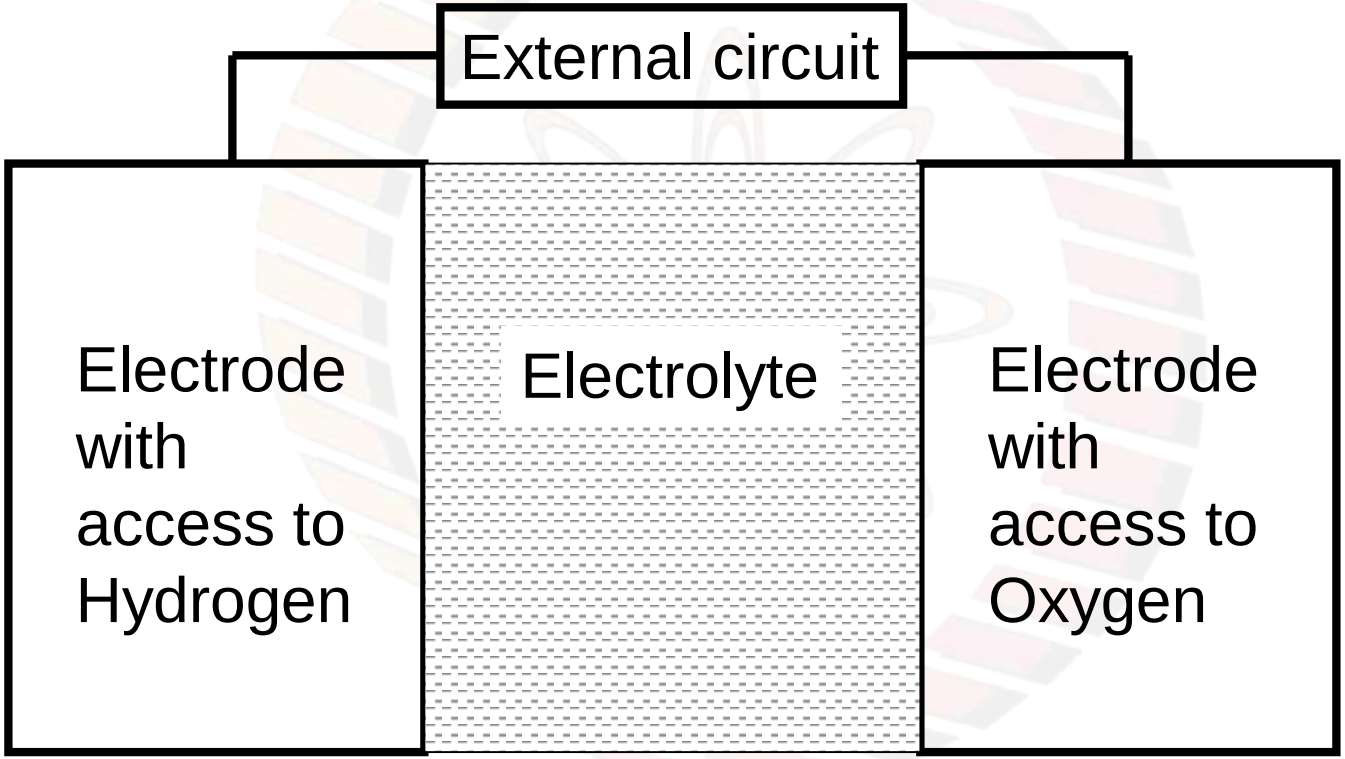
Fuel Cells

Concept to Product

Schematic of a fuel cell



Reactions in a PEM Fuel Cell

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

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

Timeline:

1800 **Alessandro Volta**

Prof. Of Physics

Univ. of Pavia, Italy

Volta Pile

Mary Shelly's
FRANKENSTEIN

Dissimilar metals

1839 **Sir William Grove**

English lawyer turned scientist

"Gas Battery" (Fuel Cell)

1930s to 1940s — **Francis T. Bacon**

Alkali Fuel Cells for Royal Navy Submarines

1960s — **Pratt & Whitney**

licensed Bacon's cell for use in Apollo Spacecraft

Image Credit: NASA

1990s — **Los Alamos National Laboratory**

Dramatic reduction in need for Pt catalyst

Late 1990s till today — **Several demonstrations of "commercial" fuel cells**

Homes:

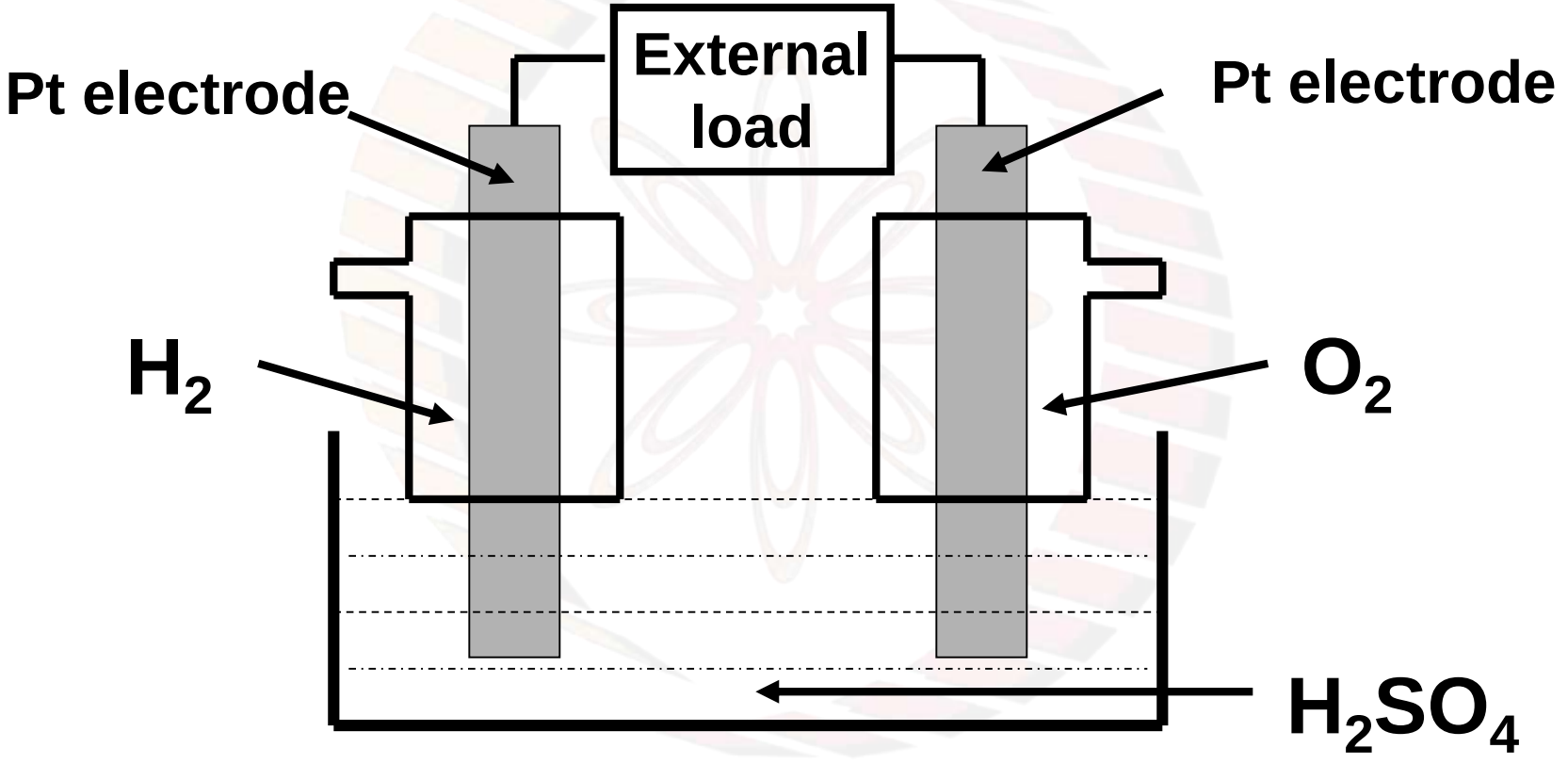
Plug Power, Latham, NY, USA

Automobiles:

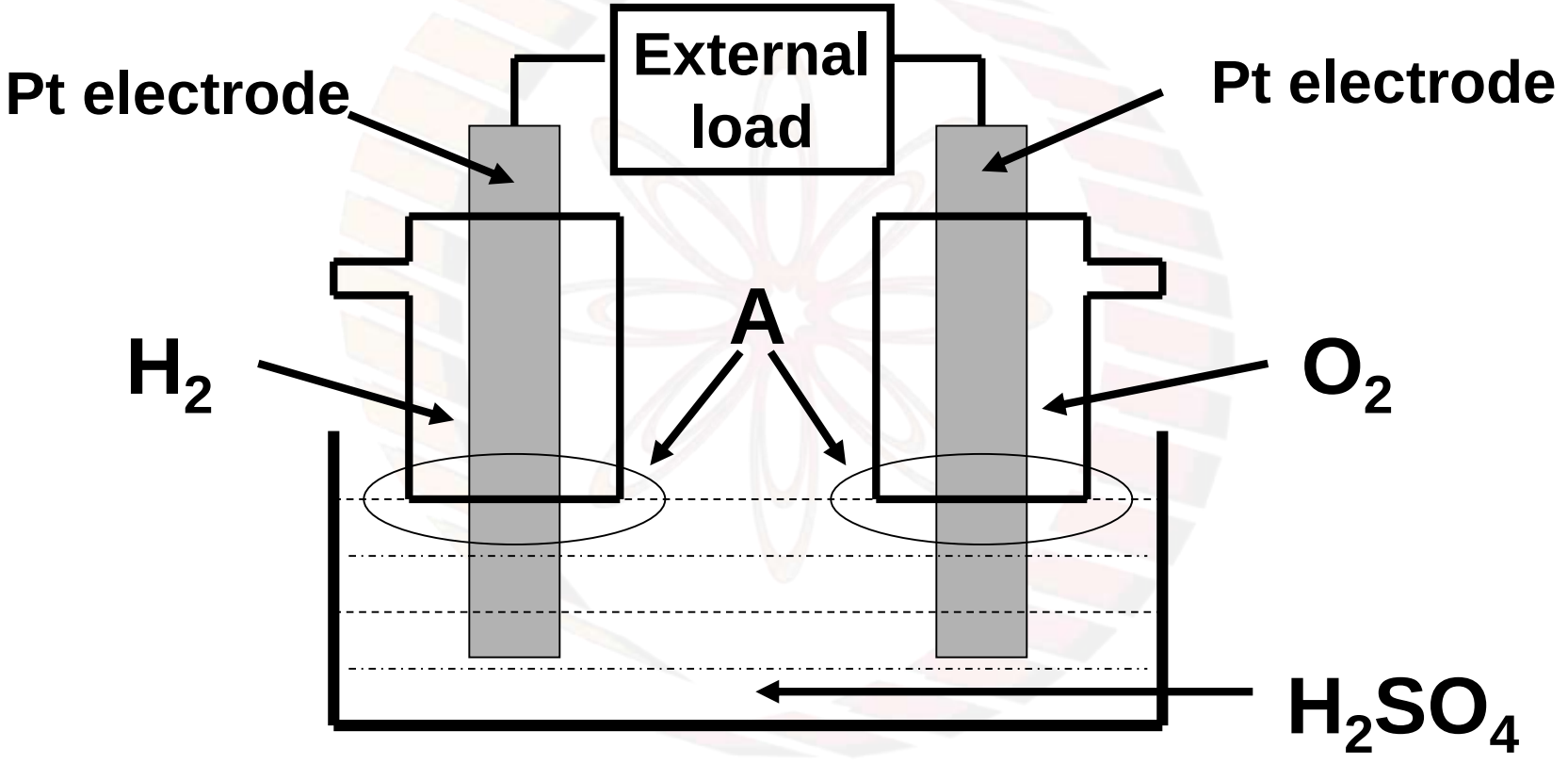
Ballard, Vancouver, Canada

Temperature	Type of fuel cell
< 100 °C	**PEFC / PEM** ***Polymer electrolyte fuel cell***
100 - 250 °C	**AFC** ***Alkaline fuel cell***
160 - 220 °C	**PAFC** ***Phosphoric acid fuel cell***
600 - 700 °C	**MCFC** ***Molten carbonate fuel cell***
~ 1000 °C	**SOFC** ***Solid oxide fuel cell***

Schematic of early design of fuel cell

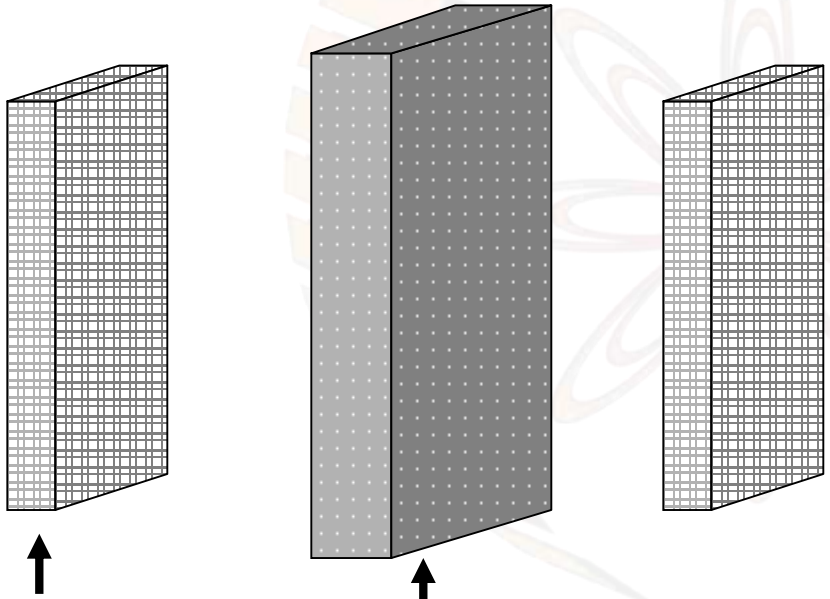


Schematic of early design of fuel cell



Improvements in design of fuel cell

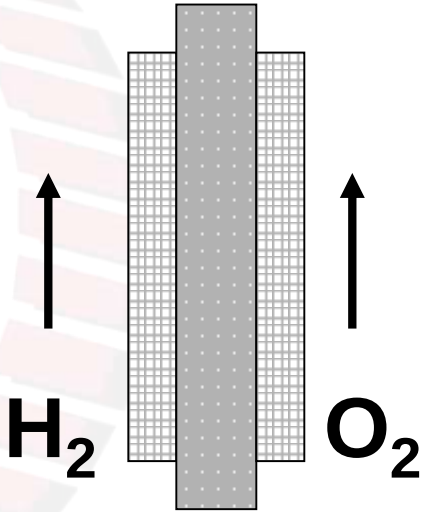
"Exploded" view



Thin, perforated Pt electrode

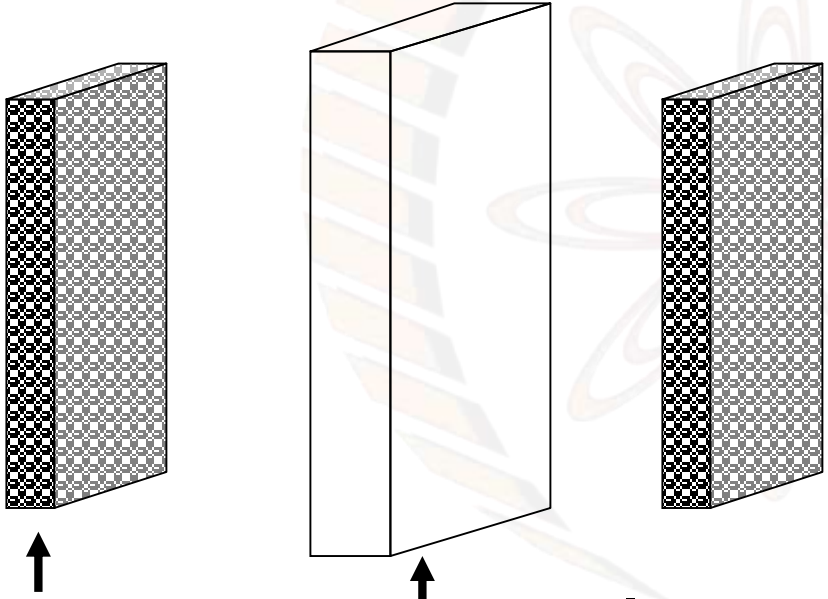
Porous material soaked in H_2SO_4

"Assembled" Side view



Improvements in design of fuel cell

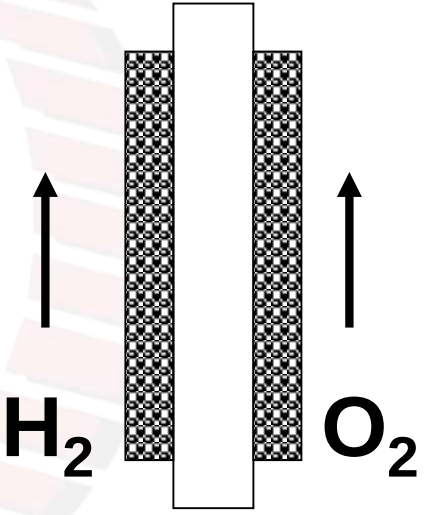
“Exploded” view

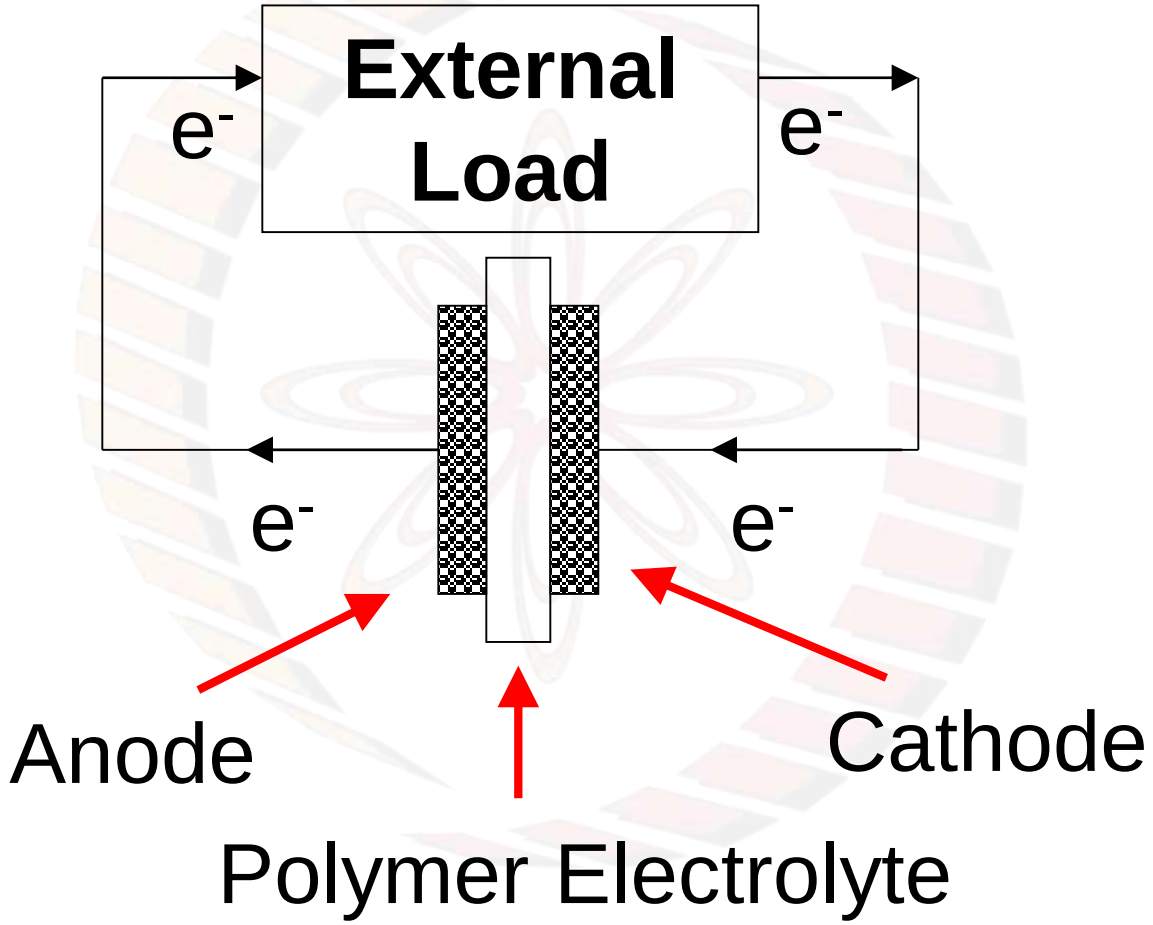


Catalyst based Pt electrode

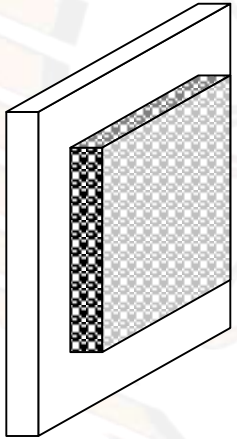
Polymer electrolyte material capable of H^+ transport

