



## Synthesis And Evaluation Of Graphene For PEMFC Catalyst Support

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### **Abstract:**

*Carbon supported platinum is a traditional electrocatalyst for proton exchange membrane fuel cell (PEMFC). The support material for the platinum is the key to the performance of the fuel cell. The catalyst performance can be enhanced by increasing the surface area as well as the electrical conductivity of the support material. Graphene is a flat monolayer of  $sp^2$  hybridized carbon atoms tightly packed into a two-dimensional honeycomb lattice, which is a basic building block for carbon-based materials. Graphene has extraordinary high electrical conductivity as well as very high surface area as compared to carbon (Vulcan XC-72). Therefore, in the present study, graphene is synthesized as a support material by thermo-chemical method. The synthesized graphene is characterized by FESEM, TEM, and XRD. The graphene supported platinum (Pt/G) is prepared by precipitation method and the prepared catalyst is characterized for particle size, surface morphology, and electrochemical performance using cyclic voltammetry. The electrochemical surface area of graphene supported platinum is around 19% more than that of the carbon supported platinum (Pt/C). The membrane electrode assembly is developed and tested in a proton exchange membrane fuel cell. The operating parameters of the fuel cell are controlled by the help of a fuel cell test station. The performances of the fuel cell developed by Pt/G and Pt/C (commercial) are compared. The maximum power densities of Pt/G and Pt/C are observed as 314 and 426  $mW \cdot cm^{-2}$ , respectively.*

**Keywords:** Cyclic voltammetry; Graphene supported Pt; TEM; PEM

## Introduction

PEMFC is one of the challenging energy conversion devices for automotive and stationary power generation. Catalyst plays important role on the performance of the PEMFC. Platinum is commonly used in the anode and cathode catalysts of PEMFC. However, the use of bulk platinum does not yield good performance of the PEMFC due to low surface area per unit weight of platinum used. Therefore, carbon supported platinum is used in commercial catalysts. Generally, the requirements for catalyst support material are high electrochemical surface area (ESA), electrical conductivity, electrochemical stability under fuel cell operating conditions, and good interaction with the catalyst. In this concern, graphene (G) has received enormous attention due to its very large surface area, highest electrical conductivity, and good mechanical strength [1]. These unique properties of graphene have attracted researchers to study its potential use in a variety of applications. Due to these features the graphene as a PEMFC catalyst support materials is being investigated [2,3]. However, there have been no reports on the evaluation of graphene supported platinum (Pt/G) catalyst at both anode as well as cathode of PEMFC. Thus, there is a scope to study the effect of Pt/G catalyst at both anode as well as cathode of PEMFC. In this connection, this paper reports the syntheses of graphene and Pt/G catalyst along with the evaluation of the catalyst in a PEMFC.

## Experimental

### *Synthesis of graphene and Pt/G catalyst*

The graphene was synthesized using chemical oxidation of natural graphite (NG) followed by thermal exfoliation [4]. The Pt/G was synthesized using precipitation method using hexachloroplatinic acid, graphene, and  $\text{NaBH}_4$  as a reducing agent [5].

### *Characterization of graphene and Pt/G catalyst*

FE-SEM (Carl Zeiss Zigma) and TEM (JEOLJEM-2010) images were recorded for morphological analysis of synthesized graphene and Pt/G catalyst. The XRD (Bruker AXS-D8) measurements were performed using a  $\text{Cu K}\alpha$  source at a scan rate of  $0.05^\circ \cdot \text{s}^{-1}$ . The ex-situ electrochemical performance of the synthesized Pt/G catalyst was evaluated using cyclic voltammetry (CV) at room temperature using potentiostat/galvanostat (CH Instruments Inc.). The  $\text{Ag/AgCl}$  (+0.236V vs. NHE) and Pt electrode used as a reference and counter electrode, respectively. The catalyst loading on the working electrode was

