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A Review Paper on Electrical System Consisting of Fuel Cell

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ABSTRACT

In one day the available sources of energies are going to finish. For that we want to find out the sources of energies and also we have to move towards next generation efficient energy sources. The need of society is increasing. To fulfill that need we also want more energy production devices. The fuel cell is the way to accomplish that need. The fuel cell generates the energy from the physical analysis and chemical reaction. It includes the general introduction of the fuel cells. The fuel cells include the anode, cathode and the main the electrolyte membrane. Mainly it includes information about the Hydrogen Fuel Cell (HFC). It also includes the information about electrodes, conductivity, membrane and pressure of the fuel entered. It gives information about the Technologies which are used in high temperature and at low temperature. Future aspect includes the Japans forward technology for the fuel cells, energy efficiency and development of Residential fuel cells in India. Also the new strategy for developing thin fuel cell electrodes, the design of fuel cell membrane.

Keywords: **Fuel Cell, Hydrogen, Cathode, Anode**

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I. INTRODUCTION

A fuel cell is an electro-chemical device that combines hydrogen and oxygen to produce electricity, with water and heat as its by-product. In its simplest form, a single fuel cell consists of two electrodes - an anode and a cathode - with an electrolyte between them. At the anode, hydrogen reacts with a catalyst, creating a positively charged ion and a negatively charged electron. The proton then passes through the electrolyte, while the electron travels through a circuit, creating a current. At the cathode, oxygen reacts with the ion and electron, forming water and useful heat. This single cell generates about 0.7 volts, just about enough to power a single light bulb. When cells are stacked in series the output increases, resulting in fuel cells anywhere from several watts to multiple Megawatts.[19]
The global population growth and the increase in industrial activity are real issues with regard to global warming and power reserves. Fossil fuels tend to disappear and the use of new natural resources is more and more encouraged. Governments have the responsibility to initiate the energy transition. Measures have been taken and concerted effort concerning wind, solar, geothermal energy and biofuels are in progress all over the world. But another resource seems very promising: hydrogen. Indeed, hydrogen has an energy density of 140 MJ/kg, which is 3 times higher than oil and 200 times higher than a lithium battery. The automotive sector, in particular, is one of the major contributors to the greenhouse effect. Indeed, there were already 1.015 billion cars in 2010 owing to Wardsauto. However, new motor technologies emerge and reduce gas emissions. [4]

Hybrid technologies combining heat engine and electric engine are currently in use:

- In 1997, the Toyota Prius was the first mass-marketed hybrid vehicle.
- In 1999, the Honda insight was born.
- Then, in 2002 the Honda civic hybrid was marketed.

But, to make further progress, it is also possible to feed an electric motor only thanks to a fuel cell (FC). Gaseous hydrogen is used as fuel and air (oxygen) as combustive. The only by product are water and heat.

This is a zero emissions technology. This FC can be reinforced with batteries and ultra-capacitors. Consequently, it is actually the source which is hybridized and not the engine.[4] Fuel cells are widely used in power-driven handy equipment such as battery charges, laptops, external power units and electronic devices. The advantages of portable fuel cell stack with respect to usual power supplies which are primary not reusable and secondary rechargeable batteries and at the same time environment friendly. PEMFC achieves most of portable fuel cell stack requirements applications, because of its high energy density, long operational time, immediate refilling and the self-discharge. [3]

Studies are being carried out on many alternative methods in order to meet the energy demand required in the place of the fossil fuels that are gradually decreasing throughout the world. One of these methods, the fuel cell directly produces electricity electrochemically from the chemical energy of the fuel is directly converted into electrical form and it uses for any reason which related to the appliances. Electrochemical reactions are used in fuel cells as in the traditional batteries (eg. batteries for the car, motor, ships, aeroplane, home appliances etc.) However, fuel cells can produce energy as per the fuel supplied to it. In which the need of charging is not required.

The main principle of the fuel cell was discovered by the Swedish scientist Christian Schoenbein in 1838. In 1839, Sir William Grove discovered the first fuel cell based on the total opposite principle of the electrolysis of water. In 1950, Francis Bacon introduced the first alkaline fuel cell of 5 kW in the University of Cambridge.[1]The fuel cell module consists mainly of two electrodes (one is anode and another is cathode) and the membranes placed between the electrodes is named as electrolyte membrane. While reactions take place between the fuel and the oxygen in the fuel cell, The electricity is generated in that electrodes. In this the natural gases, methanol as well as the phosphoric acid, alkaline etc. can be used as a fuel. Also use of the pure Hydrogen (H_2) in the fuel cell. Natural gas, methanol or coal gas can also be used as a fuel, as well as pure hydrogen. The main working or the operating principle is shown in the fig. 1.