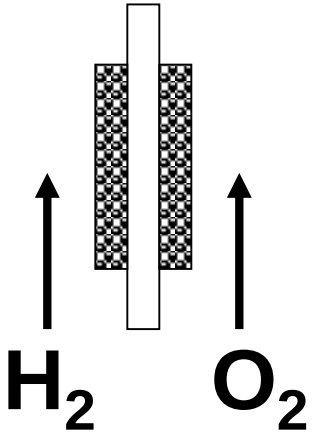
“Assembled” Side view

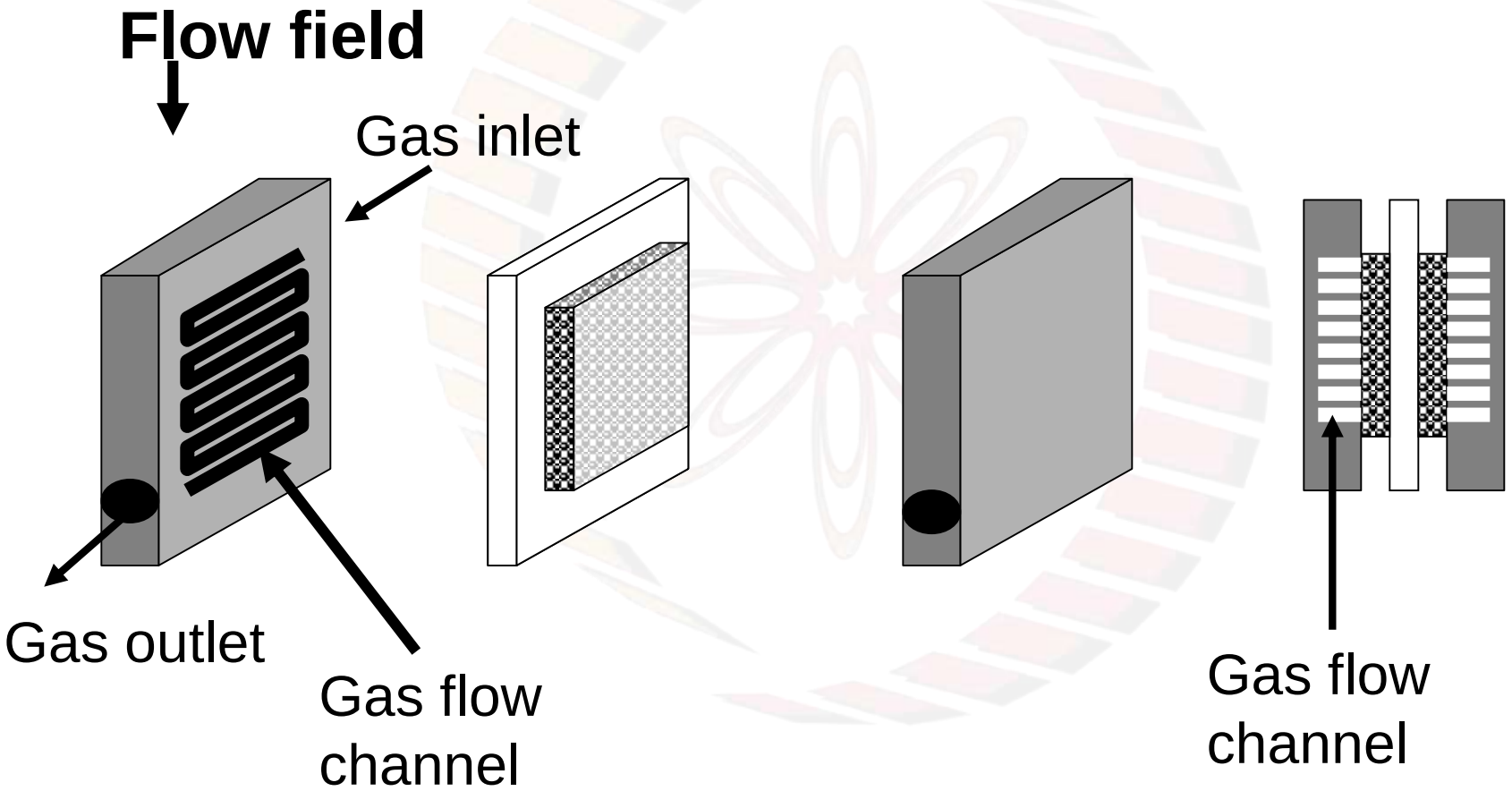


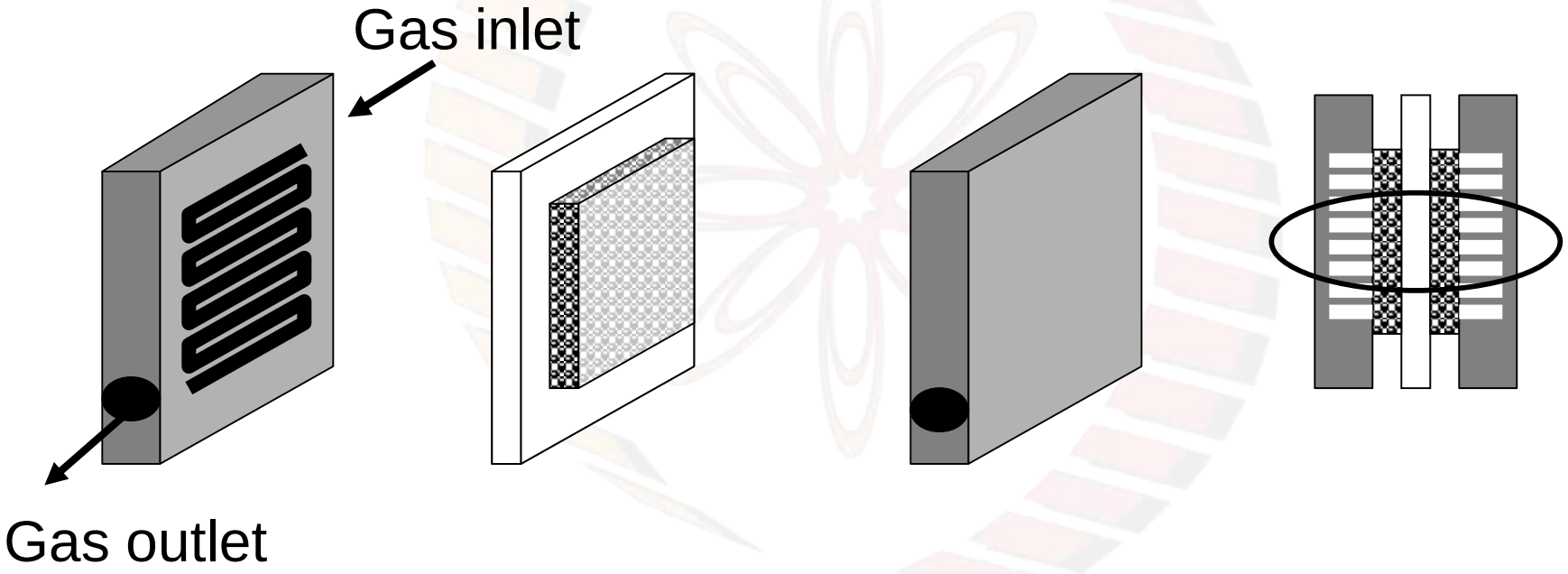