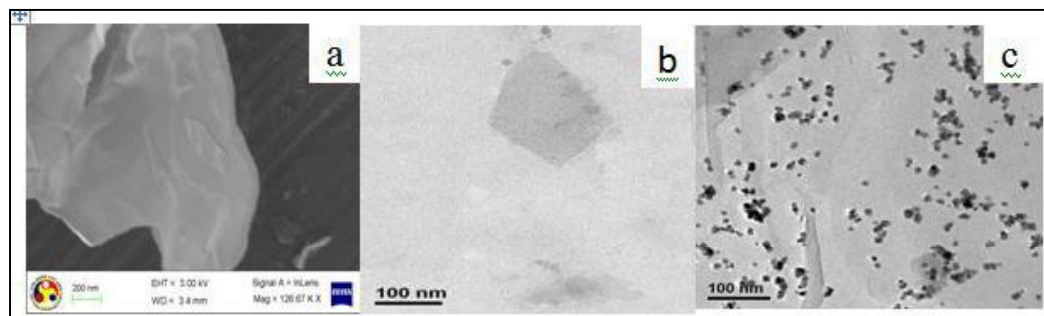
kept at  $0.6 \text{ mg}\cdot\text{cm}^{-2}$ . The  $\text{N}_2$  saturated  $0.5 \text{ M H}_2\text{SO}_4$  aqueous solution used as an electrolyte for CV analysis at a scan rate of  $50 \text{ mV}\cdot\text{s}^{-1}$ .

#### *Fuel Cell Performance Evaluation*

The performance of the fuel cell was evaluated for membrane electrode assembly (MEA) prepared with Nafion117, and electrodes with  $0.4 \text{ mg}\cdot\text{cm}^{-2}$  and  $0.6 \text{ mg}\cdot\text{cm}^{-2}$  of catalyst loading at anode and cathode, respectively. The prepared MEA was tested in a  $5 \text{ cm}^2$  PEMFC. The fuel cell was operated at  $80^\circ\text{C}$  and 100% humidity. The  $\text{H}_2$  and  $\text{O}_2$  flow rates were 75 and 150 sccm, respectively.

#### **Results And Discussion**

Figure 1(a,b) shows typical FE-SEM and TEM images of the graphene nano particles. The FE-SEM and TEM images show that the single layer graphene sheet is prepared. Figure 1(c) shows that the TEM micrograph of Pt/G. It can be seen that a large number of Pt particles are well distributed and supported on the graphene particle. The powder XRD pattern of NG, graphene nano particles, and Pt/G are shown in figure 2. The hexagonal crystalline graphite diffraction peaks (fig.2a) are obtained at around  $26.5^\circ$  corresponding to C(0 0 2) plane and at about  $55^\circ$  for C(0 0 4) plane. The broad C(0 0 2) peak near  $26.5^\circ$  (fig. 2b) is found for graphene, which is slightly shifted to lower  $2\theta$  value as compared to the graphite C(0 0 2) peak. The Pt/G diffraction peaks (fig. 2c) are found at around  $39.9^\circ$ ,  $46.2^\circ$ , and  $67.6^\circ$  due to diffraction by Pt(1 1 1), Pt(2 0 0), and Pt(2 2 0), apart from the peak at  $24.5^\circ$  for C(0 0 2) for graphene.



*Figure 1: (a) show FE-SEM surface morphology of graphene and (b) and (c) show TEM surface morphology of graphene and Pt/G, respectively.*

The average crystallite particle size on the graphene support was about 5 nm on the basis of the strongest diffraction peaks by Pt(1 1 1).

Figure 3 shows the CV results for Pt/G and Pt/C. The ESA was calculated by the eq. (1) using hydrogen adsorption peak of CV curve. The ESA is favourable for fuel cell catalyst applications. The ESA for Pt/G and Pt/C were determined as 58.86 and 48.23  $\text{m}^2 \cdot \text{g}^{-1} \text{Pt}$ , respectively.

$$\text{ESA} (\text{m}^2 \cdot \text{g}^{-1} \text{Pt}) = \frac{\text{Charge} (\mu\text{C} \cdot \text{cm}^{-2} \text{Pt})}{210 (\mu\text{C} \cdot \text{cm}^{-2} \text{Pt}) \times \text{Pt loading} (\text{g Pt} \cdot \text{m}^{-2})} \quad (1)$$

