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A Review on Proton Exchange Membrane Fuel Cell Applications & Challenges

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Abstract: ***For unpolluted and effective power generation, proton exchange membrane fuel cells are reflected to be a positive technology. This interest is due to their high efficiency, high power density and no environmental pollution. Polymer electrolyte membrane fuel cells (PEMFC) are the foremost appropriate form of fuel cells to be used in vehicles due to their low performance temperature and high power density. Proton exchange membrane is that the key component of electric cell system. But there are various challenges remaining that need to be overcome previously PEMFCs can effectively and economically substitute for the traditional energy systems. During the last few decades some, numerous efforts are made to advance the PEM cell technology and fundamental research. Factors like safe storage of hydrogen, durability and price still remain because the major barriers to fuel cell commercialization and so are the most important concern among scientists.***

Keywords: Proton exchange membrane fuel cell (PEMFC), Applications, Challenges

1. Introduction

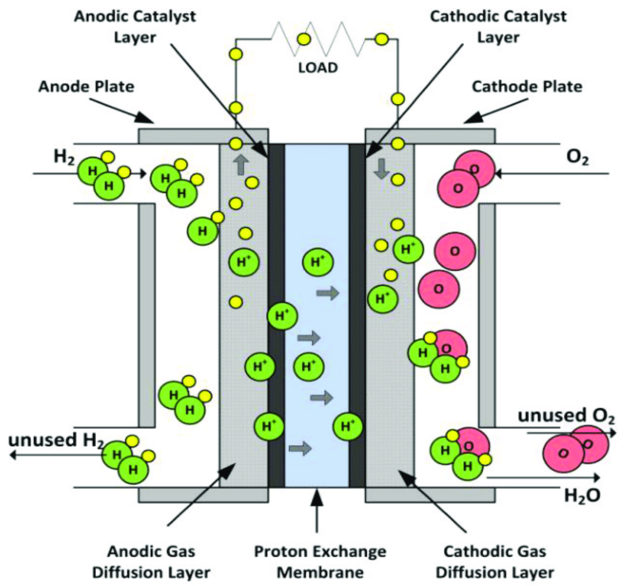

Figure 1: Proton exchange membrane fuel cell [1]

Proton - exchange membrane fuel cells (PEMFC) or polymer electrolyte membrane (PEM) fuel cells, are a kind of electric cell mainly used for transport applications, moreover as for stationary fuel - cell applications and portable fuel - cell applications. [2] Their exclusive features include lower temperature ranges (50 to 100 °C) and a distinct proton - conducting polymer electrolyte membrane. [3] Proton Exchange Membrane Fuel Cell (PEMFCs) has establishedposition as a hopeful technology because of its great energy conversion efficiency. [4, 5] In PEMFCs, the charged protons drawn out through one side of porous membrane & drift towards the cathode and hydrogen atoms are exposed of their electrons at the anode, The electrons permit from the anode to the cathode through an external circuit and supply electrical power At the cathode, the electrons, hydrogen protons and oxygen from the air combine to create water. Proton exchange membrane electrolyte must permithydrogen protons to pass through, but reject the passage of electrons and heavier gases. There are two classes of proton exchange membrane fuel cells, i. e., Hydrogen Fuel Cells and Direct Methanol Fuel Cells (DMFC). In both the cell, proton exchange membrane is employed to transfer protons. High power electric cell and high performance favor the selection of Hydrogen Fuel. [6 - 8]

2. Applications of PEMFC

There are various advantages of proton exchange membrane fuel cell such as a low operating temperature, low weight, and compactness, the potential for low cost and fast start - ups and suitability for discontinuous operation [9 - 10]. Due to these features PEMFCs becomes the most promising technology for applications like portable/micro power and transportation to large - scale stationary power systems for buildings and distributed generation. The use of PEM fuel cells emphases on transportation primarily due to their potential impact on the control of emission of the greenhouse gases (GHG). Other applications comprise distributed/stationary and portable power generation. Due to their high power density and outstanding dynamic characteristics as compared with other kinds of fuel cells, Most of the motor companies work exclusively on PEM fuel cell. Owing to their light weight, PEMFCs are typically appropriate for transportation applications. PEMFCs for buses, which use compressed hydrogen for fuel, can operate at up to 40% efficiency. . Fuel cell vehicles are not advantageous if H2 is sourced from fossil fuels; however, they become advantageous when applied as hybrids. [11 - 13]

