

Development of the Electrodes Layer (Anode / Cathode) in the Electrocatalysts of Fuel Cell System

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ملخص البحث:

أن الأقطاب الكهروكيميائية (قطب موجب / قطب سالب) في نظام خلية الوقود المنفصلة ذات وظيفتين داخليتين؛ هما المحلل الكهربائي و خلية وقود. وعلي هذا الاساس ، يمكن توحيدهم في خلية وقود واحدة قابلة للعمل كوظيفة واحدة للعمل في توليد الكهرباء من حيث أن هذه الاقطاب الكهروكيميائية الثنائية الموحدة تشترك في نفس الخلية وذلك لتخفيض حجم الخلية و تحسين كفاءة أداء الخلية. و لذلك ، فإن الاقطاب الكهروكيميائية في خلية الوقود قابلة للعمل كوظيفتين أساسيتين من حيث عكس و توحيد عمل دورة جزيئات الهيدروجين والأوكسجين في الخلية و الذي لهما أثر كبير في تحسين و رفع كفاءة توليد الكهرباء في الخلية على أغلب التطبيقات المستعملة. على أية حال ، هذه الورقة تركز عملها على تحضير الأقطاب الكهروكيميائية ثنائية الوظيفة كتصميم جديد في إضافة مادة مسحوق الكربون الاسود المدعم بمعدن البلاتين و معدن النيكل الي الاقطاب الكهروكيميائية. علاوة على ذلك ، راجعت الدراسة آخر التطورات التصميمية على الأقطاب الكهروكيميائية ثنائية الوظيفة والمحفزات الكهروكيميائية الاخرى و المشاكل الرئيسية التي حدث في هذه التصاميم السابقة للاقطاب الكهروكيميائية في خلايا الوقود.

Abstract:

The electrodes (anode / cathode) in the fuel cell system is separated for two internal functions; it is electrolyzer and fuel cell mode. Therefore, the Unitized of Reversible Fuel Cell has dual function electrodes are joined in the same cell to reduce the volume and improvement efficiency performance. electrodes of Unitized Reversible Fuel Cells operating on hydrogen and oxygen which have as high as efficiency at most the applications. However, This paper is concentrated on the preparation of bifunctional electrodes as design and material with low platinum loading and supported by Nickel

and Platinum Carbon Black and characterization by using scanning electron microscopy. Moreover, survey the latest literature on bi-functional electrodes and electrocatalysts to identify the major problems occur in design of the fuel cell electrodes.

Keywords: Fuel Cell System, Catalyst Layer, Electrodes, Electrolyzer, Anode, Cathode.

1. Introduction

Presently, the reversible of fuel cell is believed to be a promising alternative. It works both as H_2/O_2 fuel cell and water electrolyzer with a single operation unit. The practical energy density of URFC can achieve $500-800W\ h\ kg^{-1}$ [1]. In this system the electrodes are the sites where electrical energy conversion occurs and it is considered as the heart of the proton exchange membrane fuel cell which is transport the protons from the anode to the cathode. Most of the electrodes were made by 10:20 wt. % platinum supported carbon black (Pt/C) within 60:70 wt. % polytetrafluoroethylene (PTFE) as a binder and wet roofing agent and Nafion solution as a proton conductor between the catalyst layer and Nafion117 membrane as shown in Fig. 1. URFC is a reversible electrochemical device which can operate either as an electrolyser for the production of hydrogen and oxygen (water electrolysis mode WE) or as a H_2/O_2 fuel cell for the production of electricity and heat (fuel cell mode FC). In the past, the system was suffered from un acceptable low electrochemical performances. This was due to problems with membrane and electrocatalysts [2]. In 1998 Proton Energy Systems has developed a commercial product (Unigen reversible module) consuming 15 kW in electrolysis mode and producing up to 5 kW of electric power in fuel cell mode.

This article has focused on the design preparation of bifunctional electrodes with low platinum loading by using supported carbon black. The aims of the paper is to review the latest details on the development of bifunctional electrodes catalyst layer as well as the progress of reduction in the URFC cost by low platinum loadings in the latest cell design.

1. Description of the structure components of URFCs

In fuel cell assembly, there are many parts that combine together to make it a cell and to carry out the reactions. The polymer electrolyte membrane based unitized reversible fuel cells can operate as electrolyzer to split water into hydrogen and oxygen by using electric power. When fed hydrogen and oxygen or air, the same cell/stack set-up can operate as a fuel cell to supply electric power. In actual operation, URFCs can be reversed and switched so that they can act as both an electrolyzer and a fuel cell. Due to its low self discharge, a URFC system that includes a hydrogen storage unit is attracting attention for its role in long term energy storage and back-up power, and can thus replace a secondary battery in some applications [3, 4]. In Fig. 2 shown the sketch of URFC for single cell structure, the configuration of a URFC with a proton exchange membrane is consisting of a membrane electrode assembly, gas diffusion layers, and bipolar plates with flow channels [4, 5].

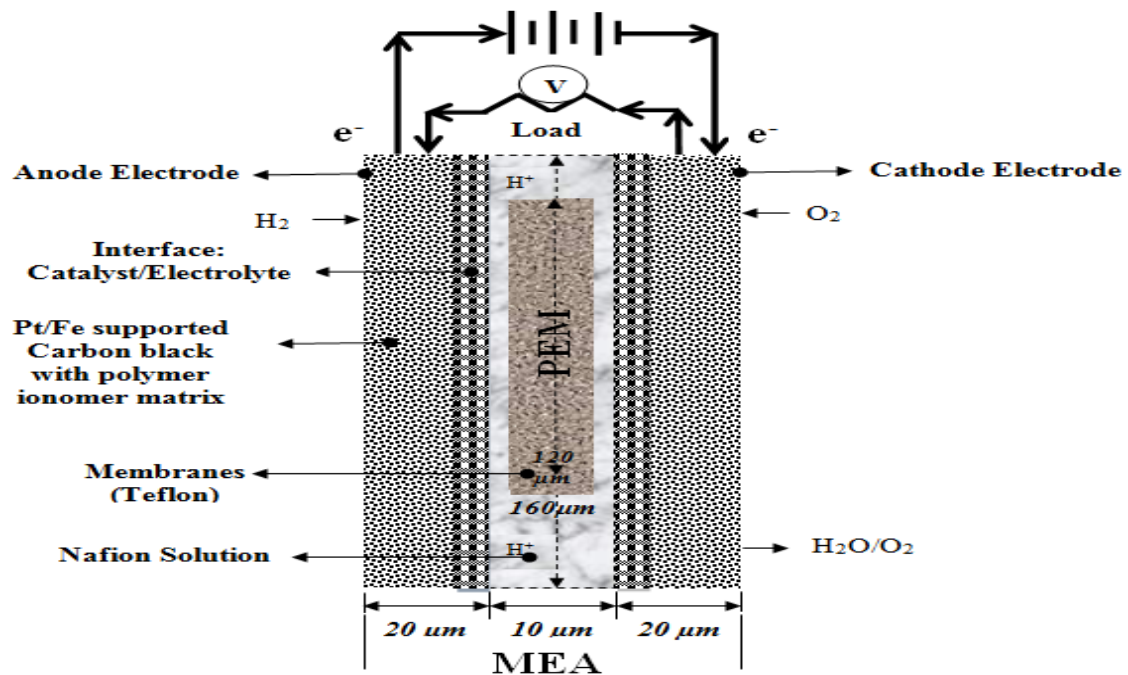


Figure 1. Sketch design of the electrodes with supported catalyst layer in MEA

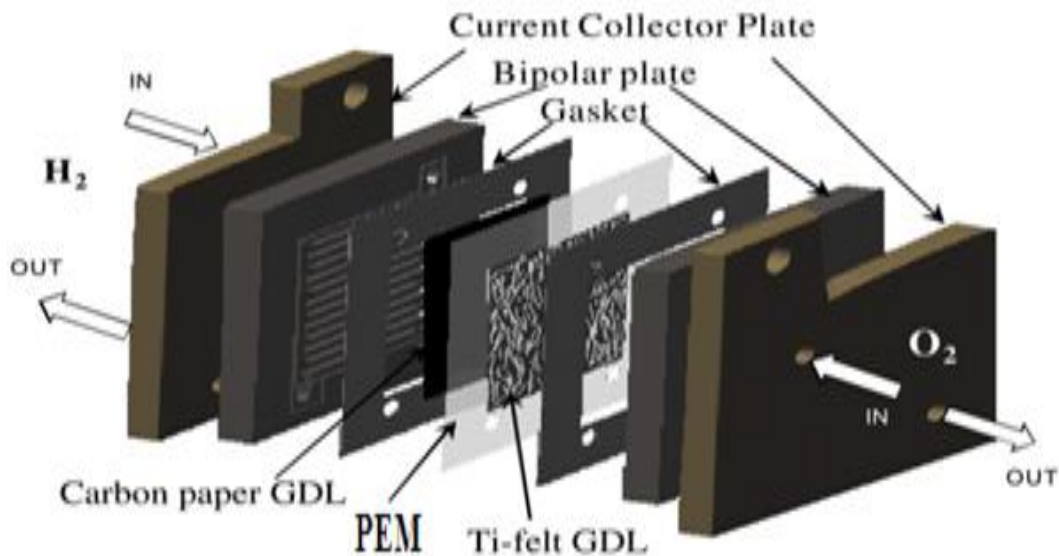


Figure 2. Sketch components of URFC for single cell structure [4]

