Part V. Functional Polymers for Energy Applications

Outline of Part

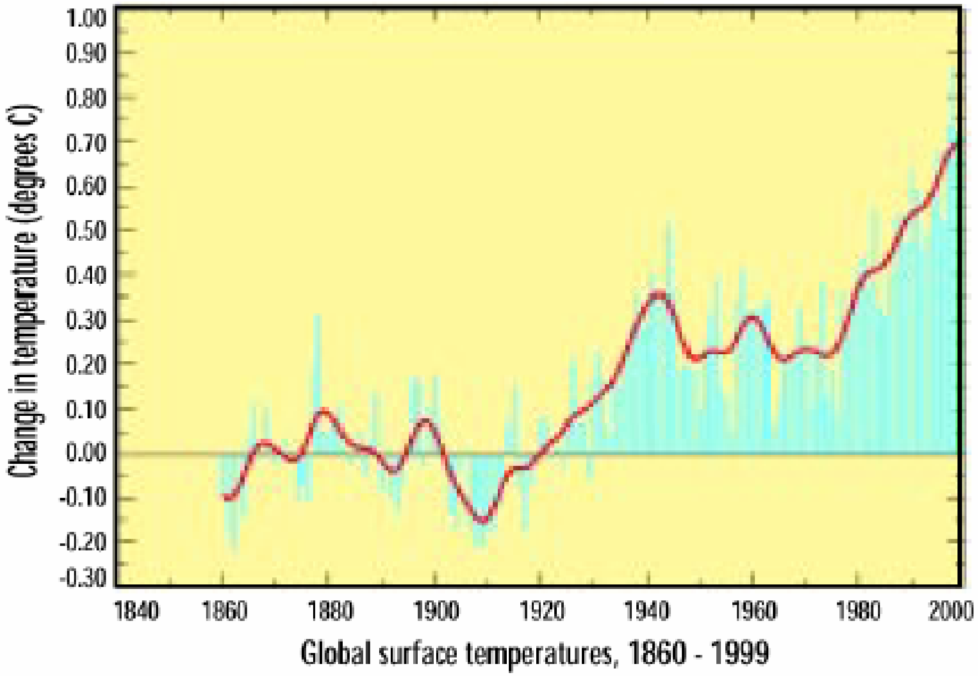
Fuel Cell

- Introductions for Fuel Cell
- Basic Principle & Structure of Fuel Cell
- Types of Fuel Cell
- DMFC
- Application Field

Background

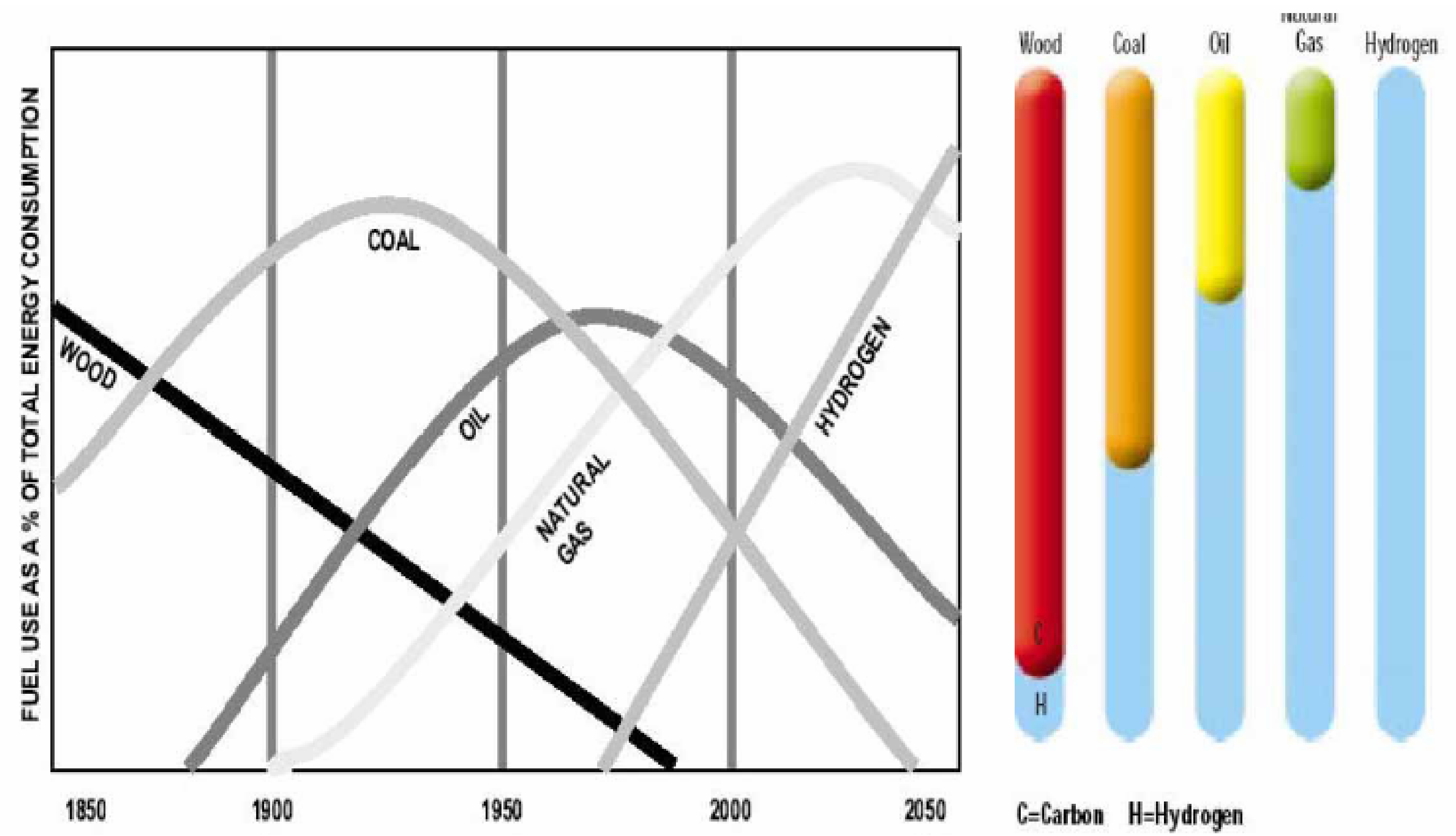

1.1
• finite supply of fossil fuels
• energy security
• climate change
• sustainable energy
21st CENTURY ENERGY CHALLENGES