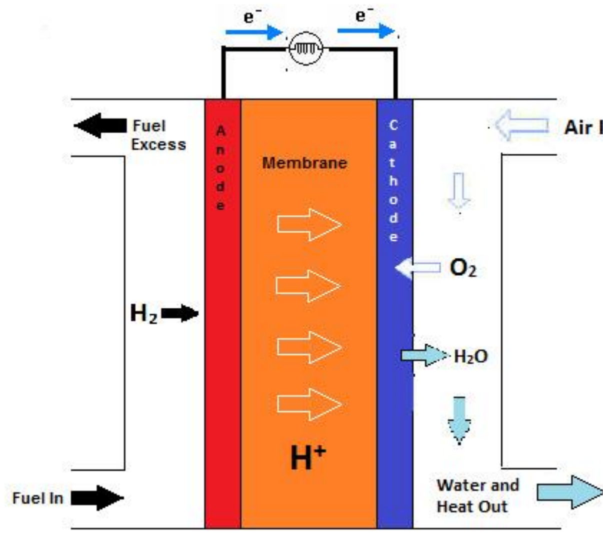

Fig. 1 - Basic Proton Exchange Membrane (PEM) Fuel Cell Mechanism [1]

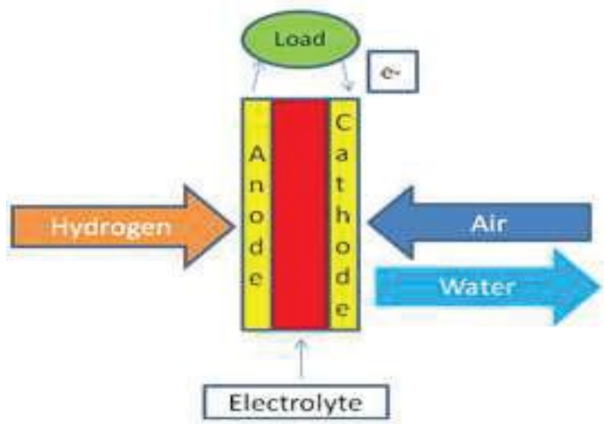

Fig. 2 - Principle diagram of a cell [4]

The fuels like natural gas etc. merges with the oxygen in the air basic fuel cell arrangement mechanism and produces electric current; and only water and heat are formed as side products. There is a membrane (electrolyte), which is in contact with the electrodes in both sides, in the middle of the fuel cell. The membrane is constantly filled by the fuels like natural gas from the anode and by oxygen from the cathode. The fuels like natural gas are decomposed into positive and negative ions at the anode side. The membrane only lets the positive ions to flow from the anode side to the cathode side, and acts as an insulator for the electrons. The ions reassemble at the cathode side for the stability of the system. The free charged electrons pass to the cathode side by means of an electronic circuit outside the membrane (electrolyte). Positive and negative ions reassemble in the cathode and form oxygen and water vapour. The chemical reactions occurring in the anode and cathode are as below.

- Anode reaction: $H_2 \rightarrow 2H^+ + 2e^-$
- Cathode reaction:
  $1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$
- Total reaction : $H_2 + 1/2O_2 \rightarrow H_2O$

In this study, the membrane thickness and the conductivity of the electrolyte are chosen for the performance analysis as variable parameters. These two values can be changed during the production stage of the fuel cell and are decisive in fuel cell selection. The change in the parameters was examined by means of the change in the current values taken from the anode side Finite elements method was used in the theoretical modeling of the fuel cell. Comsol Multiphysics program was benefited from in the analyses made using the finite elements method. [1] Theoretical Background. The finite elements method was first used in the 1950s in the field of construction engineering.(Wikipedia) Today, it has increased its popularity during the last 20 years, and this method is now preferred in many commercial software. Many devices and situations can be modelled using the finite elements method from medicine to mechanics and from electricity-electronics to chemical reactions. The main feature of the finite elements method is the necessity to define the start finish limit and surface values appropriately. In finite elements method, the surface of the material is analyzed after dividing into finite parts. In this study, the analyses were made 2 dimensionally. The electrical, physical and chemical laws used while doing this is briefly reminded in this section. It is necessary to learn the below material features of the fuel cell used to analyze the basic Proton Exchange Membrane (PEM) fuel cell performance.[1]

