Graphene based Electrodes for PEM Fuel Cells

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Abstract

A polymer electrolyte membrane (PEM) fuel cell is an electrochemical device in which hydrogen is oxidized at the anode electrode and oxygen is reduced at the cathode electrode [1]. Membrane electrode assembly (MEA), consisting of a proton exchange membrane, catalyst layers, and gas diffusion layers (GDL), is regarded as the heart of the PEM fuel cell). Typically, these components are fabricated individually and then pressed together at high temperatures and pressures.

The first generation of PEM fuel cell used platinum (Pt) supported on carbon black as the catalyst layer that exhibited excellent long-term performance at a prohibitively high cost [2]. These conventional catalyst layers generally featured expensive platinum loadings of 4 mg/cm^2, the loading is improved up to 0.04 mg/cm^2 [3]. However, the cost of catalyst layer still is the major barrier to the commercialization of PEM fuel cells [4]. Thus in our study we have aimed to manufacture low platinum loaded catalyst layers.

In our study, graphene nanosheets (GNS) were separated from graphite by an improved, safer and mild method including the steps of oxidation, thermal expansion, ultrasonic treatment and chemical reduction (**Figure 1**) [5, 6]. In the one way direction of the study, Pt was impregnated onto GNS or graphene oxide (GO) by *in-situ* nucleation to provide dispersed and uniform catalyst structure (**Figure 2**). In addition, Pt deposited samples were exposed to thermal shock to improve the crystallinity. The effect of annealing time, annealing temperature and catalyst loading was investigated on the growth of Pt nanoparticles. The structural changes and the surface morphologies of the samples were examined by Raman Spectroscopy, X-ray Diffraction (XRD), Thermogravimetric Analysis, Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) techniques.

Since electrospinning is an established technique for generating nanofibers [7] and very promising to fabricate new catalyst layers with high activity, high poisoning resistance and good durability in PEM fuel cells [8], it can increase Pt utilization through an enhancement of the three-phase boundary. Therefore, we expected that electrospun Pt/graphene plays an important role as catalyst support by mitigating CO poisoning risks and reducing cost. In order to do that, as a second direction in the study, Poly(vinyl pyrrolidone) (PVP) was used as a carrier binder and solution of PVP/Pt/GN was electrospun onto carbon paper. Moreover, PVP and synthesized Pt/GN and Pt/GO nanoparticles were also imposed onto carbon paper and a gas diffusion electrode was formed. The physical tests of resultant gas diffusion electrodes were accomplished by SEM, TEM and electrical conductivity measurements according to four-point probe technique.

Moreover, to be able to compare with commercial electrode performances, MEAs were prepared from resultant electrodes in our study. Performances of the MEAs are still under investigation in fuel cell system.

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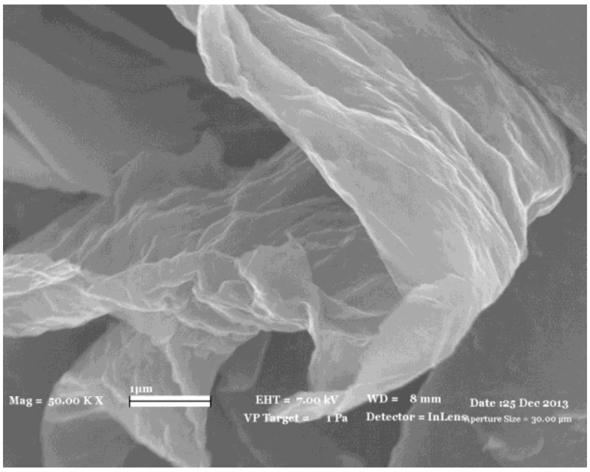

Figure1: SEM image of graphene nanosheets

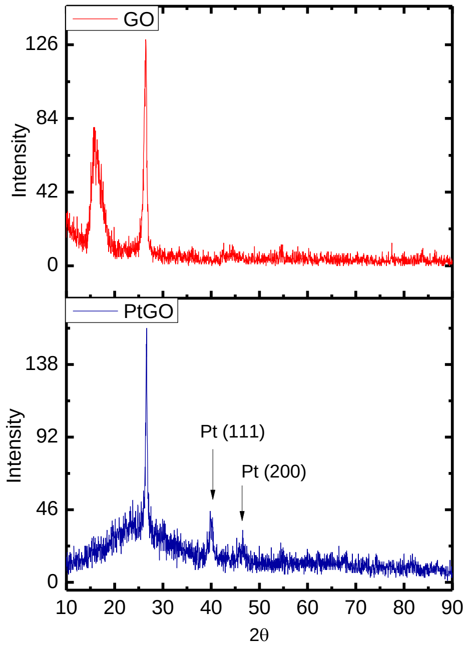

Figure 2: XRD spectrum of synthesized Pt/GO nanoparticles