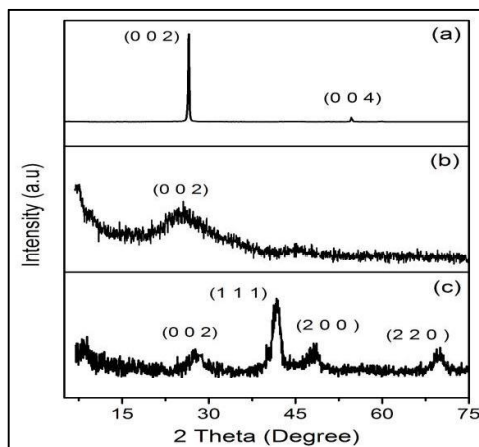


Figure 2: X-Ray diffraction pattern of (a) Graphite, (b) Graphene and (c) Pt/G catalyst.

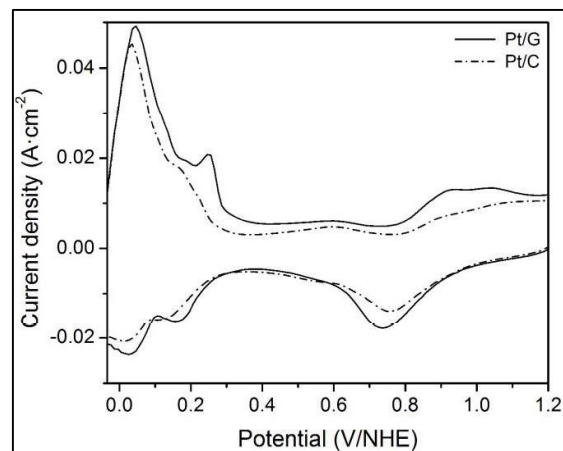


Figure 3: Cyclic voltammetry plots of Pt/G and Pt/C in aqueous solution of 0.5 M  $\text{H}_2\text{SO}_4$  at scan rate  $50 \text{ mV} \cdot \text{s}^{-1}$ .

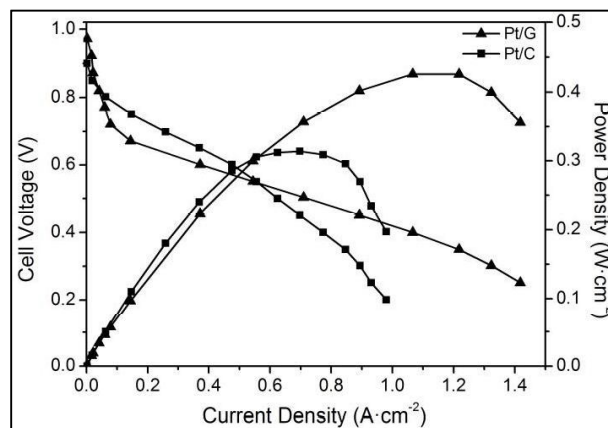


Figure 4: Single cell PEMFC performance of Pt/G and Pt/C

Figure 4 shows the performance of the fuel cell using either Pt/G or Pt/C catalyst at both the electrodes. It can be seen that superior performance was found in case of Pt/G catalysts as compared to the Pt/C. The maximum power density was improved by more than 35%. However, the performance at low current densities was inferior due to the anisotropic nature of the graphene particle, which is dominated for low current density. The anisotropic effect diminishes with increasing current density and thus the performance of the fuel cell performs better.

### **Conclusion**

Graphene was synthesized and used as support material for synthesis of Pt/G. The Pt/G was characterized and found to be more electrochemically active and the ESA of Pt/G was found to be 19% more than as compared to Pt/C. The performance of the PEMFC showed that the Pt/G catalyst improved the performance of the PEMFC by 35% as compared to the commercial Pt/C catalyst.

This preliminary study shows that the results are encouraging and thus an extensive study is required to evaluate the potential of graphene as catalyst support in PEMFC.

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