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Graphene as corrosion protection for metal foam flow distributor in proton exchange membrane fuel cells

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ABSTRACT

In this study, graphene was grown on nickel foam by chemical vapor deposition method. The morphology and crystallization of graphene films were characterized by scanning electron microscopy and Raman spectroscopy. Graphene-coated nickel foams have been used as flow distributor in a single PEM fuel cell, and the current density of the cell reached 1000 mA/cm^2 at 0.6 V. Tafel analysis indicates that graphene-coated samples showed greatly lower corrosion current density (nine times) than the uncoated ones. The contact angle was 35% larger than uncoated sample. These results clearly show that graphene-coated metal foams significantly enhances electrical conductivity and hydrophobicity.

Introduction

A proton-exchange membrane fuel cell (PEMFC) is one of the most promising technologies for the renewable energy [1–9]. Comparing with other renewable energy technologies, PEMFCs have the advantages of high power density, high conversion efficiency, and almost zero emission.

A conventional PEMFC consists of a membrane-electrode-assembly (MEA) and bipolar plates. The essential functions of the bipolar plates are to collect electric current, distribute oxygen and hydrogen gas to the catalyst layer, transport product water and remove generated heat.

Because of the existence of ribs and channels on the bipolar plates, the concentration distribution of reactants and temperature distribution inside electrodes are not uniform in MEA plane. Catalysts are not fully utilized in this ribs and channels configuration. Recently, we used highly porous metal foam to replace traditional ribs and channels plates and found it enhances fuel cell performance [10,11]. However, metal parts are prone to corrode when they are exposed to the highly oxidizing and/or reducing environment in fuel cell. To reduce corrosion, Yun used Au-coated bipolar plates for the PEMFC [12]. Fu et al. shows that Ag-coated bipolar plates can also be used for the PEMFC [13]. It has been demonstrated that Ag-coated bipolar plates exhibit high anti-corrosion

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resistance. Although Au and Ag plating could avoid the corrosion and improve the stability, Au and Ag are too expensive for practical application. Finding an alternative solution is one of the most important tasks for reduction of corrosion. Some researchers have also investigated TiN-coated stainless steels as PEMFC bipolar plates [14,15]. TiN shows high thermal conductivity and high corrosion resistance.

Because carbon coated stainless steel also shows high corrosion resistance and hydrophobicity, carbon coating were considered for PEMFC bipolar plates [16,17]. Especially, graphene, a single atomic layer of carbon allotrope, exhibits chemical stability and good electrical conductivity [18]. Hence, the use of graphene as a protective layer to improve anti-corrosion, electrical conductivity, and durability of metallic components used in PEM fuel cells seems to be very promising. In this paper we report on the fuel cell performance and corrosion characteristics with Au-, TiN-, and graphene-coated bipolar plates.

Experimental

The metal foam used in this work was made of nickel with pore size of about 800 μm. Its metal loading, usually described by its weight per geometrical surface area, was about 800 g/m^2. Because of corrosive environment in the PEM fuel cell, metal foam needed to be coated with corrosion-resistant material, similar to metal bipolar plates in that coating was needed.

Graphene has been grown on nickel foam by chemical vapor deposition (CVD) [19,20] method with a vacuum chamber (2–3 Torr) pumped by a rotary pump. The process included: (a) the furnace was heated to 1000 °C for 35 min; (b)

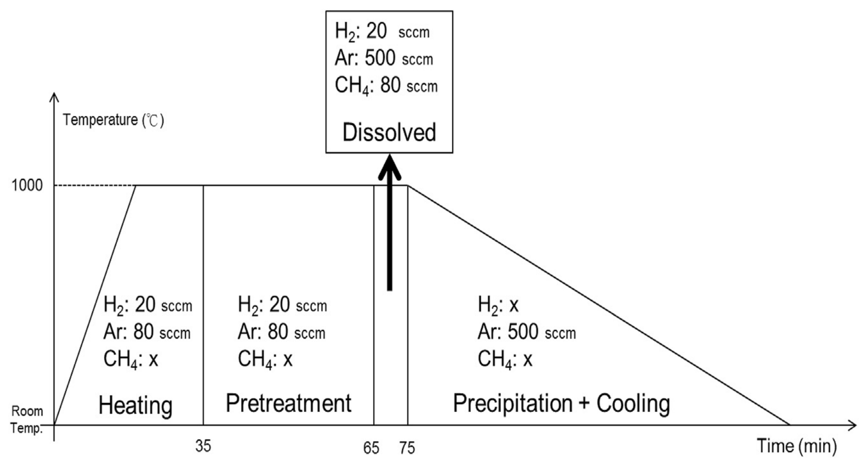

Fig. 1 – The process of graphene synthesis.

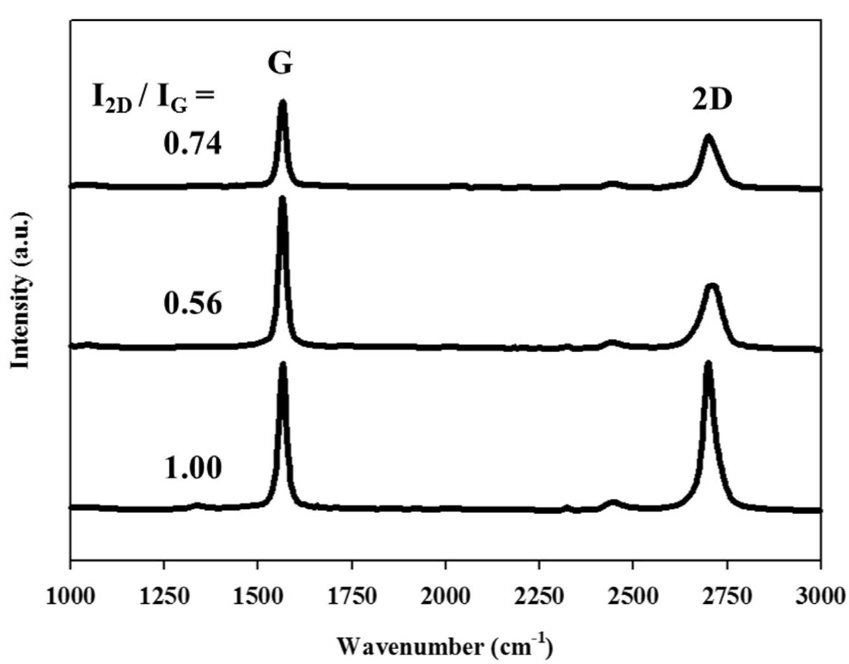

Fig. 2 – Raman spectra of graphene obtained on nickel foils.