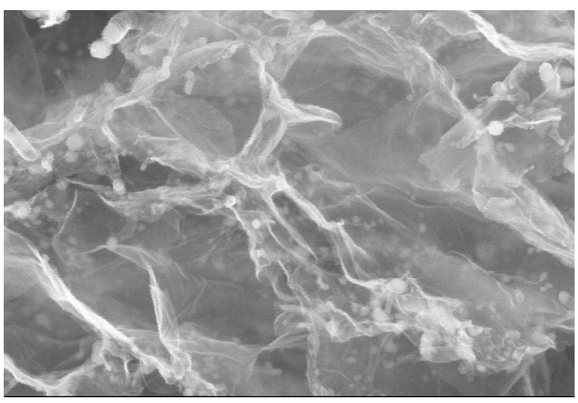

Figure 1: Fe particles on nitrogen doped graphene

The evaluation of the ORR activity is performed by rotating disk electrode (RDE) voltammetry in 0.1 M KOH electrolyte. The one-step synthesized nitrogen doped graphene with Fe nanoparticles illustrates advantages in terms of cost and performance over platinum. The enhanced ORR polarization curves obtained at a rotation rate of 900 rpm of Fe-N-G demonstrates significantly improved onset and half-wave potentials compared to commercial platinum and carbon mixture (Pt/C, 20 wt% Pt) (Figure 2).

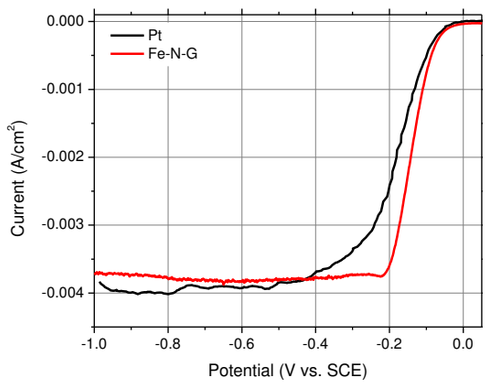

Figure 2: ORR polarization curve of Pt/C and Fe-G-N measured by RDE at a rotating speed of 900rpm.

In summary, iron nanoparticle deposited nitrogen doped graphene is easily produced in a single step method by simple pyrolysis at a high temperature. The synthesized material shows outstanding ORR performance compare to Pt/C. This excellent ORR performance is attributed to the active sites created by iron nanoparticles and nitrogen doping.

Reference:

1. Wong, C-P., et al., Facile Synthesis of Nitrogen-Doped Graphene via Pyrolysis of Graphene Oxide and Urea, and its Electrocatalytic Activity toward the Oxygen-Reduction Reaction, Adv. Energy Mater., **2**: 884–888.