Abstract: - Fuel cell or hydrogen systems offer the potential for clean, reliable and on-site energy generation. This article review current literature with the objective of identifying the latest development in membrane electrode assembly catalysts and bipolar plates materials used in fuel cell. The result shows that the most of studies related to bipolar plate materials are focusing on increasing the corrosion ability, decreasing the weight and therefore the cost and also to increase the electric conductivity. The stainless steel used as bipolar plate can be treated or coated with a thin layer of titanium to increase its ability to withstand corrosion, also gold used to enhance the performance of the stainless steel bipolar plate in term of corrosion and electric conductivity. Graphite as a famous material used as bipolar plate can be adopted with some polymer or thermoplastic materials to enhance it is mechanical properties. For the catalysts, still the Pt is the most common candidate and thus, reducing the platinum loading to eliminate the cost and implementing new method to supply the Pt to the membrane was currently under more studying concentrations.

Keywords: - Fuel cell; bipolar plate; titanium; membrane; catalyst

1 Introduction

Fuel cell based power plants offer one of the most lucrative possibilities for future power generation and the fuel cell is also found to be potentially more efficient than the conventional plants since the fuel reacts electrochemically instead of combustion. In this way there is far less air, thermal, and noise pollution issues to be considered. A fuel cell is an electrochemical device that produces electricity by separating the fuel (generally hydrogen gas) via a catalyst. The protons flow through a membrane and combine with oxygen to regenerate water with the help of the catalyst used while the electrons flow from the anode to the cathode to create electricity. Figure 1 illustrated the fuel cell stack components.

Bipolar plate is an important multifunctional component of proton exchange membrane fuel cell (PEMFC), and accounts for about 80 % of total weight and 45% of the stack cost. The plates must be of inexpensive, lightweight and must be easily manufactured for commercial application of PEMFC[1].The main materials investigated to date include stainless steel ,graphite and few other metallic materials. While, each one of these materials has advantage and disadvantage in term of corrosion, conductivity, mechanical properties and cost.

A fuel cell (PEMFC) also consists of two electrodes separated by a solid electrolyte: the negative electrode (anode) is supplied with a fuel (hydrogen, methanol, etc.); and the positive one (cathode) with a oxidant (oxygen, air, etc.))[2].both of electrode should have catalyst to facilitate the required chemical reaction to occur with better performance. The intimate contact between membrane electrode assembly (MEA) and the flow field plate are shown in figure 2.Platinum was and still the best candidate even it is consider to be a costly material for that, reduce the amount of platinum loading and investigate new methods to supply the platinum was gained more attention last decade in order to reduce the total cost of the fuel cell.

The objective of this study is to review of the latest development in the materials used for the bipolar plate and the development in the membrane electrode assembly (MEA) for fuel cell.
Flow channels are conveniently machined into a bipolar plate or field plate to allow a high electronic, good thermal conductivity and stability in a chemical environment inside a fuel cell [3]. In a fuel cell stack, each bipolar plate supports two adjacent cells and the bipolar plate is known to have five typical functions: (1) to distribute the fuel and its oxidants within the cell (2) to facilitate water management within the cell (3) to separate individual cells in the stack (4) to transport currents away from the cell and (5) to facilitate heat management [4]. The sketch of a bipolar plate is shown in figure 3.

The main target for all researchers is to focus on the bipolar cost reduction, increase the electric conductivity, decrease the weight and increase the corrosion resistance. Generally most of the bipolar plates used in conventional fuel cells are either made of graphite, stainless steel or of other metallic materials. In this article, we would like to review the latest development of each material individually.

### 2.1 Stainless Steel

Stainless steel is widely used as a bipolar plate for fuel cell application that is due to its chemical stability during the chemical reaction and also its ability to conduct electric however, its corrosion resistivity is low unless treated or coated with some other material to enhance its corrosion resistivity. Hornung and Kappelt [5] examined the suitability of economical corrosion resistance of Fe-based alloys (FeBs) in the construction of bipolar plates. The results indicate that most of the (FeBs) exhibit a characteristic comparable to that of the Ni-based alloy. Makkus et al. [6] tested several stainless steel bipolar plates and found that using stainless steel as a flow plate at the anode side of a solid polymer fuel cell (SPFC) results in a higher contamination of the MEA as compared to a stainless steel flow plate that is used on the cathode side. Davies et al. [7] tested three stainless steel alloys (310, 316 and 904L) as candidate bipolar materials for proton exchange membrane fuel cell (PEMFC). The fuel cell performance for the above bipolar materials is observed in the following order: 904L<310<316. Wang et al. [8] coated 316L and 317L stainless steel bipolar plates with 0.6 μm thick SnO₂:F. and this study suggests the possibility of using SnO₂:F coated with 317L Polymer electrolyte membrane fuel cell bipolar plate application.