2.1 Transportation

In today's time the means of transport plays a vital role. The present technologies are not environmentally sustaining in nature. So it is essential to alter the technology. The scientists have realized that they will establish the vehicles with PEMFC technology. This technology can switch the older complex technology. PEMFCs having advantage of low operating temperature range. The PEM techniques are applicable for the transporting devices. The most favoring point to consider is these technologies don't require pure hydrogen used as fuel, are often operated without any rotating parts. Also, it doesn't exhibit any significant poisoning systems. [14]

2.2 Portable Devices

This will be the widely used major applications of cell within the equipment's like portable computers, mobile phones, telephones and one in all of the important applications is military application. This area will include sustainability in terms of expansion. [15 - 16]

2.3 Stationary power Generation

India is facing an enormous power shortage which affects the expansion of economy. Use of PEMFC equipment for power generation can grab this shortage issue. Vital markets for fuel cell technology in India, as per the reading shown by the TERI - Delhi, are telecommunication sector, chlor - alkali industry, dairy industry and paper pulp industry [17]. The centralized large - scale power plants have many benefits like high efficiency, yet there are power loses due to long distance transmission which affects the efficiency. The way to overcome this drawback is a decentralized power generation which generates heat and energy for local usage. The back - up power generation is also a potential area for adoption of PEM fuel cells as power generating unit. Organizations for example banks, hospitals and telecom sector need uninterrupted power supply (UPS) to avoid sudden power breakdowns and thus are potential customers of back - up power supply by PEMFCs.

2.4 Portable power generation

As the demand of portable electronic devices such as laptops and mobile phones is growing day by day there is a high demand of power for use in portable devices. Conventional batteries used for this purpose doesn't produce satisfactory results due to their low power outputs and long charging durations. In today's world area of portable power is not only limited to laptops and mobile phones but also used in robot and power toys, boats, radio control cars and emergency lighting is also encouraged these days [18].

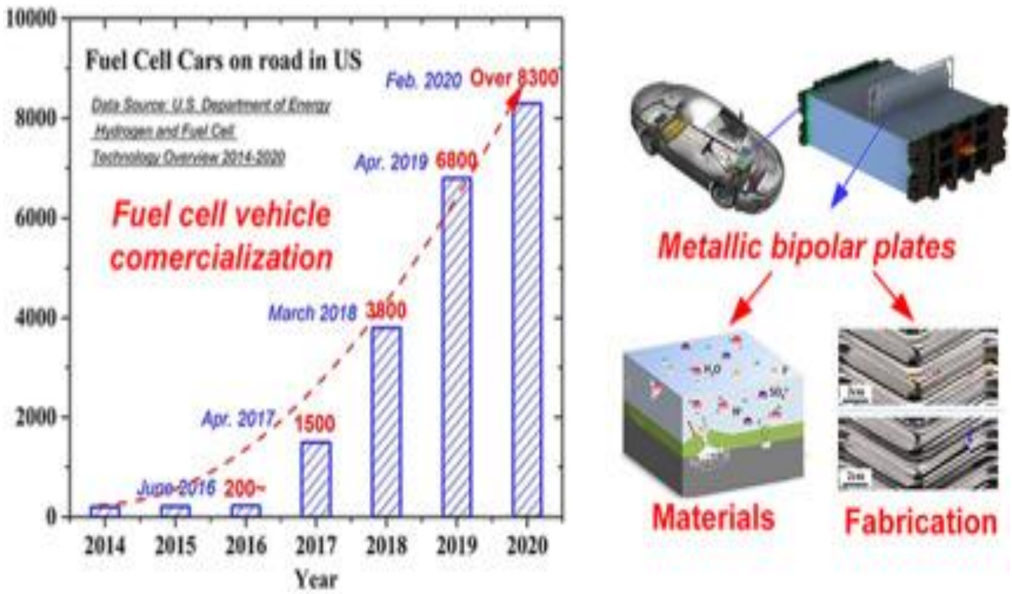

Figure II: Fuel cell vehicle commercialization [19]

3. Challenges

3.1 Cost reduction of PEM fuel cell system

The most critical challenge for PEM fuel cells today still remains in their cost. Thetotal price of a typical PEM fuel cell is the addition of the cost of the membranes, platinum electrodes, bipolar plates, peripherals and the assembly process. About 80% of the total cost is the cost of the bipolar plates and the electrodes including platinum. A typical PEM fuel cell system costs USD 53/kW as per 2016 stats. But competitively in order to sound more economical, fuel cell system must cost USD 30/kW. Especially the platinum content in these fuel cells contributes more to the overall cost, so in one way or another, this platinum content should be reduced or totally removed. Various researches on platinum loading matter have focused on improving the electro - catalytic activity of platinum based catalysts. Another approach is to eliminate the use of Platinum entirely by developing a Non - platinum group metal cathode catalyst whose performance rivals A that of platinum based technologies. [20]