Global Climate Change

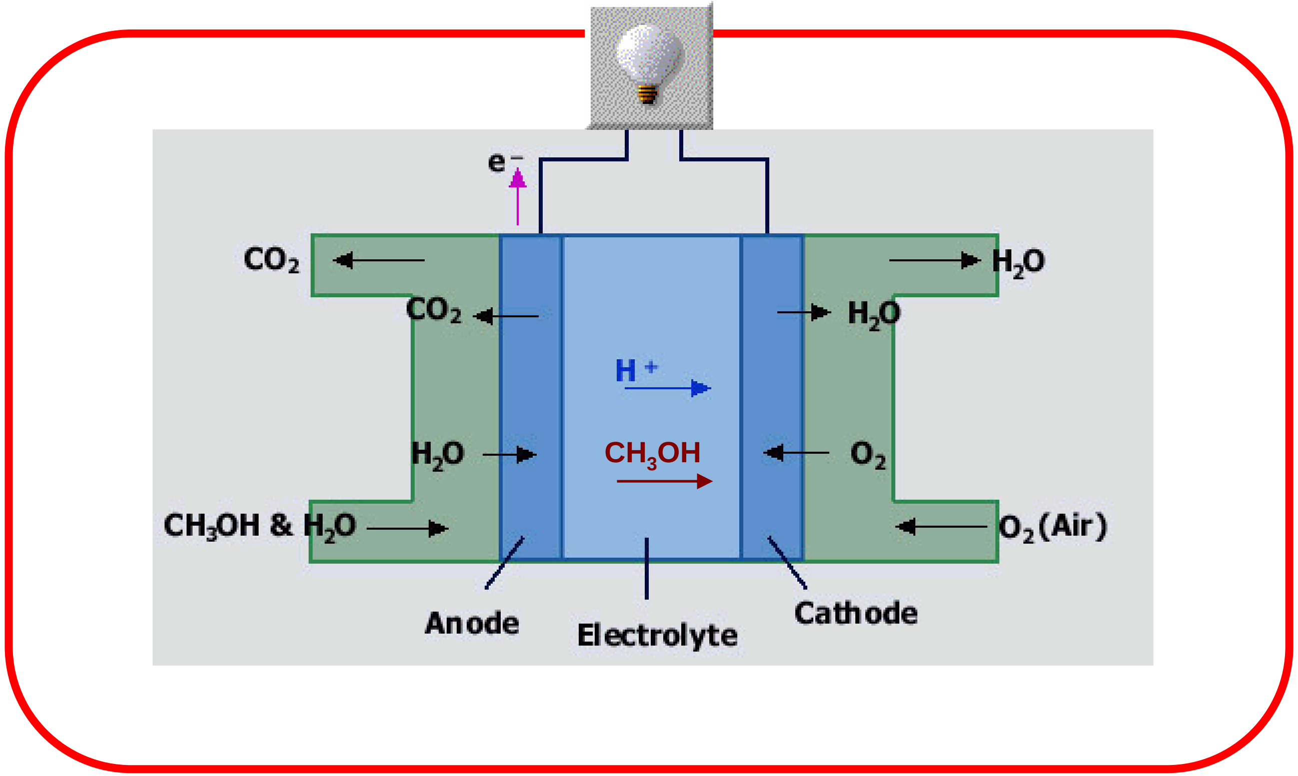


Instrumental Temperature Record from 1860-1999 indicates a global warming over the past century, with many peaks and valleys suggesting the natural year-to-year variability of climate (Hadley Centre for Climate Prediction)

Energy Source vs. Carbon Issue



Basic Principle_DMFC

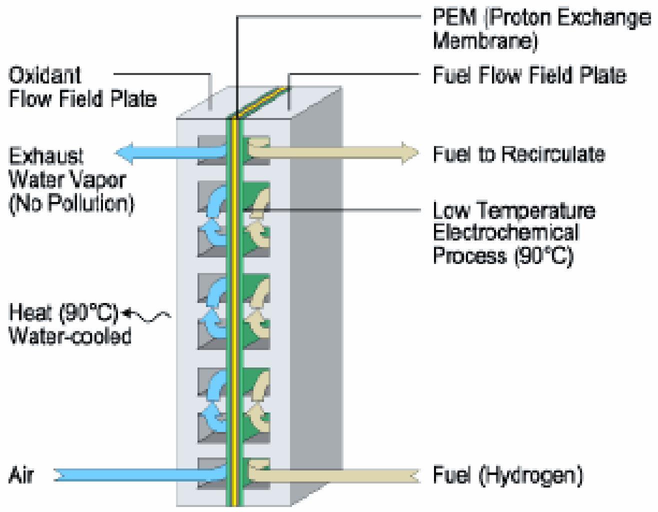


Anode: $CH_3OH + H_2O \Rightarrow CO_2 + 6H^+ + 6e^-$

Cathode: $3/2O_2 + 6H^+ + 6e^- \Rightarrow 3H_2O$

Overall reaction: $CH_3OH + 3/2O_2 \Rightarrow 2H_2O + CO_2$ (E = 1.21V)

Basic Principle_PEMFC



PEMFC schematic

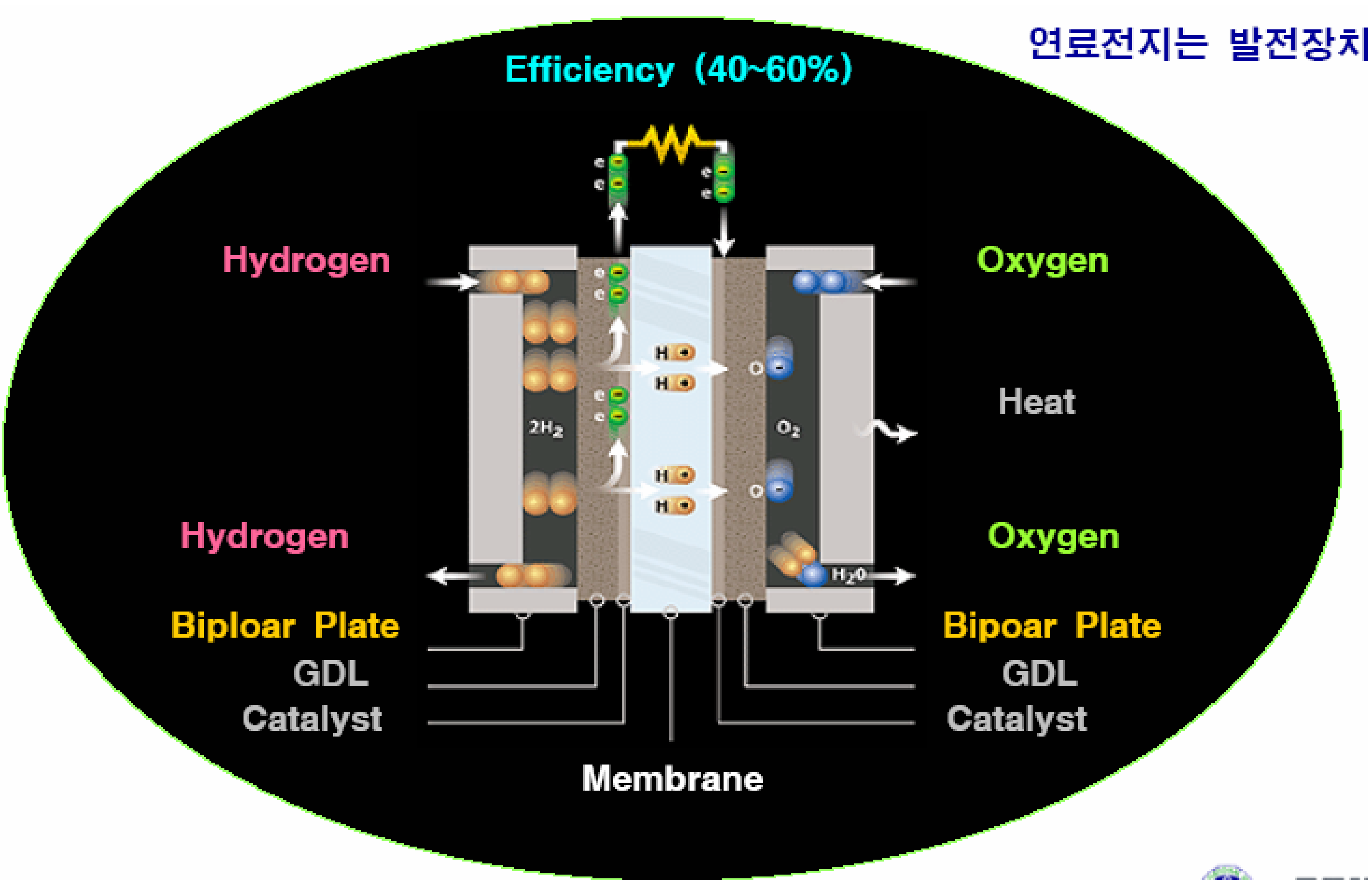
- A fuel cell produces electricity, water, and heat using fuel and oxygen in the air
- Water is the only emission when hydrogen is the fuel

