New Fuel Cell Electrodes Made from Graphene Nanosheets and their Nanocomposites

Burcu Saner[1]*, Alp Yürüm[2], Selmiye Alkan Gürsel[1], Yuda Yürüm[1]

[1]*Faculty of Engineerings and Natural Sciences, Sabanci University, Tuzla, Istanbul 34956, Turkey*

[2]*Grand Water Research Institute, Technion Israel Institute of Technology, 32000, Haifa, Israel*

Abstract— The production of novel catalyst support materials could open up new ways to enhance the catalytic activity by reduced catalyst loadings. Nanocomposites composed of conducting polymers reinforced with graphene nanosheets (GNS) or graphite oxide (GO) sheets can be potential fuel cell electrodes as an alternative to commercial fuel cell electrodes.

Polymer electrolyte membrane fuel cells (PEMFCs) deliver high power density which provides low weight, low cost and low volume [1]. There are still problems for fuel cell commercialization due to technical limitations such as on board storage, infrastructure for hydrogen fuel cell and the fuel cell system and its durability.

Catalyst has a crucial effect on both the cost and durability of PEMFCs. A suitable catalyst support must be stable in acidic media, and also have good electronic conductivity, and high specific surface area. In addition, the interaction of Pt catalyst with the support material is significant and affects the particle size, dispersion and adhesion properties. At this point, catalyst support material becomes significant to get high catalytic performance of catalysts by lowering the catalyst loadings.

In fuel cells, carbon black is preferred as the catalyst support material for Pt because of its high surface area and low cost. However, carbon black has some performance and stability issues under fuel cell operation. GNS with a larger specific surface area, better electrical conductivity, and more flexible structure, which make graphene sheets appropriate for fuel cell applications, can be an alternative material [2].

Graphene is the flat monolayer of sp^2 bonded carbon atoms in a densely packed honeycomb crystal 2D lattice [3]. There are numerous attempts in the literature for the treatment of graphite and production of monolayer graphene sheets. One of the applicable methods is the graphite oxidation in order to reduce the strong bonding between graphene sheets in graphite and to obtain single graphene sheets [4].

Recently, conducting polymer matrices reinforced with nanofillers have been studied for energy storage applications. Polypyrrole (PPy) was preferred as the conducting matrix because of its good environmental stability, facile synthesis, and high conductivity [5]. In this work, for the fabrication of novel fuel cell electrodes, PPy was coated on partially oxidized GO sheets and GNS by *in situ* polymerization of pyrrole (Py) with different feed ratios of Py and sheets. GNS were fabricated in large quantity adopting a safer and mild chemical route consists of oxidation, ultrasonic treatment and chemical reduction. Then, Pt catalyst particles were decorated on the surface of GO sheets, GNS and their nanocomposites. Catalyst dispersion and size distribution were tailored by applying three different methods including sonication and direct deposition techniques. Finally, the electrodes in the form of thin-films composite electrodes were prepared successfully by drop-casting method.

In the PPy/GNS composites, GNS are electron acceptors while PPy serves as an electron donor [6]. Figure 1 a exhibited a layer-by-layer polymer coating on GNS. Then, Pt impregnation was conducted under ultrasonic vibration about 2 hr by using H_2PtCl_6 solution and 1 M $NaBH_4$ as a reducing agent. Figure 1 b showed Pt deposited PPy/GNS nanocomposites. Pt catalyst size was in the range of 20-30 nm. Also, Pt catalyst started to grow on its surface and the particle size was about 4 nm.

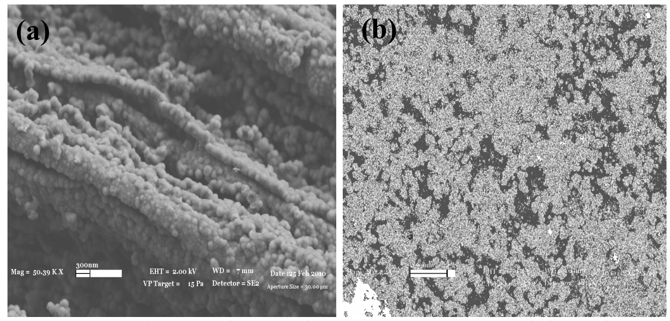

Figure 1: SEM images of (a) PPy/GNS nanocomposites and (b) Pt deposited PPy/GNS nanocomposites

Fuel cell electrodes made of GNS and their nanocomposites were fabricated by drop casting on commercial Nafion®212 membrane using %10 Nafion® solution as a binder. Then, Pt catalysts were deposited on these electrodes by chemical reduction of a Pt salt under ultrasonic treatment about 2 hr. A photograph of GNS based electrode was presented in Figure 2. Electrode seemed to be flexible.

Figure 2: A photograph of GNS based electrode

In conclusion, cost reduction and improvements for catalyst utilization are significant tasks for PEMFCs. The shortest and most effective impregnation technique was achieved by Pt deposition under ultrasonic vibration about 2 hr. Fuel cell electrodes made of GNS and GO-based nanocomposites were fabricated by drop casting and Pt deposition was successfully achieved. The performance of membrane electrode assemblies fabricated by using these electrodes is currently under investigation.

*Corresponding author: bsaner@sabanciuniv.edu

[1] L. Gubler, S. Alkan Gürsel, G. G. Scherer, Fuel Cells **5**, 317 (2005)

[2] Y. Wang, Z. Shi, Y. Huang, Y. Ma, C. Wang, M. Chen, Y. Chen, J. Phys. Chem. C **113**, 13103 (2009).

[3] K. S. Novoselov, A. K. Geim, S. V. Morozov, D. Jiang, Y. Zhang, S.V. Dubonos, et al., Science **306**, 666 (2004).

[4] B. Saner, F. Okyay, Y. Yürüm, Fuel **89**, 1903 (2010).

[5] T. V. Vernitskaya, O. N. Efimov. Russ. Chem. Rev. **66**, 489 (1997).

[6] A. Zhamu, B. Z. Jang, US patent 0092747 A1 (2009).