3.2 Stable supply of hydrogen with high purity

Traditional methods of hydrogen production just like the steam reforming of gas or by coal gasification, causes the unavoidable CO2 emission. Additionally the assembly of CO can cause serious poisoning of the anode electro catalysts within the fuel cell. Hydrogen are often stored as compressed gas or as a cooled liquid. Despite these methods, storing hydrogen to power a car requires a oversized tank. These problems should be resolved otherwise PEMFC will unsuccessful in various application field. Several studies are meted out on high - purity hydrogen producing technologies including the water electrolysis, using the electricity from wind turbines and solar cells. For instance, Lee et al applied a study of manufacturing hydrogen using the surplus electricity from wind turbines. [21] The price of the hydrogen produced by this program was over twice that produced by methane reforming. So it is said that further studies on areas like the electrolyzer design and energy flow are going to be needed to develop a more efficient system. A compact on - site hydrogen generator produces noticeably pure hydrogen from methanol water mixture. This technique consists of a methanol steam reformer to urge hydrogen rich reformed gas and a metal membrane purification part to recover high purity hydrogen from the reformed gas.

3.3 Other technical issues

In addition to the previously discussed challenges, there are another technical issues in a PEMFC system. They include water and thermal management, scale - up from single cells to cell stacks, fuel processing, CO poisoning of the platinum anode electro catalysts and therefore the over potential of cathode electro - catalysts. Sometimes due to improper thermal management, comes various complications. Among them the electrolyte dehydration and cathode flooding impose the foremost critical challenges to PEMFC operation. Liquid water accumulation within the pores of the cathode electrode (including catalyst layer and GDL) causes the cathode flooding. [22] Also the delaying oxygen transport to the catalyst site is one among the fore most common issues in water and thermal management.

Table I: Various challenges in PEMFC [23]

Task	*Approach*	*Activities*
Catalysts/ Electrodes	• Optimize electrode design and assembly • Makeelectro catalysts and electrodes with reduced platinum group metal (PGM) loading, increased activity, improved durability /stability	Argonne National Laboratory: Tailored High Performance Low - PGM Cathode Catalysts • Brookhaven National Laboratory: Platinum Monolayer Electrocatalysts
Membrane Electrode Assemblies, Cells, and Other Stack Components	Integrate membranes, electrolytes and electrodes • Enlarge MEA operating range, addressing temperature and humidity range, improving stability, and mitigating effects of impurities	3M: High Performance, Durable, Low Cost Membrane Electrode Assemblies for Transportation • Advent Technologies: Facilitated Direct Liquid Fuel Cells with High Temperature Membrane Electrode Assemblies
Fuel Cell Performance and Durability	• Improve component stability and durability • Improve cell performance with optimized transport • Make new diagnostics, characterization tools, and models	• Fuel Cell Performance and Durability Consortium (FC - PAD): Los Alamos National Laboratory, Lawrence Berkeley National Laboratory
Membranes/ Electrolytes	• Identify electrolytes and membranes/matrices with improvedconductivity over the entire temperature and humidity range of a fuel cell and Improved mechanical, chemical, and thermal stability. • Construct membranes from ionomers with scalable fabrication processes, increased mechanical, chemical	Colorado School of Mines: Advanced Hybrid Membranes for Next Generation PEMFC Automotive Applications • Fuel Cell Energy: 'Smart' Matrix Development for Direct Carbonate Fuel Cells • Los Alamos National Laboratory: Advanced Materials for Fully Integrated MEAs

4. Conclusion

The excellent applications of PEM fuel cells have been look over. The major challenges to world - wide commercialization were explained viz. stable supply of high purity hydrogen, durability and cost reduction. Perfluorosulfonic acid membranes are the most widely used membranes but proton conductivity of these membranes is very small at high temperatures and they are very expensive. Therefore studies have been also focused on the investigation of alternative membranes. Ultimately, there is a serious need on fundamental research and associated challenges. Concentrating on materials development, cheap alternatives, attainment of fundamental knowledge and experimental tools are required. Hydrogen fuel research and development is also essential to reduce the cost of producing hydrogen from renewable resources and to economically advance hydrogen storage systems.

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