Anode : $2H_2 \rightarrow 4H^+ + 4e^-$

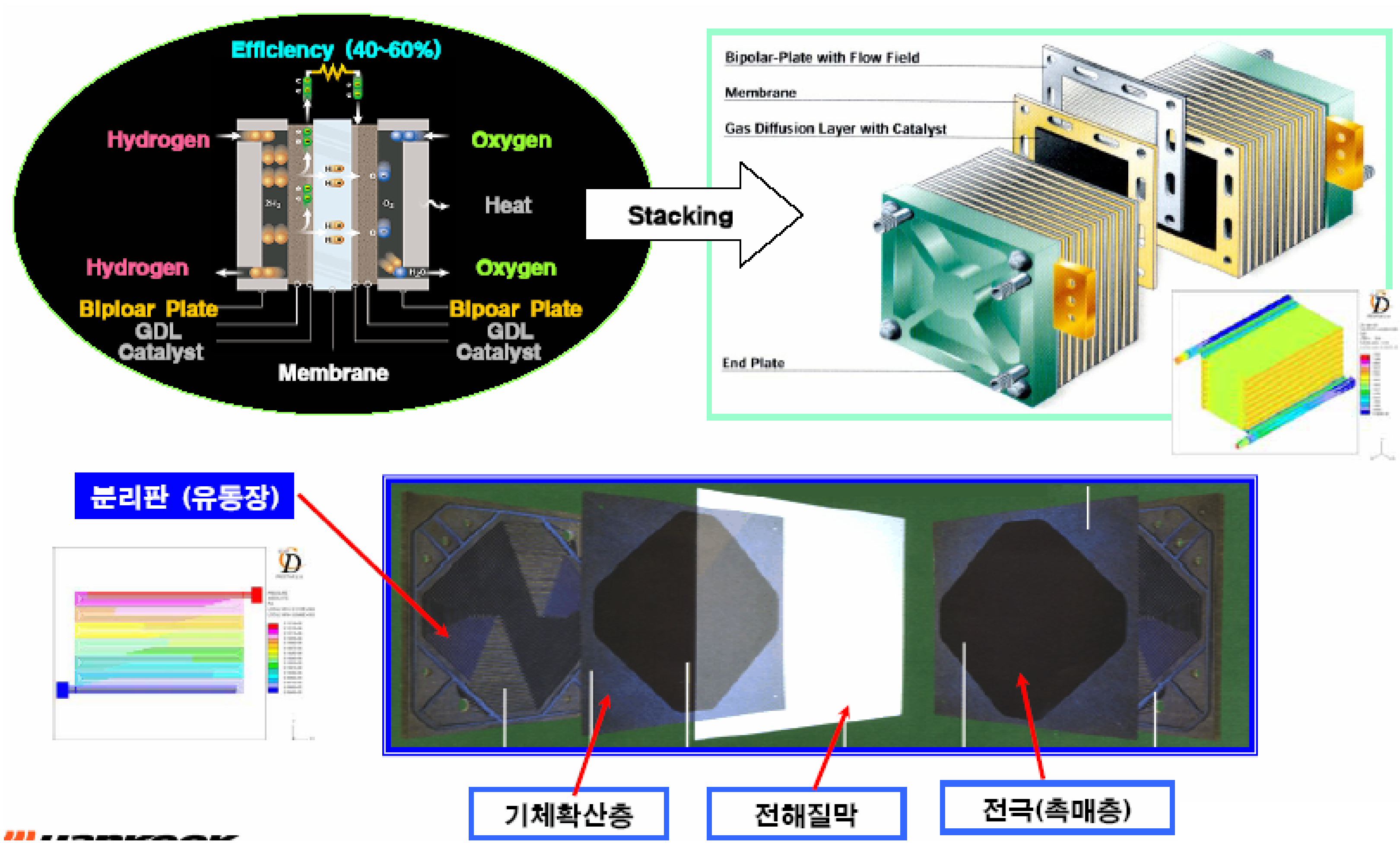
Cathode : $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Overall : $2H_2 + O_2 \rightarrow 2H_2O$ + Electrical Energy + Heat Energy

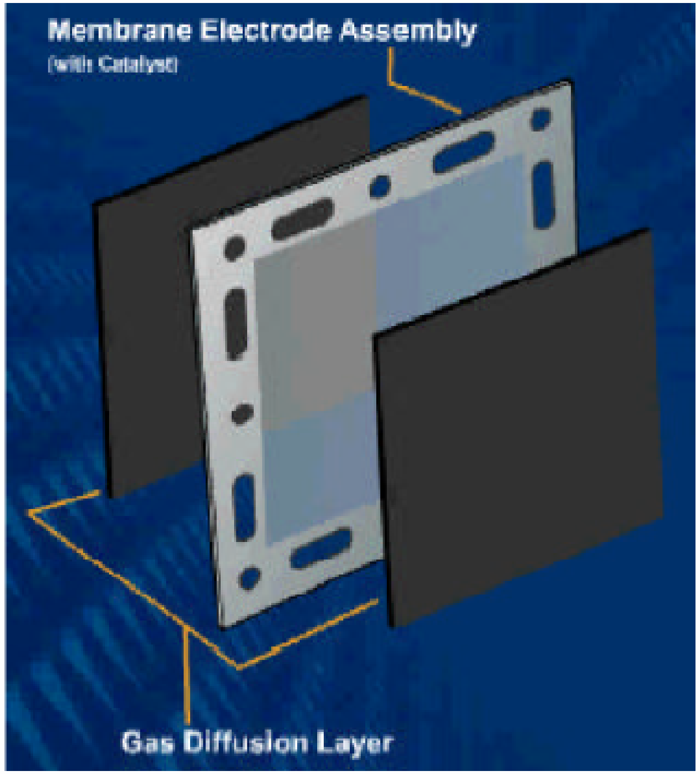
Structure_PEMFC

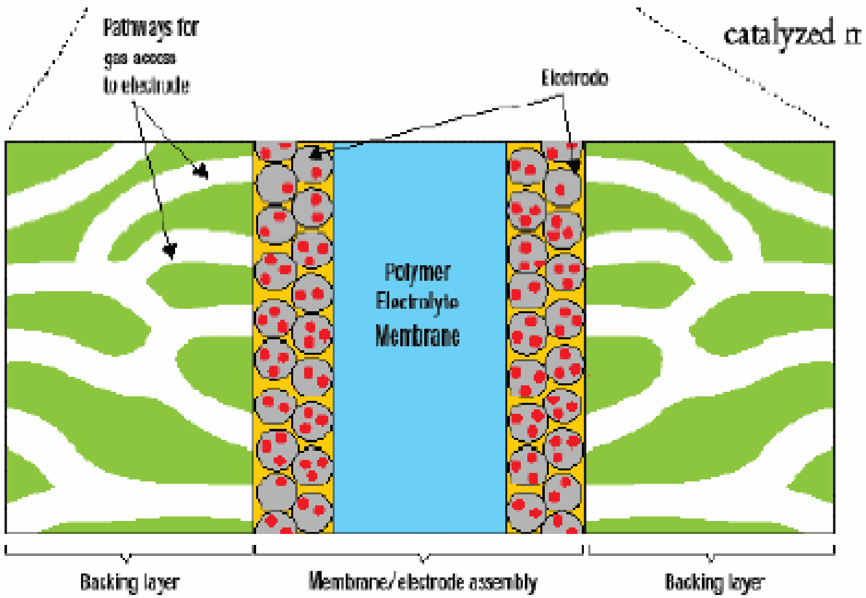


Structure


Efficiency (40~60%)
Hydrogen
Oxygen
Heat
Hydrogen
Oxygen
Biploar Plate
GDL
Catalyst
Bipoar Plate
GDL
Catalyst
Membrane
Stacking
Bipolar-Plate with Flow Field
Membrane
Gas Diffusion Layer with Catalyst
End Plate
분리판 (유동장)
기체확산층
전해질막
전극(촉매층)