- Electrode conductivity
- Membrane thickness
- Membrane permeability
- Hydrogen input pressure
- Oxygen input pressure

In 2011, total global energy use for heat in buildings and industry was 172 EJ. Around 75% of this heat was generated using fossil fuels, leading to emissions of 10 GtCO2. The only substantial renewable fuel contribution was from biomass, which provided 9% of the total energy use. Table 1 shows a breakdown of fuel consumption in the residential, commercial and industrial sectors. Markets for low-carbon heating areemerging as a result of policy drivers and in response to the emergence of a number of low-carbon technologies, including fuel cells.

II. USE OF FUEL CELL IN RESIDENTIAL SECTOR

Residential sector accounts for 39% of global final energy in buildings and industry. Fuels are used to provide space heating, water heating and cooking, but the demand for these varies widely according to the climate, house size and building construction. For example, Fig. 3 shows that houses in the UK have a wide range of heating demands in winter but similar demands in summer. Peak electricity consumption occurs in winter in cold temperate countries such as the UK, but in summer in warmer countries when air conditioning is widely used. This has important ramifications for the relative competitiveness of fuel cell CHP and heat pumps, as part of their value is determined by their impact on the electricitysystem, as discussed. Biomass and waste currently supply more than 40% of residential heat provision, primarily in less developed countries or in areas of low population density. For people in poorer countries, access to modern energy services using clean gaseous or liquid fuels, or electricity, is a priority, but hydrogen and fuel cell technologies are likely to be prohibitively expensive for such applications in the near and medium-term due to the high capital costs relative to other options. Natural gas supplies around 20% of global residential heat, primarily in OECD countries. Gas is widely used in highly-populated regions of Northern Europe and North America; for example, in the UK and the Netherlands more than 80% of houses use in-house gas boilers. This is important for two reasons. First, such a strong incumbent technology could prove difficult to displace with alternatives, particularly as studies of consumer preferences regarding heating systems show a strong cultural affinity in these countries for gas boilers, which are perceived as safe, cheap, effective and easy to control . Second, markets and infrastructure already exist for gaseous heating fuels and it might be possible to convert these to use hydrogen, while providing a similar service to households that natural gas provides at present. Commercial sector Space and water heating are the most important energy service demands for commercial and public sector buildings, but the diversity of buildings is much greater than for the residential sector in terms of their size, shape, and level of heat demand. This diversity, coupled with the low fuel consumption relative to the residential and industrial sectors, means that decarbonising the commercial sector often receives much less attention than the residential sector. Natural gas and electricity are the dominant fuels. In contrast to residential buildings, electrically-powered HVAC systems are used in many larger commercial buildings and these could run in cogeneration with fuel cell CHP, with the fuel cell contributing to the power and heating loads as well as providing an alternative electrical backup to UPS systems and/ or diesel generators. The major barriers to the deployment of hydrogen and fuel cell heating systems are high costs when compared against alternatives, and their perceived technological immaturity . Many commercial organisations are often reluctant to adopt innovative technologies, favouring instead established technologies and processes . CHP is an important commercial technology in some countries, whether supplying only single large buildings or providing district heat to a range of residential and/or commercial properties. industrial sector The potential market for low-carbon heat technologies in the industrial sector is distinct from the commercial and residential parts of the economy because space heating is a relatively minor end use for heat demand. Demands for water heating and for the direct supply of industrial processes at different temperatures are much larger, particularly outside the food and drink sector . The result shows that industrial fuel use is quite different to the other two sectors, with a greater dominance for fossil fuels. Coal is the most used fossil fuel, followed by natural gas and petroleum products. Possible roles for hydrogen and fuel cell products include the substitution of hydrogen for natural gas in some processes and the use of CHP technologies. Industry is a major market for CHP, as many companies that use significant amounts of process heat find that generating their own electricity on site can help to offset production costs [6]

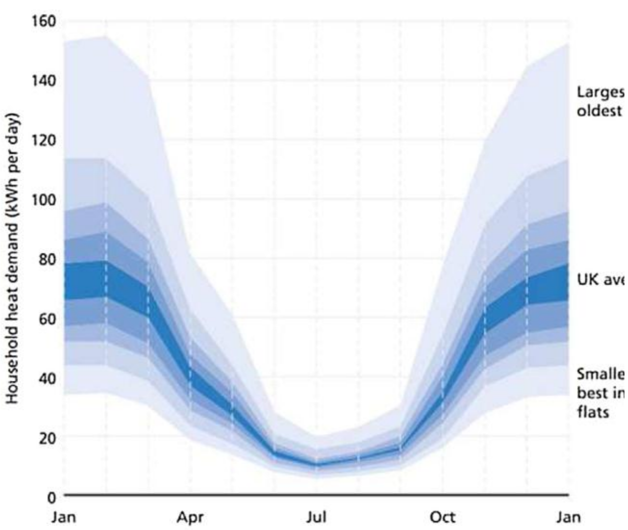

Fig. 3 - Heat demands from different households throughout the year in the UK. The demands include both space and water heating. Winter consumption is strongly temperature-dependent and the winter peaks can be much higher in a cold year. Based on data from Ref. [6]

III. The Waste Hydrogen HeatAnd Electricity (WHHE) Concept

This concept and research relies on the successful integrationof proven cutting-edge fuel processing, energy production andenergy storage technology in a new and innovative manner toachieve a highly efficient and flexible decentralized energysystem for the building industry. These technologies include:thermal plasma gasification, gas filtering, hybrid fuel cell/heatengine combined cycle, hydrogen production (electrolysis),hydrogen storage (nanostructured high capacity metal hydrides),enhanced heat exchange and effective thermal managementsystems, This system represents an ambitiousstep in the direction of energy decarbonisation and security byproviding decentralised clean and efficient energy centres forthe long term, comprehensive management of heat, electricity,hydrogen and waste. [5]

IV. Operational working of fuel cell

Hydrogen generating apparatus and its operation method, as well as fuel cell system. The present invention relates to a hydrogen generating apparatus and its operation method, as well as fuel cell system. More particularly, to a hydrogen generator and a driving method and a fuel cell system having a start-up mode to reduce power consumption when starting power is supplied from the self-supporting activated power source. Conventionally, the energy as a distributed power generator is effectively possible to use the power generation efficiency and overall efficiency are both high fuel cell cogeneration system (hereinafter, simply referred to as "fuel cellsystem") has attracted attention. The fuel cell system as the body of the power generation section is provided with a fuel cell. As the fuel cells, for example, phosphoric acid fuel cells, molten carbonate fuel cell, an alkali aqueous solution fuel cell, a polymer electrolyte fuelcell or a solid electrolyte fuel cell or the like is used. Among these fuel cells, phosphoric acid fuel cells and polymer electrolyte fuel cell (abbreviated, "PEFC") is due to the relatively low operating temperature during the power generation operation, the fuel cell of the fuel cell system It can be suitably used as. In particular, polymer electrolyte fuel cells, less degradation of the electrode catalyst as compared to the phosphoric acid fuel cells, and, since the dissipation of the electrolyte does not occur, the portable electronic equipment and electric automobiles of applications, particularly preferred. Many fuel cells, for example, in the form phosphoric acid fuel cell and solid polymer fuel cell, hydrogen is used as fuel in the power generation operation. However, the supply means of the hydrogen required in the power generation operation in those fuel cells, not been developed normally, the infrastructure. Therefore, in order to obtain electric power by the fuel cell system comprising a phosphoric acid fuel cells or polymer electrolyte fuel cells, the location of the fuelcell system, it is necessary to generate hydrogen as a fuel. As a method of producing hydrogen supplied to the fuel cell, the reforming reaction is generally used. Reforming reaction, for example, a city gas and water vapor as a raw material, using a Ni-based or a Ru-based reforming catalyst, by reacting at a high temperature of about 600ºC ~ 700ºC, composed mainly ofhydrogen It is a reaction to produce a hydrogen-containing gas [17]

Hydrogen generator of the present invention includes a reformer for reforming a raw material containing a hydrocarbon to generate a hydrogen-containing gas,and the raw material supply unit for supplying a raw material to the reformer, at least one of the feedstock and hydrogen-containing gas and burning in the combustor for heating the reformer, the combustion air supply device for supplying combustion air to the combustor, and the power autonomous start supplying power to at least a raw material supply unit and the combustion air supply device It has a. Moreover, typically at startup, start by powering the accessory including at least self-supporting materials from the first power source other than the start-up power supply unit and a combustion air supply device, andthe special the power supply from the first power source not available At start-up, to start with power supplied to the auxiliary machine from self start-up power only. The special first heating amount to be burned in the combustor during startup, it has a configured controller to control to be larger than the second heat quantity to be burned in conventional combustors at startup.

The configuration as described above, in the special start-up, so increasing the amount of heat input to the hydrogen generator, faster temperature rise rate to a proper temperature of the catalyst, the power supply time from the autonomous start-up power supply to the auxiliary device The short, it is possible to reduce the power supply, the autonomous start-up power supply it is possible to miniaturize. In order to suppress the power consumption of the hydrogen generating apparatus, early enters the power generation, it is effective to supply electric power consumed by the accessory. Therefore the need to generate a hydrogen-containing gas quality that can be used in fuel cells, For it is necessary to warm up to proper temperature the catalyst installed in the hydrogen generator.According to the hydrogen generating apparatus and its operating method, and a fuel cell system of the present invention, when activated by the power supply from the autonomous start-up power source, it is possible to quickly warm the temperature of the catalyst than the conventional, the start-up time a it can be shortened. Therefore, it is possible to reduce the amount of power consumed by the auxiliary device, the autonomous start-up power supply can be miniaturized. [17]

V. TECHNOLOGIES

Fuel Cells offer a wide choice of power outputs dependent on the system chosen. These vary from smaller portable fuel cells which produce low power outputs from 1W to 150W running on gaseous hydrogen or methanol, to standby power units from 10kW to 100kW running on hydrogen through to prime power 250kW+ units mainly fuelled by natural gas, with alternative sources of methane such as biogas now becoming available. Today’s fuel cell development continues apace with new technologies appearing on a regular basis. In terms of those systems which could be deemed commercially available, there are several variants all of which can be chosen, dependent on the requirement of the user.[18]

A. High Temperature Technologies:

Solid Oxide Fuel cell (SOFC)
– operating at 500-1000°C

Molten carbonate fuel cell (MCFC)
– operating at 600-650°C

Phosphoric Acid fuel cell (PAFC)
– operating at 150-200°C

These fuel cells have long start-up times and are generally higher power units from 200kW upwards. As such they are best suited to continuous use. Even though fuel cells in general are considerably more fuel efficient than other forms of power production, use of the high-grade heat produced by these types of fuel cell for combined heat and power (CHP) or cooling via absorption chillers, can increase efficiency further by up to 85% in total. [18]

B. Low Temperature Technologies:

Alkaline fuel cell (AFC)
– operating around 80°C

Direct methanol fuel cell (DMFC)
– operating around 70°C

Proton exchange membrane fuel cell (PEM)
– operating around 75°C

These fuel cells have rapid start-up but produce little in the way of usable heat. They are generally of lower power output (up to 20kW) and are ideal for standby and low-power, long runtime, prime power applications.Fuel cell technologies are continuing to develop, but whilst they share the fundamentals and the technology adopted within them, their differing power outputs make each one suitable for differing applications.

In summary fuel cells generally offer the following benefits to the end user:

- High electrical production efficiency compared with other forms of power generation.
- The use of high grade heat where available can improve efficiency even further.
- Local power production eliminates transmission wastage
- Low emissions
- Quiet – comparatively but especially for lower powered units
- Controlled power production with no direct combustion [18]

VI. FUTURE ASPECTS

Japan is working on doing for the hydrogen fuel cell what it accomplished with computer chips and cars in the last century, slashing costs to make them more appealing to consumers. As fuel-cell technology finds its way into factories and commercial buildings, Japanese manufacturers including Panasonic Corp. Are working to make them small and cheap enough for the home. The country has set a goal of installing them in 5.3 million homes by 2030, about 10 percent of all households. With 100,000 already installed, residential fuel cells fit into Prime Minister Shinzo Abe's vision of a "hydrogen society," using the most abundant element in the universe as an alternative to nuclear power and fossil fuels. The systems produce electricity through a chemical reaction that also generates heat, which is captured to make hot water for homes. "Home fuel cells are one strong weapon to improve energy efficiency," said Chihiro Tobe, head of a Ministry of Economy, Trade and Industry office promoting fuel cells. "The use of hydrogen can contribute to saving energy, tackling environmental issues and increasing energy security." After shutting down its nuclear reactors following the 2011 Fukushima disaster, Japan is applying decades of experience in slashing manufacturing costs to become the first major market where residential fuel cells are taking hold. The systems, known generically in Japan as Ene-Farms, are about the size of a refrigerator and run on hydrogen extracted from city gas that's delivered through existing pipes. [10]