Ren and Zeng [1] prepared compact titanium carbide as a coating for the type 304 stainless steel bipolar plate with a metallurgical bonding between the coating and the substrate. In this study it is found that TiC coating increases the corrosion potential and significantly decreases its corrosion current density. For the TiC-coated steel, it is observed to have no obvious degradation after a 30-
day exposure in the solution. Lee [9] coated thin stainless steel bipolar plates with 5 µm thick of multi-layered corrosion resistant material. The proposed manufacturing procedure proves to be a promising technology in producing metallic bipolar plates with micro-features.

Nam and Lee [10] evaluated the electrical and corrosion properties of surface-nitride AISI316L stainless steel bipolar plates for a PEMFC. The study shows that stainless steel with the Cr2N nitride protective coating layer exhibits a better interfacial contact and corrosion resistance than the as-rolled or (CrN + Cr2N)-coated AISI316L stainless steels.

Wang and Turner [11] tested ferrite stainless steels (AISI441, AISI444, and AISI446) coated with 0.6 µm thick SnO2:F bipolar plate simulated in PEMFC environment. The results show that a SnO2:F coating enhances the corrosion resistance of the alloys and AISI446 shows an excellent corrosion resistance and the SnO2:F coating seems to create additional resistance in the native air-formed films on these stainless steels. Wang and Northwood [12] used a Coated TiN on a martensitic stainless steel (SS410) as a bipolar plate. The results of this study show that this coating forms a much improved corrosion resistance on SS410 and therefore these coated materials could potentially be used in PEMFCs as a bipolar plate material provider. Lafrance et al. [13] coated a stainless steel (316L) bipolar plate with amorphous Zr75Ti25 alloy in simulated PEMFC in conditions of 25°C and 80°C. It is concluded from the corrosion data of this work that in the anode environment of a PEMFC, the Zr75Ti25 alloy could be a better candidate than 316L for bipolar plates. The contrary is observed in the simulated cathode environment.

Jayaraj et al. [14] developed Fe- and Ni-base amorphous alloys as alternative bipolar plate materials for PEMFC. The results show that the Fe-base have lower interfacial contact resistance as compared to the Ni-base and both the Fe- and Ni-base amorphous alloys display a higher corrosion resistance than stainless steel. Wang and Northwood [15] coated SS316L with TiN as a developing metallic bipolar plate. The tests show that the corrosion resistance of SS316L significantly increases at 70°C by coating with TiN for both anode and cathode conditions because the TiN-coated specimen is affected by pitting corrosion.

2.2 Graphite
One of the most well established material for bipolar plate is graphite. Graphite is electrically conductive and reasonably easy to machine. It has also a very low density. However, it has three major disadvantages [16]:

- The machining of the graphite may be done automatically but the cutting takes time even on an expensive machine.
- Graphite is a brittle material and so the resulting cells need careful handling and the assembling is made difficult.
- Graphite is quite porous and therefore the plates need to be a few mm thicker to keep the reactant gases apart; this means that although the material has a low density, the final bipolar plate is not particularly light.

Due to these reasons above, many researchers work to enhance the performance of graphite bipolar plate such as, Scholta [17] which presented a novel low cost graphite composite material bipolar plate as a promising candidate for PEMFC bipolar plate. Kakati [18] prepared composite bipolar plates for PEMFC by the compression molding technique using polymer as a binder and graphite as an electric filler material with some other reinforcements. Shen [19] used sodium silicate/graphite composite as an acid corrosion resistant bipolar plate. The metal ionic content leach from this new bipolar plate is less than that from austenitic stainless steel. Dweiri [20] adopted polypropylene, carbon black with graphite as prospective replacements for the traditional graphite bipolar plate in PEMFC. Yin [21] mixed phenol formaldehyde resin powder with graphite powder as raw materials and used it as a kind of conductive composite for bipolar plate after a hot pressure molding process. The results show that: the conductivity decreases with the increase of PF resin content and the best conductivity is 142 s.cm\(^{-1}\) when its PF resin content is 15% molded at 240 °C for 60 min. Radhakrishnan [22] prepared hybrid composites bipolar plate consisting of high-temperature thermoplastic, graphite and a third additional conduction component. Table 1 listed the electric conductivity of some selected materials.