MEA (Membrane Electrode Assembly)

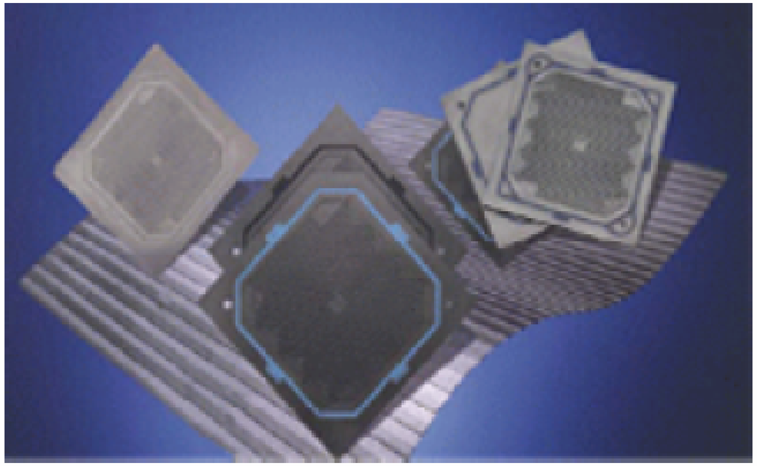




- Requirement : 고기능, 장수명(신뢰성), 저가격
- Technology : 코팅, lamination, 전극제어, 설계

Bipolar Plate

- Anode면에 연료가스(수소), Cathode면에 반응가스(산소, 공기) 공급
- Anode에서 생성된 전자를 집전한 후 이동
- 전기발생으로 인해 생성된 수분의 배출 통로
- MEA 지지체
- 양극면의 가스가 섞이지 않게 분리시킴



