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Highlights of Accelerated Degradation Mechanisms for Polymer Electrolyte Fuel Cell

PROBLEM

Polymer electrolyte fuel cells are electrochemical devices that use hydrogen and air to produce electricity. Their design allows them to operate between 3,000 and 80,000 hours in various applications, but the periods of use are too long to evaluate the variables that affect their performance.

GENERAL OBJECTIVE

The objective of this study is to conduct a survey of information regarding accelerated degradation methods and the influence of these processes on the components that internally structure a polymer electrolyte fuel cell.
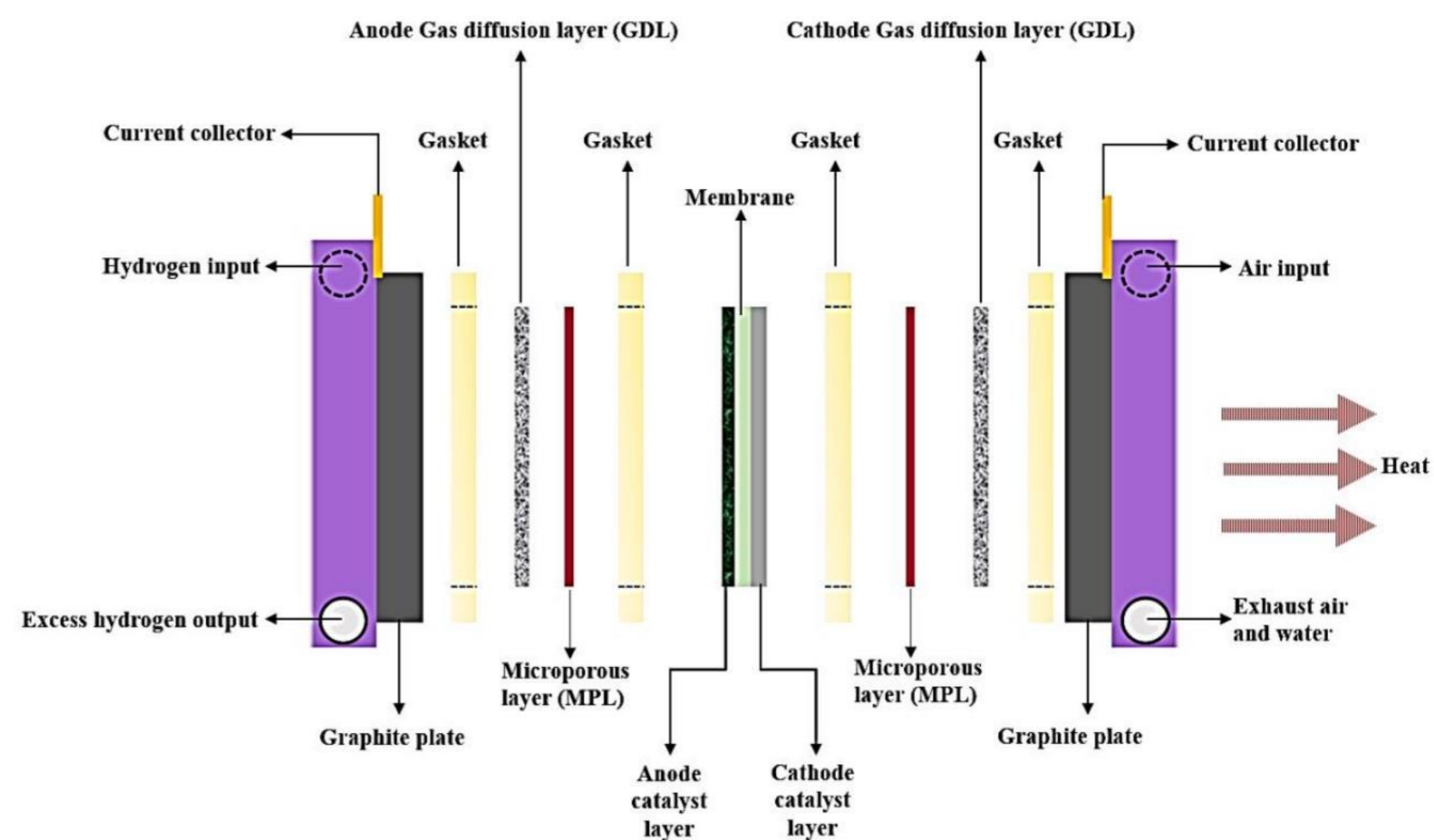
PROPOSAL

Accelerated degradation methods are instrumental in the study of the main layers of the fuel cell. These layers can be enumerated as follows: the membrane, the catalytic layer, the gas diffusion layer, and the bipolar plates.

