Exploiting carbon nanotubes in fuel cells

Mao Boyang*, Abdullah Kurtoglu*, Anthony R.J. Kucernak* and Milo Shaffer*

* Department of Chemistry, Imperial College London,
London, SW7 2AZ, UK, boyang.mao10@imperial.ac.uk, abdullab.kurtoglu08@imperial.ac.uk,
Anthony@imperial.ac.uk, m.shaffer@imperial.ac.uk

ABSTRACT

In order to improve the performance of polymer electrolyte membrane fuel cells, carbon nanotubes have been considered as catalyst support and as the gas diffusion layer. The multi-walled carbon nanotube (MWCNT) thin films were produced by filtration. By changing the diameter and the aspect ratio of the carbon nanotubes, the thin film's density and pore size can be adjusted. This will also affect the film's permeability and conductivity. Graded porosity gas transport layers shows promising performance. Platinum was deposited on the MWCNTs by reacting modified carbon nanotubes with Pt precursor solutions

Keywords: multiwall carbon nanotubes, proton exchange membrane fuel cell, bucky paper, platinum deposition

1 INTRODUCTION

For many years, attempts to reduce the cost of polymer electrolyte fuel cells (PEFCs) have been hampered by the large quantities of platinum required for their operation. This project explores the use of carbon nanotube thin films as a catalyst support to replace conventional carbon powders or paper in order to improve catalytic efficiency of the platinum used in (PEFCs). The efficiency of PEFCs strongly depends on the membrane-electrode assembly (MEA). Carbon nanotubes as a component of the electrode and catalyst support of PEFCs have attracted interest in recent years because of their structural, physical and electronic properties such as high chemical and thermal stability, high elasticity, tensile strength and metallic conductivity [1]. Girishkumar et al. (2005) reported that as a support material the surface area of CNT is three times larger than carbon black supports [2]. Multi-layer carbon nanotube thin film structures can be used as the catalyst support and as the gas transport layer (GTL) with the properties tailored locally to optimise transport of the relevant species.

In this work, multi-walled carbon nanotube (MWCNT) thin films were prepared, by filtration, from various treated CVD sources and characterized by microscopy, density, and wetting measurements. By changing the diameter and the aspect ratio of the carbon nanotubes, the thin film's density and pore size can be adjusted; the resulting characteristics can be estimated by a simple mathematic model. Graded GTLs structure is good for electron transfer and water management. Figure 1 shows a graded multilayer of CNT thin film as a proposed electrode for the PEMFC.

Platinum was deposited on the MWCNTs by reacting modified carbon nanotubes with Pt salt solution; the catalyst layer was characterized using cyclic voltammetry and roughness factor calculated using the hydrogen desorption charge. The optimized fuel cell electrodes were assembled into prototype PEMFC devices.

2 EXPERIMENTAL

2.1 Bucky Paper Production

The production of carbon nanotube sheets "Bucky papers" was first described by Rinzler et al. [3] Multiwall carbon nanotubes powder were dispersed in a surfactant like Triton X-100 (1wt%-2wt%) and the mass of the dispersed carbon nanotubes depends on the size of filter membrane (up to 400 mm) and thickness of the desired Bucky paper. Ultrasonic assistance is indispensable to break up the agglomerates. Ultrasonic tip is shown more effective than an ultrasonic bath in dispersing MWCTs. With an ultrasonic tip typical treatment times are 30min and 225kw energy until aggregates were reduced. Longer treatment time lead to a shortening of the CNTs. Centrifuge was introduced to remove undispersed carbon nanotube powder. Consecutive centrifugation for 30 min, 10000 rpm is recommended. The obtained CNT-suspension is then filtered using 0.40 μm polycarbonate filter membrane. The filtration can be done by vacuum or high pressure filtration. After filtration, the surfactant should be washed by ethanol. A systematic optimization of the parameters influencing the Bucky paper production was done along the production steps shown in the schematic view in figure 2.

2.2 Platinum/MWCTs Catalyst Layer Production

This method, that is used here, was adapted from the method followed by Whenzen Li et al [4]: Oxidized MWCNT were used as the platinum substrate, typical preparation processes for MWNTs-supported Pt catalysts (denoted as Pt/MWNTs) are as follows: 10 ml of surface oxidized MWNTs(1mg/mL) were sonicated for 10 minutes and suspended in 60 ml EG solution, during which 23 mg potassium tetrachloro-platinic acid K_2PtCl_4 (50 wt.% Pt) was sonicated in 10 ml water for 10 minutes then added to the solution drop-wise by an eyedropper. The pH of the solution was adjusted to above 13 using 2.0 M NaOH solution after which the mixture was sonicated for an hour. The mixture was then transferred to a round bottom flask for the deposition process on the magnetic stirrer. The solution was then heated in an oil bath at 120 °C to reduce Pt completely. After filtration and washing 0.2 µm pore size PCTE membrane, the Pt/MWNTs samples were kept as suspension in water and not dried out.