External Load
e-
e-
e-
e-
Anode
Cathode
Polymer Electrolyte

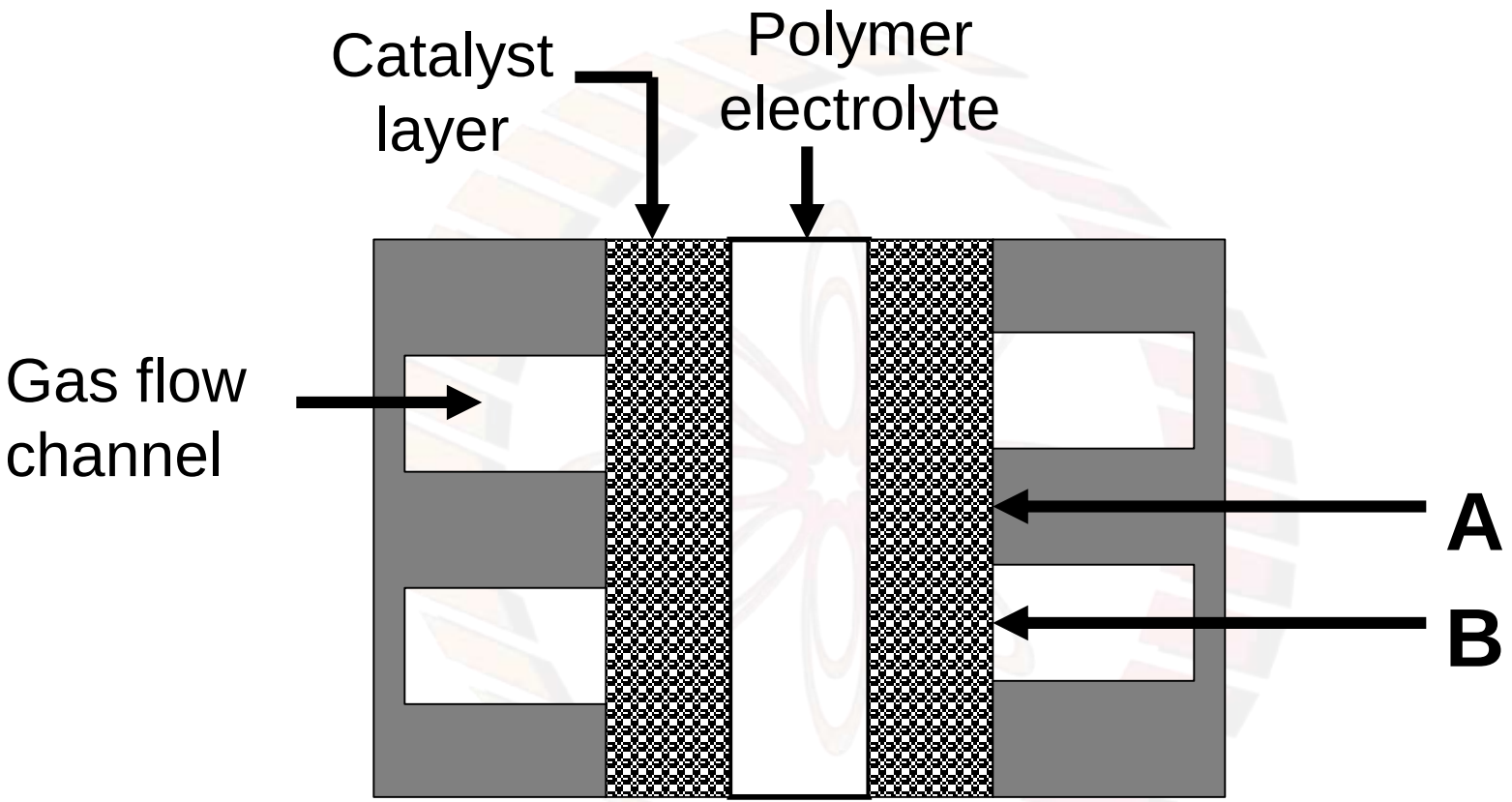
Polymer electrolyte with catalyst layer on either side



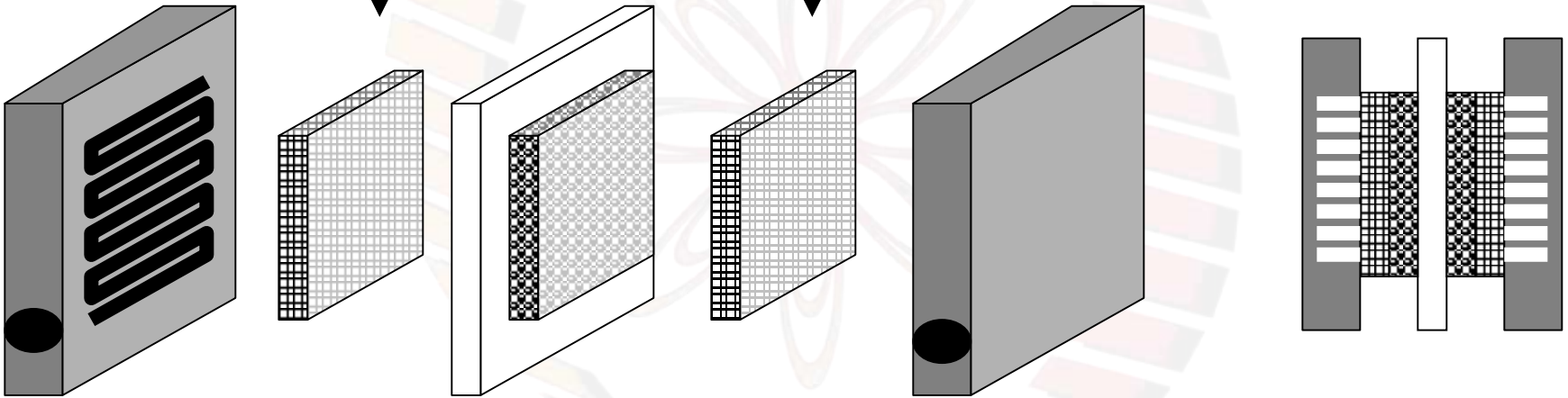


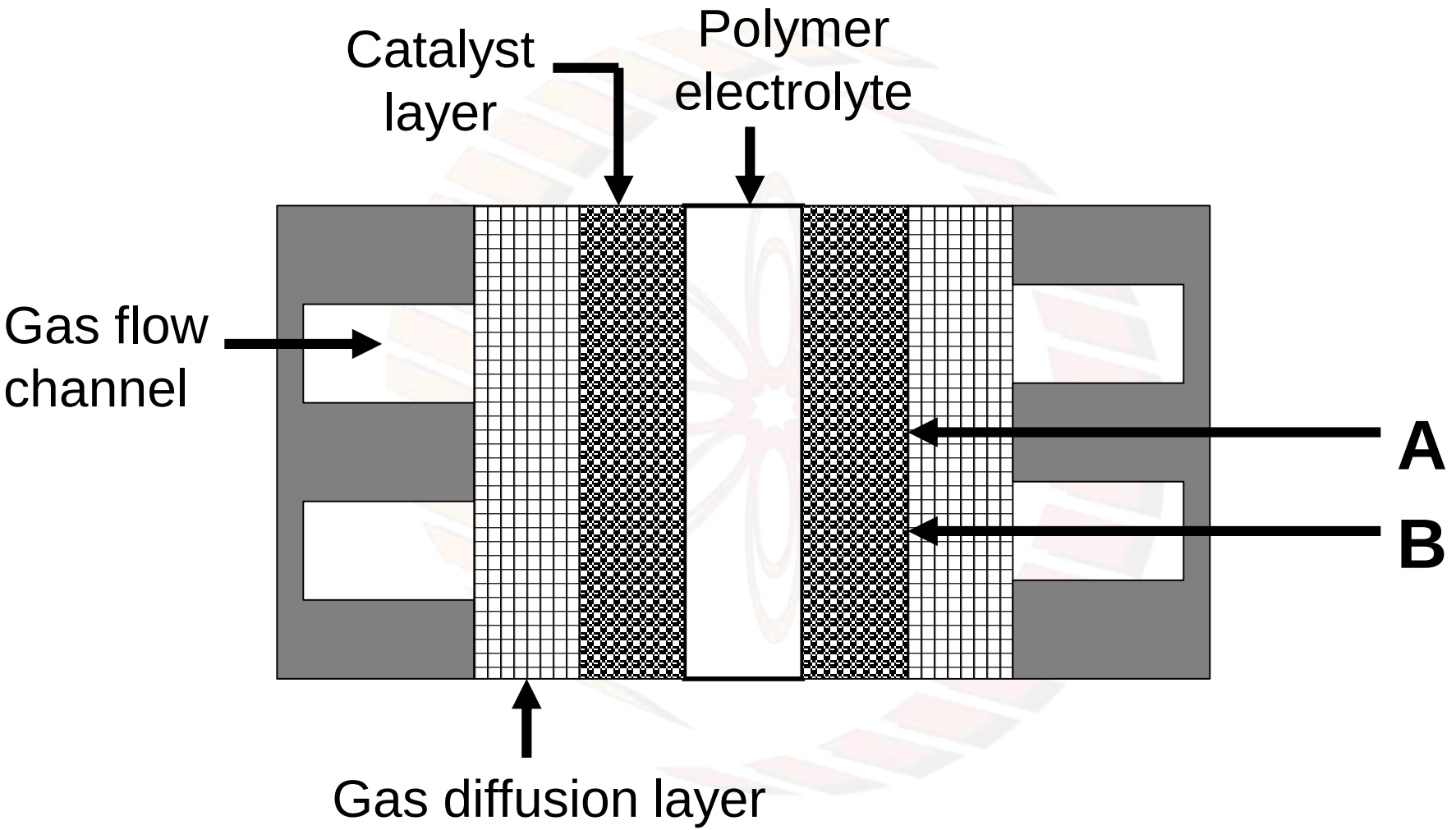

Flow field
Gas inlet
Gas outlet
Gas flow channel
Gas flow channel


Gas inlet
Gas outlet

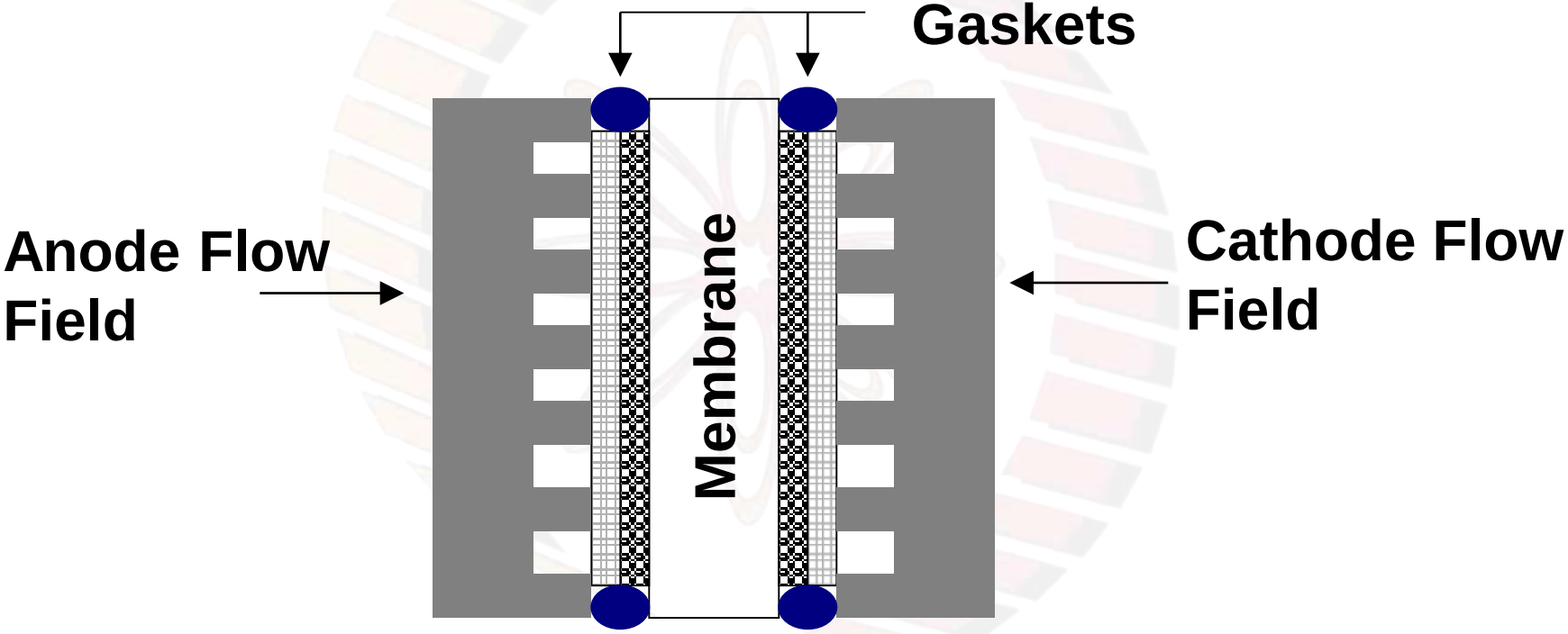

Catalyst layer
Polymer electrolyte
Gas flow channel
A
B

Gas diffusion layers (GDLs)