Each of the layers in question presents factors, defects, and signs of degradation, which are presented in the attached table. The points in each category also show the degree of impact that would be had on the general and final performance of the fuel cell.

Concurrently, specific evaluations conducted on the fuel cell layers are available for review. Each evaluation assesses the operational conditions stipulated by the United States Department of Energy and the primary conclusions derived from the investigative process. The collated data facilitates an examination and synthesis of the theoretical and practical ramifications of accelerated degradation methodologies on fuel cells.

Structure	Factors	Defects	Aging effects
Membrane	Mechanical Thermal Electrochemical	Perforations Cracks Tears Pinholes	Crossover of reactant gases Decrease in protonic conductivity
Catalyst layer	Mechanical Electrochemical	Sintering of Pt on the carbon support. Dissolution of Pt into the electrolyte Corrosion of the carbon support	Decrease in conductivity Decrease mass transport Loss in the activation
Gas diffusion layer	Mechanical Thermal	Loss of hydrophobicity Weight loss Oxidation of the carbon	Chemical attack Decrease in GDL conductivity
Bipolar plates	Mechanical Electrochemical	Corrosion	Electrical resistance

Accelerated Stress Test	Operating conditions	Research findings
Relative humidity cycling	OCV RHC 90°C H_2/air (anode/cathode) 2 min dry/2min 92°C dew point	Increases MEA thinning rate by over two orders of magnitude compared to experimental field tests.
Wet Drive Cycle	Current cycling from 0.02 A/cm² to 1.2 A/cm² for 30 s each at a cell temperature of 80°C with anode and cathode dew points at 83°C	After 1000 hrs., a 50% decrease in CCL thickness
Ex-situ test	Water and hydrogen peroxide (30%) for 1000 and 24 hrs., respectively. Fuel cell performance was evaluated at 60 and 100% RH at 70°C. Air and O_2 as oxidants	VULCAN carbon-based GDL loss of performance by 20% after 50 h for air. PUREBLACK carbon-based GDL loss of performance by 12% after 50 hrs.
Carbon corrosion	Voltage swept between 1 and 1.5V. Temperatures of 80°C under fully humidified H_2/N_2 Gas flow rate 0.25/0.25 slpm.	During the first 1000 cycles, loss of polarization between 100 and 500 cycles
Relative humidity cycling	OCV RHC 90°C H_2/air (anode/cathode) 2 min dry/2min 92°C dew point	Increases MEA thinning rate by over two orders of magnitude compared to experimental field tests.

RESULTS

Mechanical and electrochemical degradation mechanisms are the most prevalent and are present among standardized methods. The majority of these methods employ cyclical forms of voltage, temperature, and relative humidity, as well as start-stop methods, and finally, freezing and thawing methods.