Cell Structure

연료공급 — Liquid Supplying Layer

Liquid Diffusion Electrode

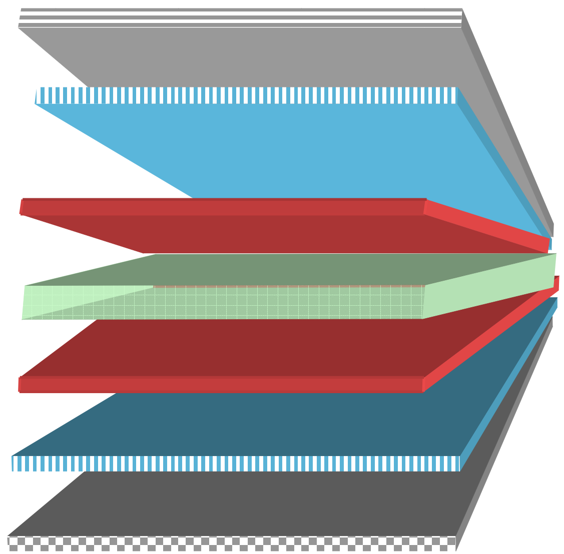
산화반응 — Oxidation Catalyst Layer

이온전달 — Proton Conducting Membrane

환원반응 — Reduction Catalyst Layer

Air Diffusion Electrode

연료공급 — Air Breathing Layer



용어 정리

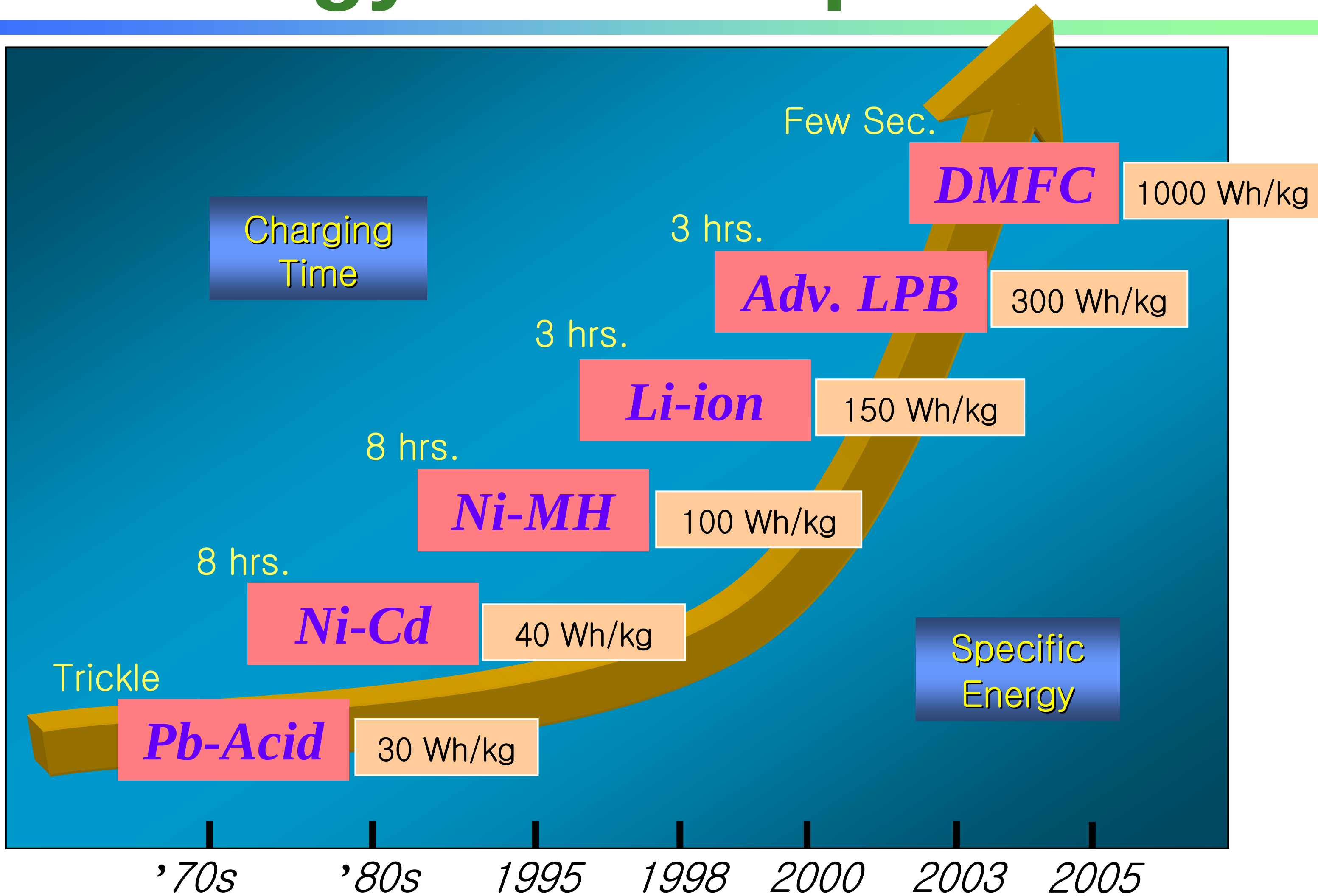
- **DMFC : Direct Methanol Fuel Cell** 메탄올과 공기중의 산소의 전기화학반응을 통해 전기를 발생시키는 장치
- **Anode :** 메탄올 산화반응으로 수소이온과 전자가 발생되는 전극.

  Catalyst layer와 **Liquid diffusion e lectrode**로 구성되어 있음
- **Cathode:** 산소가 수소이온 및 전자를 만나 물로 환원되는 전극.

  Catalyst layer와 **Air diffusion electrode**로 구성되어 있음
- **Electrolyte: Anode**에서 발생된 수소이온을 **Cathode**로 전달해 주는 고체고분자 막
- **MEA: Membrane**과 전극의 접합체 **(Membrane Electrode Assembly)**로 **Cell**의 기본단위
- **Liquid supplying layer:** 연료저장 용기에서 액체연료를 전극으로 전달해 주는 층
- **Air breathing layer:** 공기중의 산소를 전극으로 전달해 주는 층
- **Cell Pack:** 여러 장의 **Cell**을 직렬로 연결하여 원하는 출력을 얻게 하는 구조
- **Ionic conductivity : Membrane** 내에서 수소이온의 전도도로 **S/cm** 로 표시
- **Crossover : Methanol**이 **anode**반응에 참여하지 않고 **membrane** 통해 **cathode**로 넘어가는 현상

  (상용 **Nafion membrane**에 대한 상대치로 표기)
- **Power density : MEA** 단위면적당 출력으로 **W/cm²** 표시 **(0.3 V** 기준**)**
- **Energy density: Cell Pack(**연료저장용기 포함**)** 무게 또는 부피 당 에너지량으로서 **Wh/kg** 또는 **Wh/L**로 표시

