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POLYMER ELECTROLYTE MEMBRANE (PEM) FUEL CELLS

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Abstract: Polymer electrolyte membrane (PEM) fuel cells that are demonstrated and built as a differential reactor empower an examination of the energy and flow associated with the working fuel cell. The differential reactor sidesteps more unpredictable two-and three-dimensional basic reactors and rearranges the fuel cell to a one dimensional framework where spatial inclinations are evacuated. The harmony between water generation and water evacuation in the differential reactor offers ascend to ignition/extinction marvels and various enduring states. This wonder is an immediate aftereffect of the polymer electrolyte membrane's part as a repository for water. A striking relationship between water adjust in the differential fuel PEM fuel cell and the vitality adjust in the traditional exothermic mixed tank reactor can be set up. In the underlying sections of this proposition, the reason behind the plan of the PEM fuel cell as a differential reactor is depicted. A numerical model of the PEM fuel cell as a mixed tank which fuses four of the key working parameters: stack resistance, fuel cell temperature, delta hydrogen stream rate, and gulf oxygen stream rate, effectively catches the ignition/extinction marvels. Changes in the water stock therefore of an adjustment in any working parameter will modify the membrane resistance. This influences the rate of water generation and at last will influence ignition/extinction

I. INTRODUCTION

Despite the fact that polymer electrolyte membrane (PEM) fuel cells have as of late earned far reaching consideration as an option power source, they were really created more than forty years back (Fuel Cell Handbook, 2000). In the mid 1960s, PEM fuel cells created by General Electric (GE) were utilized as an essential power source in Gemini space-crafts. Lamentably, both the lifetime and execution of PEM fuel cells were unsatis-processing plant until DuPont presented a perfluorosulfonic-corrosive membrane with a Teflon spine, named Nafion™, in 1968. With the presentation of Nafion, cell execution enhanced significantly with power densities achieving 100 W/ft2 in 1970 and watched life-times on the request of 103 hours (Watkins, 1993). After the sensational change delivered by Nafion, different organizations and government offices, for example, United Technologies Corporation (UTC), Ballard Power Systems and Los Alamos National Laboratory (LANL) proceeded with research in PEM fuel cells. Notwithstanding, leaps forward in PEM fuel cells were troublesome because of the absurdly high expenses associated with the impetus and the membrane. Along these lines, PEM fuel cells remained largely unnoticed until Raistrick and his gathering at LANL found a technique to impregnate the gas diffusion electrodes with Nafion before hot squeezing the electrodes onto the membrane itself (Raistrick, 1986).

Obstacles to Fuel Cell Development:

PEM fuel cells are broadly sought after for both mobile and stationary power applications (Fuel Cell Handbook, 2000; Acres, 2001; Perry and Fuller, 2002). All the more as of late, PEM fuel cells have turned out to be especially attractive for automobile and mobile electronics applications because of their moderately lightweight and reduced construction notwithstanding their low working temperature. In any case, specialists should address a few key issues in PEM fuel cell advancement before they will have the capacity to mass create and market PEM fuel cells as a shopper item. Four principle worries in PEM fuel cell improvement are talked about in what takes after and are summarized in Figure 1.

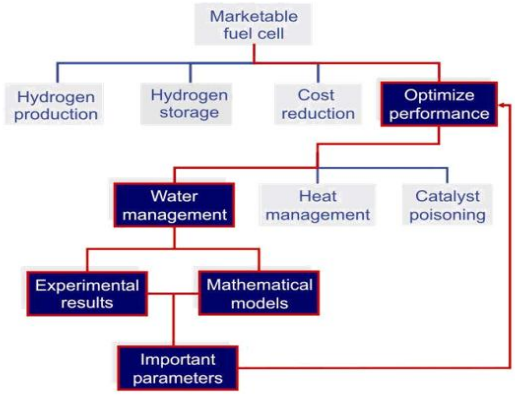

Fig. 1. Our PEM fuel cell research pathway

We address the issue of PEM fuel cell execution by presenting a differential PEM fuel cell which empowers us to concentrate on water administration in the cell. In the later parts, we will see that water is a variable that offers ascend to complex nonlinear dynamical conduct reminiscent of established exothermic mixed tank reactor dynamics. Through both exploratory and displaying endeavors, we recognize parameters that assistance us work and enhance the fuel cell execution.

$$CH_4 + H_2O \rightarrow 3H_2 + CO$$

$$CO + H_2O \rightarrow H_2 + CO_2$$

Better Performance Fuel Cells:

Fuel cells for mobile applications will fundamentally acclimate to different non-unfaltering state necessities, for example, factor stacks in power plants, atmosphere impacts on temperature and mugginess, and quick changes, for example, vehicle increasing speed. The fuel cell execution should be enhanced for most extreme power yield under such changes. To create improved fuel cells, three primary issues

should be tended to: water administration, warm administration, and impetus harming.