A. Energy Efficiency:

Wider use of fuel cells promises to change the standard home-energy model by generating electricity close to where it's consumed. That's a shift from using giant generating plants, such as the Fukushima reactors that suffered meltdowns in March 2011 after a tsunami slammed into the facility.

One result is more efficient use of power that may reduce carbon dioxide emissions, helping Abe meet pledges in the global fight against climate change. Delegates from more than 190 nations, including Japan, are meeting in Lima for a United Nations conference on curbing global warming. "Hydrogen is the energy of the future, all have deregulated rules involving various ministries that used to hinder hydrogen development. The hydrogen society used to be a dream, and now it is about to become reality." [10]

B. Developement Residential Fuel Cell:

In January 2013, Pune- India and Boston-based Mayur R Energy Solutions signed a contract with the

Fraunhofer Institute of Ceramic Technologies and Systems IKTS, Germany, to develop solid oxide fuel cell (SOFC) products for residential and agricultural markets in developing countries. Commenting, Mayur Managing Director Mr Siddharth R. Mayer said that the company will develop a cost-effective fuel cell product to help meet the need for electricity in every Indian home. His ambition is to alleviate energy poverty in India and other developing countries by bringing affordable, reliable and clean energy to homes. The alliance with Fraunhofer IKTS is expected to help develop a world-class product at local prices and to generate high-volume business in the urban residential segment in the Indian subcontinent. Dr Christian Wunderlich, department head at Fraunhofer IKTS, points out the value in establishing a decentralised electricity generation network in places where it is mostly absent right now. As part of this project Fraunhofer IKTS will develop prototypes based on the established eneramic® fuel cell system, which will be extended for higher power classes. The fuel cell system will run on pipeline natural gas or LPG, either producing just electricity or running in combined heat and power. Ultimately, it is intended to combine this will solar or wind power and biogas. A prototype is expected to be ready in 2014. Fraunhofer IKTS will develop the product and transfer the know-how to Mayur, which in turn will work on commercialising the technology. Mayur is already in the process of setting up a world-class laboratory for fuel cells and a manufacturing facility where the stacks, reformer and other components could be made. Local manufacturing will be key to keeping costs low. Mayur is also a real-estate developer in India and the company has committed to using the product in all its residential and commercial projects once available. [15]

C. The new strategy for developing thin fuel cell electrodes

Proton Exchange Membrane Fuel Cells (PEMFC) hold great promise for addressing the evergrowing energy demand because of their high efficiency, simplicity in operation and zero emission. Despite these advantages, fuel cells deployment faces stiff economical and technical barriers. A principal drawback is the slow oxygen reduction reaction leading to inadequate efficiency of energy conversion in PEMFCs. To overcome this limitation and to achieve practical current densities, Pt is the best suited catalyst till date. However, to obtain better performance a proper dispersion of Pt nanoparticles on a suitable support material is needed. So far one-dimensional nanostructures of carbon such as nanotubes and nanofibers have triggered wide interest, mainly due to their exciting features such as anisotropy, unique structure and surface properties. However, notwithstanding the much hyped advantages of these materials for fuel cell electrode applications, the inherently low surface area possessed by them restricts the amount of active component (Pt) that can be dispersed on these materials. A catalyst with higher carbon to Pt ratio can lead to better dispersion, but this will result into a thick layer of catalyst with concomitantly higher mass transfer and electric resistances. From the point of view of design of membrane electrode assemblies (MEAs) [which is the active power producing center of a PEMFC] on a commercial point of view, apart from controlling the size of Pt and its dispersion a proper tuning of mass transfer rate is also important. To overcome these two prevailing constraints on mass transfer and electric resistance there is a need to develop MEAs with thin electrodes. To accomplish this goal, a desired level of Pt loading should be achieved while restricting the carbon content to the minimum possible level. [7]

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