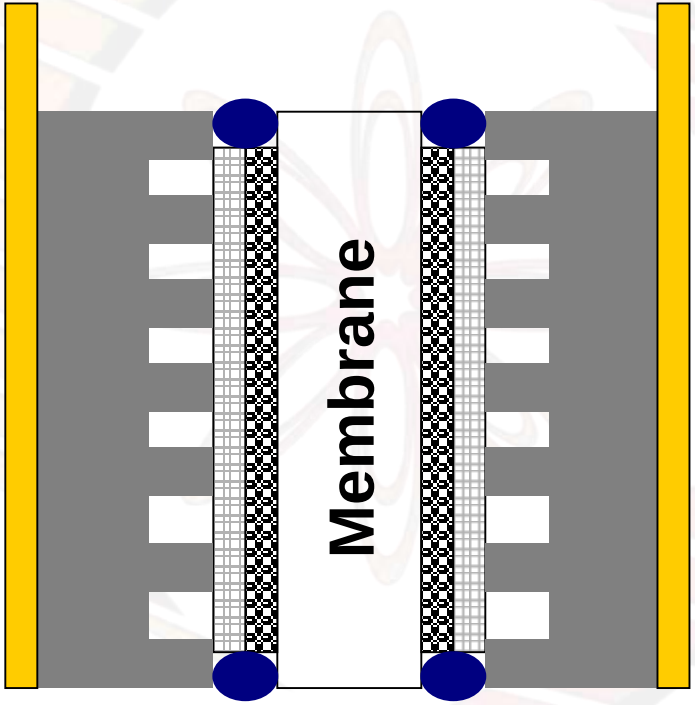



Catalyst layer
Polymer electrolyte
Gas flow channel
A
B
Gas diffusion layer

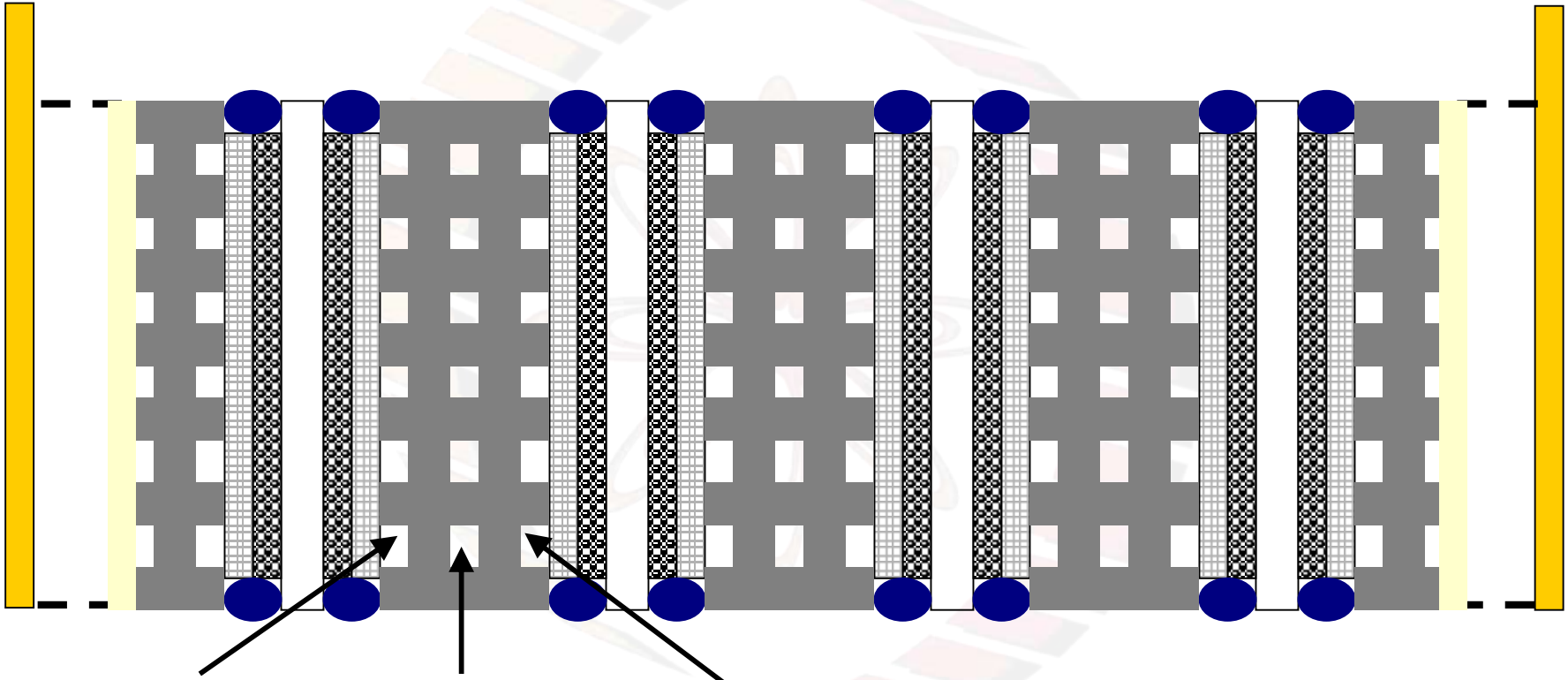
Cross section of a typical PEM Fuel Cell



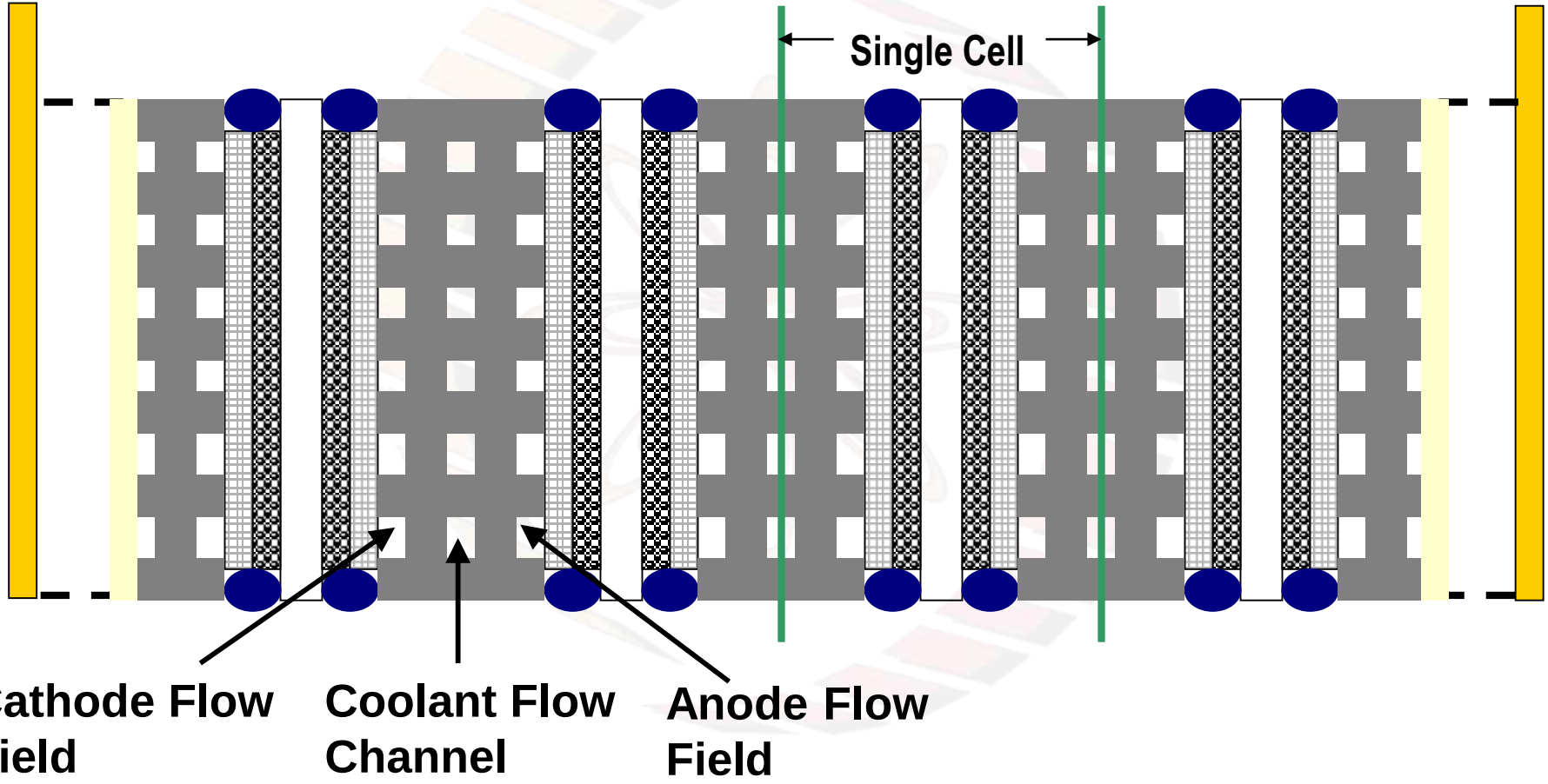
Cross section of a typical PEM Fuel Cell