Some others used other materials, Kumar [23] used a porous material for a gas flow-field bipolar/end plate. It is observed, that the performance of fuel cell with Ni–Cr metal foam was highest, and decreased in the order SS-316 metal foam, conventional multi-parallel flow-field channel design and carbon cloth. Show [24] tested a Ti bipolar plate coated with amorphous carbon (a-c) film for PEMFC. The results show the fuel cell output is 1.4 times higher than the output of a bare (not a-c coated) Ti bipolar plate fuel cell.
Maheshwari [25] developed a polymer composite bipolar plate by making use of carbon fiber network in a specific form as a filler component. The plate when used in the unit fuel cell assembly show I–V performance comparable to that of the commercially available bipolar plates but with a higher strength and stiffness. Wang [26, 27] developed a light weight and corrosion resistant bipolar plate for the PEMFC. The bipolar plate was made from titanium and coated with gold.

Table 1 Electrical Conductivity for Selected Materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Electrical Conductivity (S/m)</th>
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<tbody>
<tr>
<td>Gold</td>
<td>45.2x10^6</td>
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<tr>
<td>Aluminum</td>
<td>37.7x10^6</td>
</tr>
<tr>
<td>Titanium</td>
<td>2.34x10^6</td>
</tr>
<tr>
<td>SS 316</td>
<td>1.33x10^6</td>
</tr>
<tr>
<td>Graphite</td>
<td>1.27x10^5</td>
</tr>
</tbody>
</table>

3 Membrane Electrode Assembly (MEA) For Fuel Cell

For the conventional fuel cell the problem of corrosion is less than the URFC because the cell works only as a fuel cell. However, continuous research has been carried out to enhance the ability of the membrane to produce the required chemical reaction. Towne [28] developed a new method for fabricating MEAs for PEMFCs using a homemade inkjet printer device to deposit successive layers of Pt/C catalyst. The cell successfully operated 10% less of catalyst loading than the commercial membrane which operates by 33% less of the catalyst loading of 0.2 mg/cm^2 of Pt approximately. Qi [29] also found that the loading rate of 0.2 ± 0.05 mg/cm^2 lead to maximum performance.

Taylor [30] also used the inkjet printer device as a catalyst application method for PEMFCs and the results show that this method will lead to a very low platinum loading but the low loading is not easily attained when using conventional loading method. Gruber [31] fabricated a mini fuel cell with maximum power density of 149 mW/cm^2 at a very low loading of 0.054 mg/cm^2 for both anode and cathode. Gruber [32] also used sputter-deposited method for applying the Pt as a catalyst material for PEM fuel cells with an ultra low loading of 5 µ g/cm^2. The author also studied the effect of using the sputter-deposited method on different porous electrodes and found an 8% performance improvement after adding chromium or by coating with a thin film-like layer of palladium. Moreira [33] used Palladium (Pd) as a catalyst with Carbon and Vulcan as supporting materials. The results indicate that Pd, with Vulcan presented a better performance.

4 Conclusions

This paper reports the development on bipolar and membrane catalysts material for conventional fuel cells and the following conclusions from this study can be summarized as:

1. Most of the research on fuel cell component materials focus on cost and weight decreasing and increase the electrical conductivity, therefore currently a metallic material has received more attention to be used as fuel cell bipolar plate selection material.
2. Coating the stainless steel with Ti, Ni or other metallic material will enhance the corrosion resistivity and increase it is conductivity and consequently increase the fuel cell stack performance.
3. Graphite is a brittle material so a bipolar plate with low thickness will facing rupturing when stack it in the fuel cell stack, for that mixing of graphite with some polymer or thermoplastic material will enhance it is mechanical properties.
4. For the conventional fuel cell catalyst material most of the research focuses on decreasing the rate of platinum loading and therefore the total stack cost. Recent research used ultra low rating with less than 0.05 mg/cm^2 with very competitive cost and performance.

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References:


