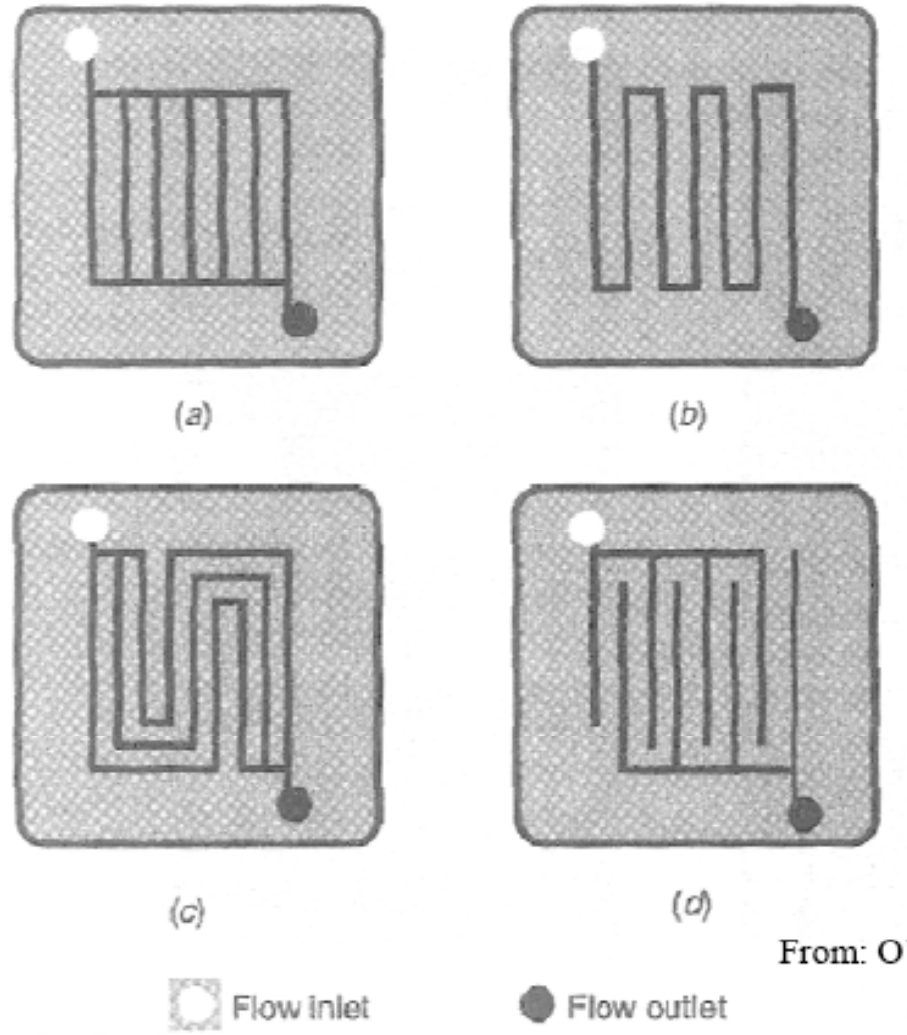
Major Types of Flow Channel Configuration