Technology Roadmap



Types of Fuel Cell

종 류	발전 온도	주 연 료	기술 수준	적용 대상 (최고 개발 용량)
고분자형 (DMFC,PEMFC)	상온-100 °C	메탄올, 수소	개발 및 실증 단계	자동차 (수십kW) 정지형 (수십kW) 소형전원 (수kW)
인산형 (PAFC)	150-220 °C	천연가스, 메탄올 등	상용화 단계	열병합 발전 (200kW, 11MW)
용융탄산염 (MCFC)	600-700 °C	천연가스, 석탄가스	개발단계	복합 발전(25kW, 1MW)
고체전해질 (SOFC)	800-1000 °C	천연가스, 석탄가스	개발개발	열병합 (1kW) 복합 (250kW)
알카리형 (AFC)	상온-100 °C	순수수소	사용중	잠수함, 우주선

PEM (Proton Exchange Membrane)

The primary candidates for light-duty vehicles and buildings and potentially for much smaller applications such as replacements for rechargeable batteries in video cameras.

It operates at relatively low temperatures (about 200 degrees F), It has high power density, can vary their output quickly to meet shifts in power demand, thus is suitable for applications, such as in automobiles where quick startup is required.

It operates at relatively low temperatures (about 200 degrees F).

DMFC (Direct Methanol Fuel Cell)

These cells are similar to the PEM cells in that they both use a polymer membrane as the electrolyte.

The anode catalyst itself draws the hydrogen from the liquid methanol, eliminating the need for a fuel reformer.

Efficiencies of about 40% are expected with this type of fuel cell.

Typically operating at a temperature between 120-190 degrees F.

Higher efficiencies are achieved at higher temperatures.

PAFC

The most successfully developed commercial type of fuel cell.

It is already being used in diverse applications such as hospitals, nursing homes, hotels, office buildings, schools, utility power plants, and airport terminals.

It can also be used in larger vehicles, such as buses and locomotives.

It generates electricity at more than 40% efficiency -- and nearly 85% if the steam produces from this fuel cell is used for cogeneration -- 30% efficiency for the most efficient internal combustion engine.

Operating temperatures are in the range of 400 degrees F.

MCFC

It promises **very high fuel-to-electricity efficiencies** and the ability to consume coal-based fuels.

This cell operates at about **1,200 degrees F**.

The first full-scale molten carbonate stacks were built in California in 1996 for testing.

SOFC

It is used in high -power applications including industrial and large-scale central electricity generating stations.

Some developers also plan solid oxide to use in motor vehicles (a 100-kilowatt test in Europe and two small, 25-kilowatt units, in Japan)

Power generating efficiencies could reach 60%.

A solid oxide system usually uses a hard ceramic material instead of a liquid electrolyte, allowing an operating temperature to reach 1,800 degrees F.

AFC

Long used by NASA on space missions.

Power generating efficiencies of up to 70 percent.

Alkaline potassium hydroxide as an electrolyte.

Until recently they were too costly for commercial applications, but several companies are examining ways to reduce costs and improve operating flexibility.

Comparison

Fuel cell	Electrolyte	Operating Temperature(°C)	Electrochemical Reactions
Phosphoric acid (PAFC)	Liquid phosphoric acid soaked in a matrix	175-200	Anode: $H_2 \rightarrow 2H^+ + 2e^-$ Cathode: $1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$ Cell: $H_2 + 1/2O_2 \rightarrow H_2O$
Molten Carbonate (MCFC)	Liquid solution of lithium, sodium and/or potassium carbonates, soaked in a matrix	600-1000	Anode: $H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$ Cathode: $1/2O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$ Cell: $H_2 + 1/2O_2 \rightarrow H_2O$
Solid Oxide (SOFC)	Solid zirconium oxide to which a small amount of ytrria Is added	600-1000	Anode: $H_2 + O^{2-} \rightarrow H_2O + 2e^-$ Cathode: $1/2O_2 + 2e^- \rightarrow O^{2-}$ Cell: $H2 + 1/2O_2 \rightarrow H_2O$
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100	Anode: $H_2 + 2(OH)^- \rightarrow 2H_2O + 2e^-$ Cathode: $1/2O_2 + H_2O + 2e^- \rightarrow 2(OH)^-$ Cell: $H_2 + 1/2O_2 \rightarrow H_2O$
Polymer Electrolyte Membrane (PEM)	Solid organic polymer poly-perfluorosulfonic acid	60-100	Anode: $H_2 \rightarrow 2H^+ + 2e^-$ Cathode: $1/2O_2 + 2H^+ + 2e^- \rightarrow H_2O$ Cell: $H_2 + 1/2O_2 \rightarrow H_2O$