2. Electrodes in unitized reversible fuel cell

URFC electrode designs have typically used proven and tested methods to produce (electrode//membrane//electrode) interface. Most widely used is the transfer print technique followed by hot press or roll press of the design for more intimate contact of active materials [6]. The electrodes of unitized regenerative fuel cell are electrochemical cells working both as fuel cells and water electrolyzers. In water electrolysis mode, the

water is electrolyzed to hydrogen and oxygen which are recombined to produce electricity in the subsequent fuel cell mode. With the advantages of being free of self-discharge and theoretically higher energy densities [6, 7]. The electrodes are typical gas diffusion electrodes. The backing layer of the electrode is a porous carbon cloth/paper with a hydrophobic coating of Teflon, for the electrochemical reactions to take place at useful efficiency [8]. The demands on fuel cell electrodes are perhaps even more extreme than those on the electrolyte. The ideal electrode must transport gaseous or liquid species, ions, and electrons; at the points where all three meet, so-called triple point boundaries, the electrocatalysts must rapidly catalyze electro-oxidation (anode) or electro-reduction (cathode). Furthermore, the electrocatalyst is typically restricted to a very thin layer adjacent to the electrolyte, and another layer, the "gas diffusion layer" serves the role of transporting electrons and gases from the rest of the MEA [7, 8]. SEM of a single-cell of electrodes for anode and cathode URFC system is shown in Fig. 4.