II. A BRIEF BACKGROUND OF PEM FUEL CELLS

As far back as the presentation of the polymer electrolyte membrane (PEM) fuel cell by William (Grubb and Niedrach, 1960), analysts have been endeavoring to fuse the PEM fuel cell technology into more up to date applications. This chapter starts with a diagram of the PEM, trailed by a short foundation on PEM fuel cells. A depiction of current fuel cell displaying endeavors is exhibited toward the finish of this chapter.

2.1 The Polymer Electrolyte Membrane (PEM)

The PEM is a low thickness material with a generally high mechanical quality, making it appropriate as a particle conductive gas hindrance in fuel cells. The PEM displays attractive levels of oxygen dissolvability and proton conductivity while keeping up chemical stability (Srinivasan et al., 1993). PEMs need to work at low temperatures to counteract membrane drying out since dry membranes show diminished conductivity (Thampan et al., 2000; Yang, 2003; Yang et al., 2004). In spite of the fact that there is enthusiasm for creating more slender membranes for enhanced cell performance, this advantage is balanced by the improved probability of reactant gas cross diffusion (Watkins, 1993) notwithstanding a loss of mechanical quality. DuPont's presentation of a perfluorosulfonic-corrosive membrane known as Nafion gave a critical change to past hydrocarbon based membranes. Early membranes comprised of polystyrene-divinylbenzene sulfonic corrosive crosslinked with a latent fluorocarbon film. The C-H bonds in these early membranes tended to de-review oxidatively, shortening the polymer lifetime in a working fuel cell (Perry and Fuller, 2002). As shown in Figure 2, Nafion contrasts from different membranes in light of its Teflon-like spine. Nafion's inactive properties in unforgiving conditions, for example, solid acids or bases make it an appropriate membrane in many applications. In a PEM fuel cell, the Nafion membrane goes about as a boundary to anions, permitting just the transport of cations (protons).

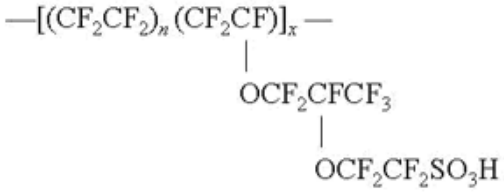

Fig.2 The chemical structure of Nafion

2.2 The PEM Fuel Cell and its Components

A normal PEM fuel cell comprises of the anode, cathode, and the membrane electrolyte. Both electrodes contain platinum stores to catalyze the responses. Hydrogen sustained into the anode compartment is separated into protons and electrons. The protons are transported over the membrane to the cathode side, while the electrons travel by means of an outer electrical circuit to the cathode. At the cathode, hydrogen and oxygen respond to shape water. A schematic of the PEM fuel cell is shown in Figure 3.

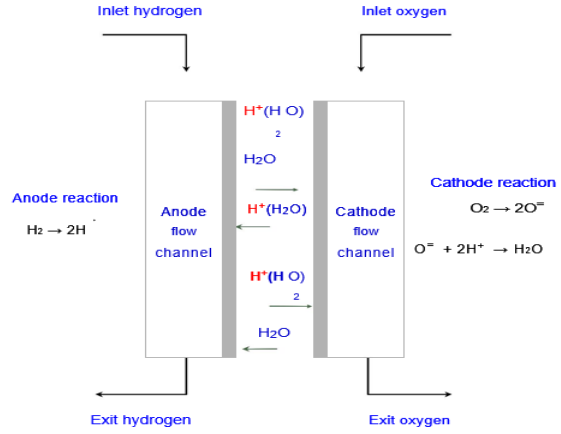

Fig. 3. Schematic diagram of a typical PEM fuel cell. The membrane must remain sufficiently hydrated for proton transport.