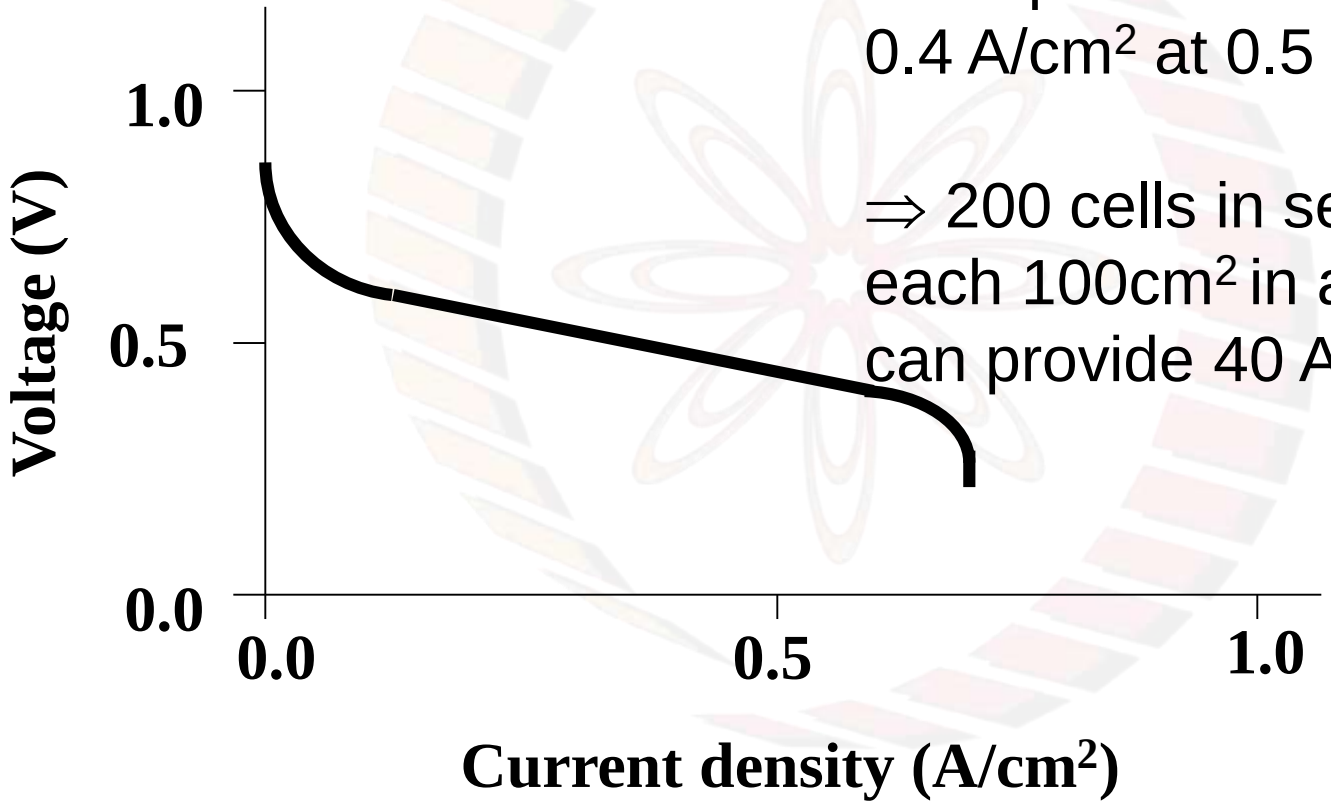
Cross section of a typical PEMC stack



Cross section of a typical PEMC stack



Schematic of polarization curve from a fuel cell



Example:
0.4 A/cm^2 at 0.5 V

$\Rightarrow$ 200 cells in series,
each 100cm^2 in area
can provide 40 A at 100 V (DC)

Other important design Issues:

Safety!

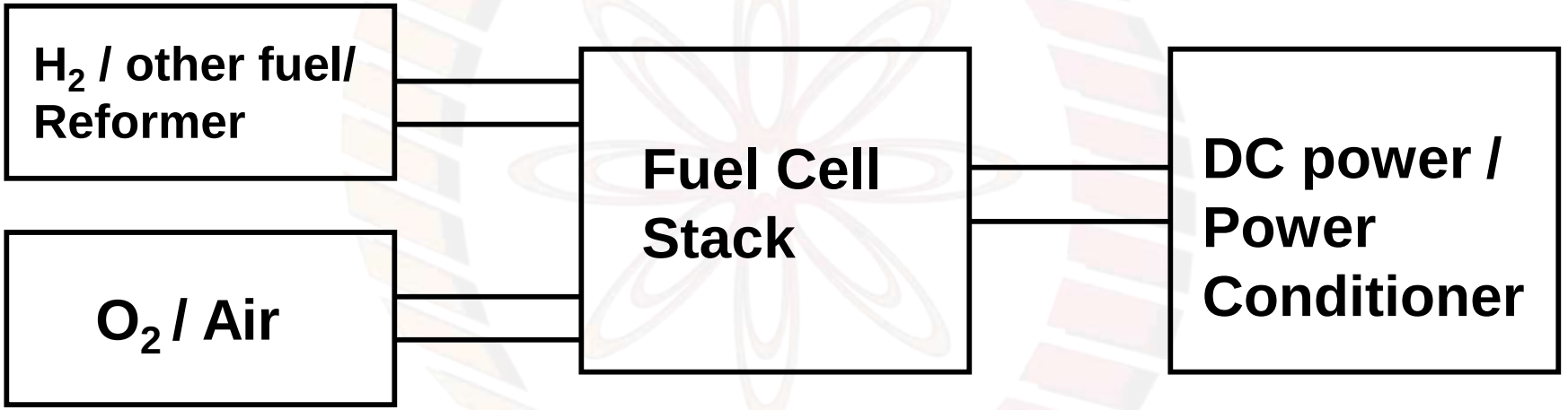
Hazard from use of pure H_2 and pure O_2

Replacements:

Air for O_2

Natural gas / other fuel that can be reformed to a H_2 rich fuel stream just before use.

Schematic of typical Fuel Cell systems



Residential use:

- Sizing not a critical issue
- 40,000 hours of lifetime is the target

Automotive use:

- Sizing *is* a critical issue
- 4,000 hours of lifetime is the target