From: O'Hayre et al., 2006

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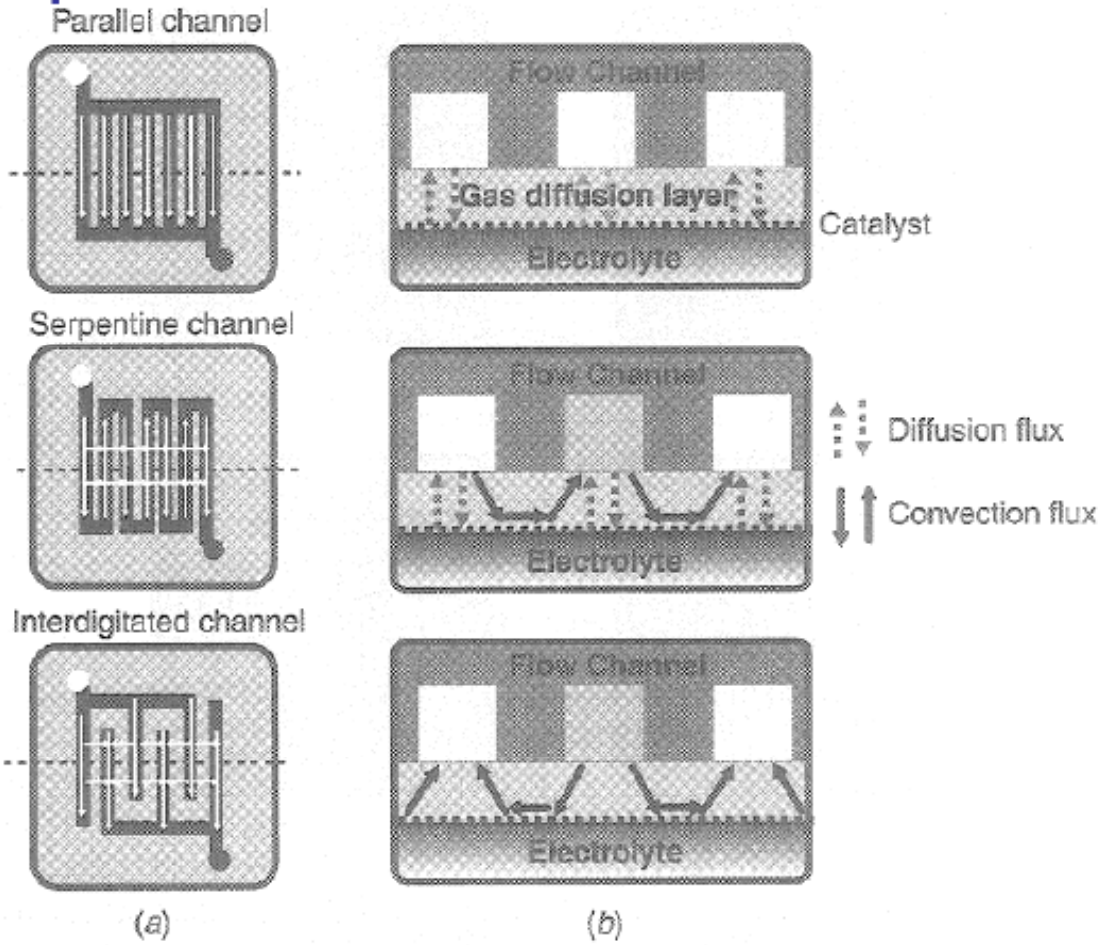
Mass Transport

Modes of mass transport within anode and cathode compartments



From: O'Hayre et al., 2006

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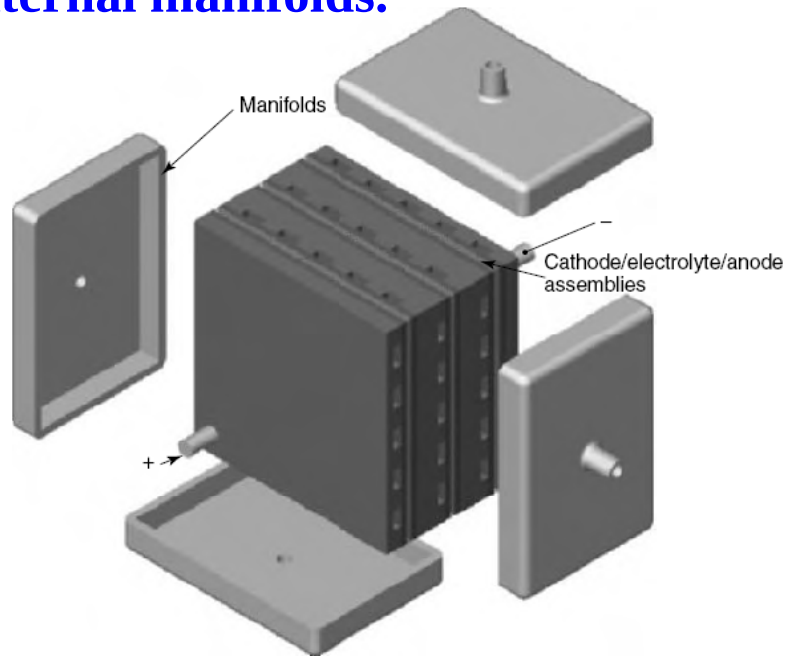
Other Stack Components