$$CH_4 + H_2O \leftrightarrow CO + 3H_2$$

$$CO + H_2O \leftrightarrow CO_2 + H_2$$

Polarization effects (the loss of cell voltage because of current) are show in plots of cell voltage as an element of current density. The polarization bends in Figure 4 portray the impact of low CO levels in a PEM fuel cell at 800C as exhibited by (Gottesfeld and Pafford, 1988). Indeed, even low levels of CO altogether diminish the cell voltage, bringing about a littler power yield at a given current density; the nearness of CO unequivocally in-hibits fuel cell performance. Luckily, CO levels might be lessened by infusing low measures of oxygen into the hydrogen anode bolster stream. The additional oxygen oxidizes the adsorbed CO to CO2. Be that as it may, an immediate response amongst hydrogen and oxygen may likewise happen, prompting a loss of fuel conversion (on the request of a few percent).

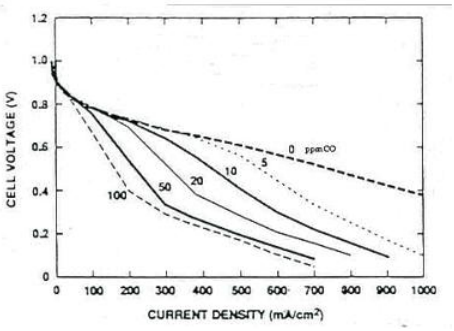

Figure 4 Effect of low CO levels in the anode at T = 800C. Even ppm levels of CO significantly decrease the cell voltage and result in a smaller power output at a given current density (Gottesfeld and Pafford, 1988).

III. LITERATURE SURVEY

Mariana Díaz, Alfredo Ortiz, Inmaculada Ortiz[1]: This work gives a basic audit of the advance in the utilization of Room Temperature Ionic Liquids (RTILs) as Proton Exchange Membrane (PEM) electrolytesin FuelCells (FCs). It is notable that for an efficient early commercialisation of

this technology it is important to build up a proton trade membrane with high proton conductivity without water reliance equipped for working at temperatures over 100 1C. The utilization of ionic fluids as electrolytes in electrochemical gadgets is a developing field because of their high conductivity, and in addition their warm, chemical and electrochemical stability under anhydrous conditions. This paper endeavors to give a general outline of the cutting edge, identifies the key elements for future research and compresses the recent progress in the utilization of ionic fluids as an imaginative sort of PEMs. N. Djilali[2]: Fuel cells are as yet experiencing exceptional advancement, and the mix of new and upgraded materials, enhanced item improvement, novel models, more efficient transport procedures, and plan streamlining and incorporation are required to prompt real picks up in performance, efficiency, unwavering quality, manufacturability and cost-adequacy. Computational fuel cell building (CFCE) devices that permit orderly reproduction, plan and improvement of fuel cell systems would encourage the incorporation of such advances, permit less overwhelming dependence on equipment prototyping, and diminish advancement cycles. CFCE requires the strong coordination of models speaking to an assortment of complex multi-material science transport forms portrayed by a Chunsheng Wang, A. John Appleby[3]: A polymer electrolyte membrane fuel cell with nebulous hydrated ruthenium dioxide (RuO2" xH2O) supercapacitative sublay-ers embedded between the electro catalyst layers and the Nafion membrane was created to improve the cell's heartbeat power yield. RuO2 " xH2O material demonstrated a high capacitance ~ca. 230 F/g! and permitted a substantially higher heartbeat power yield, which was shown by cyclic voltammetry and millisecond-width beat voltammetry in a nitrogen environment on both anode and cathode at 50°C. At the point when the gasses were changed to hydrogen and air, the sublayer somewhat diminished the consistent state power yield of the cell by diminishing both proton conductivity and the rate of oxygen lessening. Regardless of this, the nearness of the sublayer gave a substantially higher heartbeat power yield, which is of incentive for, e.g., communications applications. This modified fuel cell plays out an indistinguishable capacities from those of a more perplexing fuel cell/supercapacitor mixture framework without significant increment in weight, volume, and cost. In addition, the blocking impact of the thin RuO2 on methanol hybrid is invaluable for direct methanol fuel cell applications.