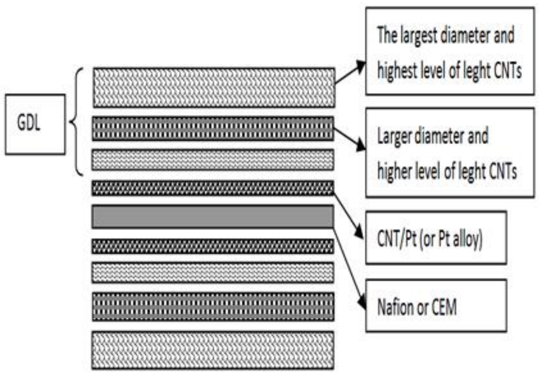

Figure 1: graded multilayer CNT thin film as a propsed electrode for the PEMFC

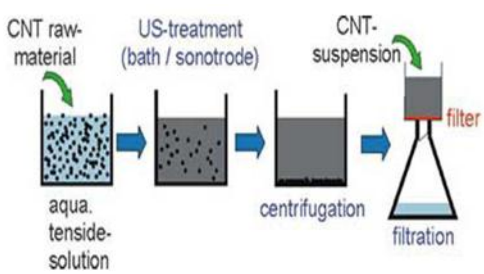

Figure 2: Schematic view of the steps to produce bucky papers

2.3 Graded CNTs Film Electrode Production

A graded or composite catalyst layer is producing by using a multi deposition method. Reducing the thickness of the supported catalyst layer and increasing the utilization of the catalyst are the objective of this method. Production of a supported catalyst layer or thin-film electrode is the goal of this technique. Different diameter and aspect ratio of MWCNT was introduced to produce this graded CNTs film electrode. The bottom layer is manufactured by CNTs with largest diameter. The buffer layer is manufactured by CNTs with smallest diameter and the top layer is Pt depositing layer.

3 RESULTS AND DISCUSSION

In order to characterize the performance of the manufactured graded gas diffusion layer, air permeability and electrical conductivity were measured as key parameters. The CNT thin film may have different porosity, thickness or density as mentioned earlier. Different aspect ratio and the amount of surfactant can affect physical features of “Bucky paper”. The thickness of the film can be controlled by changing the amount of surfactant. The resistivity “Bucky paper” is decrease with an increasing number of CNTs available for electron transport, it is accepted that thicker CNT with high CNT length provides higher conductivity. We try to find a relationship between the film thickness and the film permeability. Figure 3 show the relationship between permeability and thickness. Figure 4 shows a relationship between resistance and thickness. Figure 5 shows Pt deposited on CNTs structure.

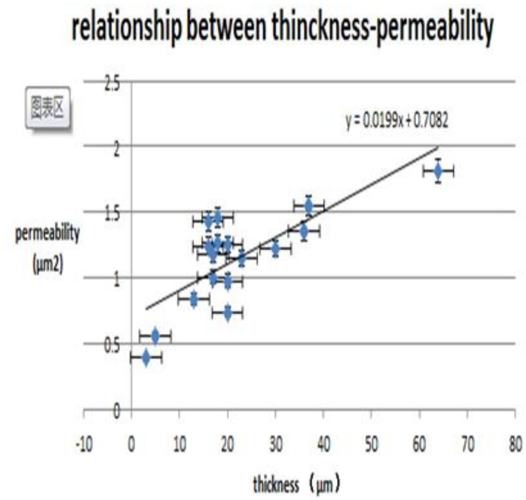

Figure 3: The relationship between thickness and permeablility

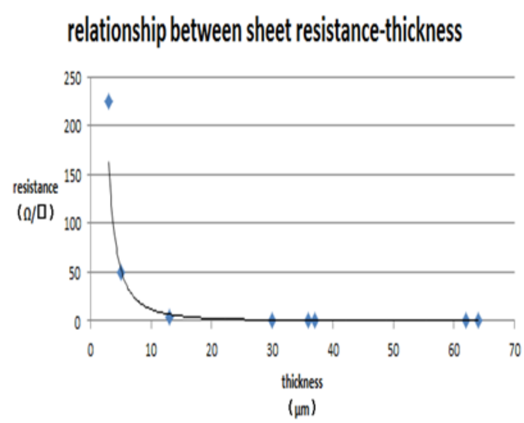

Figure 4: The relationship between thickness and sheet resistance

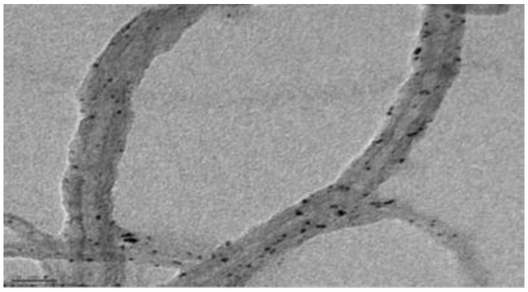

Figure 5: Pt deposited on CNTs structure

REFERENCES

[1] S.Iijima, Nature, 354 (1991) 56.

[2] G. Girishkumar, M. Rettker, R. Underhile, D. Binz, K. Vinodgopal, P. McGinn, P. Kamat, Langmuir 21, 2005, 8487-8494M. .

[3] A. G. Rinzler, J. Liu, H. Dai, P. Nikolaev, C. B. Huffman, F. J. Rodriguez-Macias, P. J. Boul, A. H. Lu, D. Heymann, D. T. Colbert, R. S. Lee, J. E. Fischer, A. M. Rao, P. C. Eklund, R. E. Smalley, Applied Physics A (1998) 29.

[4] Li and W., Homogeneous and controllable Pt particles deposited on multi-wall carbon nanotubes as cathode catalyst for direct methanol fuel cells. Carbon 2004, 42(2): p. 436-439.