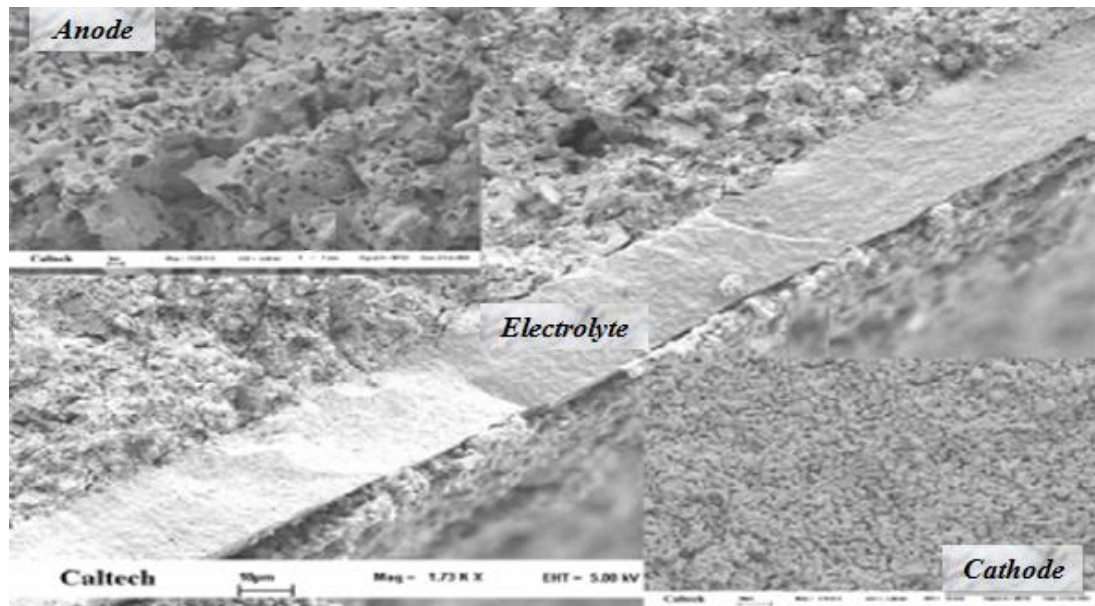


Figure 3. SEM of a single-cell of electrodes of URFC [8]

3. Potential and barriers of URFCs

The required commercial fuel cell is over 5000hr for light-weight vehicles and over 40,000hr for stationary power generation with less than a 10% performance decay. A few years ago, the fuel cell cost has been reduced from \$275/kW in 2002, \$108/kW in 2006, and \$94/kW in 2007 to \$73/kW in 2008, which equates to almost \$6000 [9, 10]. The Pt loading has been reduced by two orders of magnitude in the past decade and there is still room for further loading reduction. The 2010 and 2015 DOE targets for the fuel cell cost is \$45/kW and \$30/kW, respectively, for transportation applications [11, 12]. A discussion of cost breakdown and projections for URFCs is provided below in Table 1.

The Electrodes currently dominate the URFCs cost prototype, as they are manufactured manually. Electrodes cost may be reduced from between \$1,500/m² to

\$150/m² through mass production and new technologies that require less Pt. Current systems require 0.6-0.8 mg Pt/cm², equal to around 1 g/kW. The goal is to arrive at 0.2 mg/kW [13, 14].

Table 1. Cost Projections for URFCs [\$/kW]

URFCs	Prototype		Mass production		Target	
	\$/kW	%	\$/kW	%	\$/kW	%
Membrane	250	14	14	16	13	25
Electrodes	710	39	50	49	25	48
Bipolar plate	825	45	28	29	8	17
Pt catalyst	27	2	3	3	2	4
Assembly	8	0	2	3	3	6
Total	1820	100	97	100	51	100

4. Conclusions

The review was reported the recent details on the improvement of electrodes catalyst layer for URFCs in the latest stack designs and materials. However, it is still a need for further reductions in the cost through enhancement in the design and performance of the electrodes membrane assembly for URFC system. The following conclusion was out come of the review that can be pointed as follow:

- ❖ The supported catalyst layer guides to a better performance in the cell. Therefore, the membrane electrode assembly able to be preferred for reversible fuel cell applications.
- ❖ The increasing forced in the water concentration at the electrode assembly improved the performance of high PTFE electrode as well as, may be by increasing platinum active area.
- ❖ The better behavior performance when there is less contact between electrode and electrolyte that leads to reduce the power density at higher current density in the URFC system.

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