IV. THE DIFFERENTIAL PEM FUEL CELL

Tentatively constructing and demonstrating the PEM fuel cell as a differential reactor enables us to maintain a strategic distance from the mind boggling points of interest of water and proton transport through the PEM, electron exchange responses at the electrodes, and transport through different layers of the fuel cell. In particular, spatial and worldly varieties are uncoupled in a differential PEM fuel cell, empowering us to concentrate the dynamics. We propose here a response building point of view of the PEM fuel cell as a differential reactor and portray the rationale behind its plan.

4.1 The Stirred Tank Reactor PEM Fuel Cell:

PEM fuel cells comprise of two graphite stream channels that sandwich a membrane anode get together (MEA). Reactant gasses are nourished into the graphite stream channels, also called serpentine stream channels, normally contain convoluted pathways. Because of these crisscross pathways, slopes in reactant concentration in both the anode and cathode stream channels emerge, creating a non-uniform current appropriation over the membrane. While it is plausible to track the current development over the membrane in both space and time. Focusing on such a little component enables one to expect that the reactant concentrations are uniform in the anode and cathode chambers and that the main arrangement slope is transverse to the membrane. These very much blended chambers are the premise of the mixed tank reactor (STR) PEM fuel cell (Benziger et al., 2004).

4.2 Experimental Setup

The first dimensional STRPEM fuel cell framework was built by past gathering individuals (Moxley et al., 2003) and we have likewise built up a scientific model of it (displayed in the accompanying chapter). There are four fundamental parameters which an operator can control: warm contribution to the cell (temperature), the variable outside load resistance, hydrogen stream rate into the anode, and oxygen stream rate into the cathode. The STRPEM fuel cell is associated with the variable load resistance. The current through and the voltage drop over this heap are measured. The test setup is schematically represented in Figure 5.

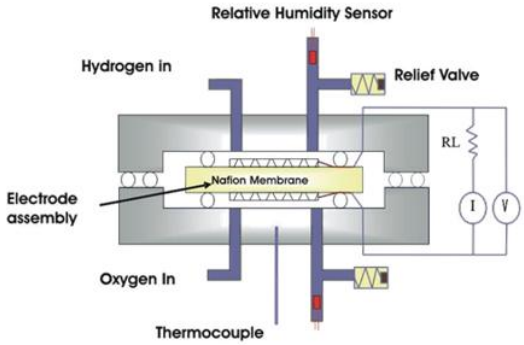

Figure 5: A schematic of the STR-PEM fuel cell experimental setup. The STR-PEM fuel cell consists of two graphite plates that are sandwiching a membrane electrode assembly. The gas volumes above (anode chamber) and below the membrane (cathode chamber) are well mixed. The controllable parameters include the temperature, variable load resistance, and inlet reactant flow rates.

4.3 System Variables and Parameters

It is essential to distinguish the framework factors from the framework parameters before continuing to the exploratory outcomes. The framework factors in the STR-PEM fuel cell framework are amounts that portray the neighborhood condition of the fuel cell and these amounts can-not be specifically controlled. Nonetheless, the framework parameters are amounts that a musical show tor can physically change in light of his/her carefulness. For

example, one can manage the measure of water bolstered into the fuel cell yet the membrane water substance is a quantifiable amount that cannot be specifically controlled. The membrane water content (as shown by the membrane water movement aw) relies on upon many components including the rate of water generation (as demonstrated by the current), the delta water content (water bolstered), and leaving water content (water expelled), and also the cell temperature. Since the operator cannot straightforwardly settle the membrane water content, it is a case of a framework variable. We will later demonstrate that the membrane water substance is an imperative variable that is in charge of the novel dynamics normal for the STR-PEM fuel cell.

4.4 Experimental Results

4.4.1. Fuel Cell Startup

We are especially inspired by the fuel cell startup conduct from various introductory conditions. In a past investigation, the significance of an ideal level of water in the fuel cell was outlined (Benziger et al., 2004). The membrane was first dried by streaming dry nitrogen gas through the anode chamber and dry oxygen gas through the cathode chamber at stream rates of 100 mL/min for 12 hrs while keeping up the cell temperature at 60*C. The membrane was then preconditioned to a settled humidification level by stopping the oxygen stream to the cathode and passing 10 mL/min of nitrogen gas through a water bubbler (equilibrated at room temperature) before it was nourished into the a anode chamber.