Accelerated degradation methods have been shown to induce various forms of stress, including mechanical, thermal, and electrochemical, within the layers of the fuel cell. These stresses have been observed to result in the formation of cracks, perforations, delamination, a reduction in the active area, a decline in efficiency at the interfaces, and even corrosion. The presence of these degradation effects can be determined through a comprehensive analysis of the materials comprising each layer of the fuel cell.
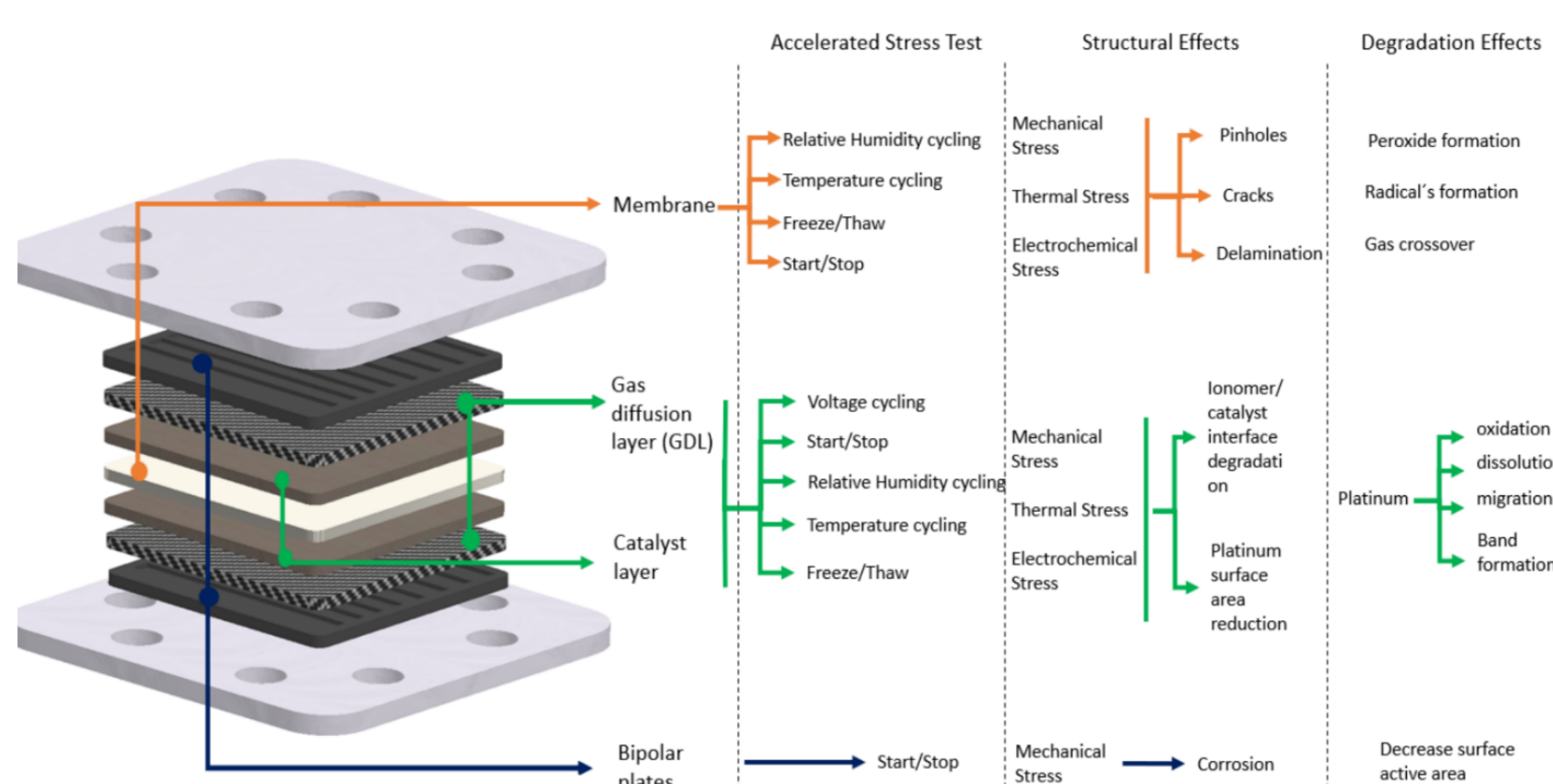
CONCLUSIONS

▪ The membrane, the catalytic layers, and the gas diffusion layers have been identified as the elements with the greatest impact or rate of degradation. In contrast, the bipolar plates are only exposed to corrosion phenomena.

▪ The United States Department of Energy has established a standardized protocol for the execution of degradation tests. This protocol ensures the replicability of test results across different geographical regions by allowing for modification of specific properties of the fuel cells.

▪ A substantial body of work has been dedicated to the development of cross-cutting mitigation strategies, with the objective of leveraging the collected information to enhance the long-term performance of fuel cells.

▪ The study of cell degradation has prompted particular interest in this technology, as the objective is to extend the cycle and lifespan of the product, thereby rendering it commercially viable for the industrial sector.