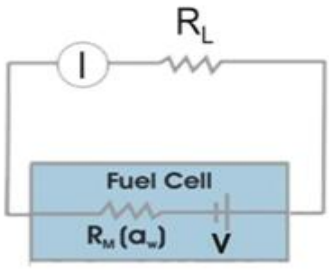

Figure 6: Equivalent electrical circuit for the PEM fuel cell. Both resistances are connected electrically in series so that any increase in either resistance will lead to a decreased cell current. The membrane resistance is a strong function of the membrane water content (activity).

The anode effluent relative stickiness was measured as an element of time to decide the water take-up into the membrane. At the point when the membrane achieved the coveted humidification level, the nitrogen stream was killed and the dry hydrogen stream into the anode and dry oxygen stream into the cathode (both at 10 mL/min) were continued. The mutt lease through the 5 Ω outside load resistor was checked and recorded after some time.

V. MODELING WATER BALANCE AND STEADY STATE MULTIPLICITY IN A STR-PEM FUEL CELL

We return to enduring state variety in the exothermic CSTR and portray the relationship between warmth autocatalyticity in an exothermic CSTR and the autocatalyticity seen in the STR-PEM fuel cell. We additionally build up a scientific model of the STR-PEM fuel cell which catches the basic material science that control the ignition/extinction marvels. We additionally investigate the dynamic and parametric operation of a STR-PEM fuel cell with demonstrating devices for the dynamic/parametric examination of chemical reactors (continuation, peculiarity hypothesis, numerical stability and bifurcation examination) to investigate the STR-PEM dynamic and parametric operation (Balakotaiah and Luss, 1982a; Balakotaiah and Luss, 1982b; Doedel, 1981; Farr and Aris, 1986).

5.1 Steady State Multiplicity

Membrane water content assumes a noteworthy part in both the dynamics and the relentless state conduct of the cell. Abundance water or too little water will hamper the fuel cell performance. In spite of the fact that an ideal level of water is alluring, as beforehand settled, the membrane water substance is a dynamic variable that progressions with parameters. The exemplary chemical building ignition/extinction marvels are brought on by the Arrhenius temperature-based rate quickening because of the warmth created by an exothermic response. The warmth delivered as an exothermic response advances expands the temperature and further quickens the response. The similarity of a positive input remains constant in both the exothermic CSTR and the STR-PEM fuel cell. In the fuel cell, as water is delivered, the membrane conductivity increments, and the response quickens. Similarly that the response rate relies on upon temperature exponentially,. In this way an experimental spasm of the membrane conductivity substantial over the deliberate scope of temperatures can be gotten (Yang, 2003). Alluding back to the great CSTR, joined vitality and mass adjust conditions yield expressions for the warmth production and warmth evacuation. At the point when plotted as elements of temperature, crossing points of the warmth expulsion line and warmth production bend speak to the consistent states. In the STR-PEM fuel cell, since we are worried with the adjust between water evacuation and water production, plots of water expulsion and water production

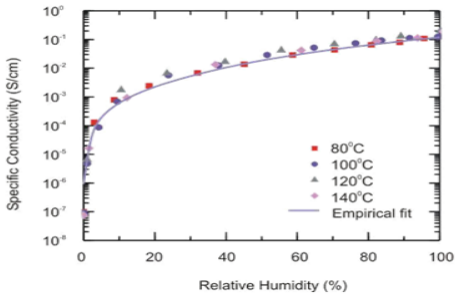

Fig.7. Conductivity of a Nafion 115 membrane. The conductivity de-pends strongly on the relative humidity but is only weakly dependent on tem-perature. easing proton transport across the membrane. A positive feedback loop on the transport drives the reaction even further (Yang, 2003).

VI. CONCLUSIONS

We have concentrated the PEM fuel cell from a chemical response building perspective and have built up a differential (mixed tank reactor) form of the fuel cell through both test

and computational work. The straightforwardness of the STR-PEM fuel cell empowers us to concentrate on the basic material science that offer ascent to rich dynamical conduct coming about because of the harmony between water production and water expulsion in the fuel cell. This adjust is astoundingly comparable to the warmth adjust in the traditional exothermic blended tank reactor (Aris, 1965; Perlmutter, 1972; Schmitz, 1975; Uppal et al., 1974; van Heerden, 1953). Water production inside the fuel cell enhances proton transport through the membrane and accordingly auto chemically quickens the response. We have demonstrated that the special harmony between water production and water evacuation in the STR-PEM fuel cell offers ascend to different enduring states – as shown by the crossing points of both the water expulsion and water production bends.

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