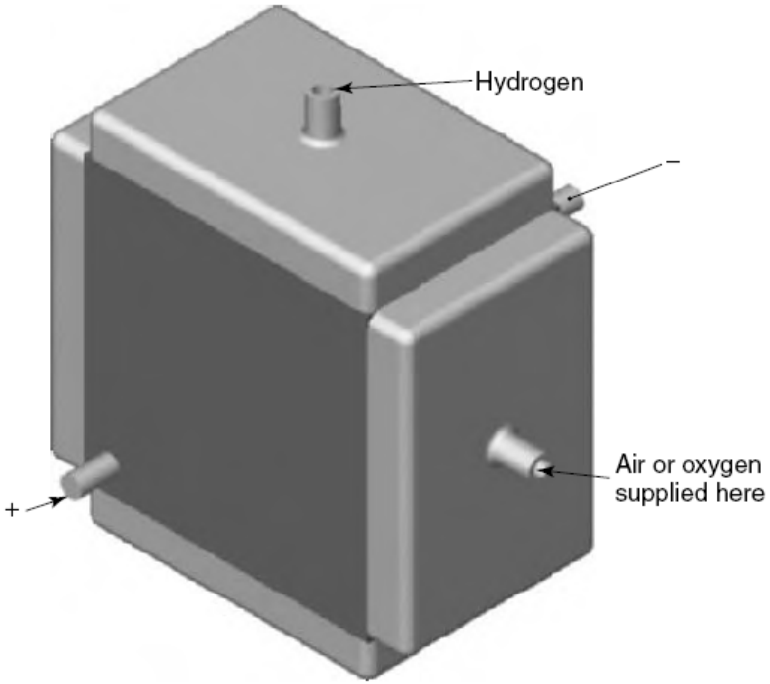
Manifolds

- Reactant gases need to be supplied in parallel to all cells in the same stack via common manifolds. Some stack designs rely on external manifolds, whereas others use internal manifolds.

External manifolds.



Three-cell stack with external manifolds.



The external manifolds are fitted to the fuel cell stack.

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Other Stack Components

External manifolds.

- The electrodes are about the same area as the bipolar plates, and
- The reactant gases are fed in and removed from the appropriate faces of the fuel cell stack.

Advantage

- Its simplicity, enabling a low-pressure drop in the manifold and good flow distribution between cells.

Disadvantages

- The two gas flows are at right angles to each other – cross-flow – and this can cause uneven temperature distribution over the face of the electrodes.
- Gas leakage and migration (‘ion-pumping’) of electrolyte.

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Other Stack Components

EXTERNAL MANIFOLDS

Route fuel to anode chamber

Route oxidant (air) to cathode chamber

'Plumbing' – not mundane, challenging

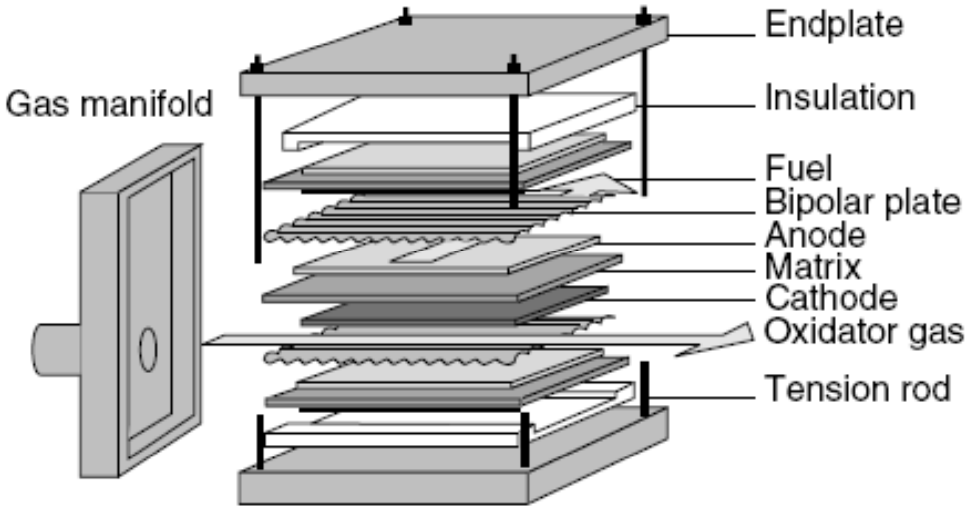
Even distribution of fuel and oxidant

Exposed to operating conditions and species of fuel cell

- High temperature
- Corrosive

Low pressure drop

Compact space requirements



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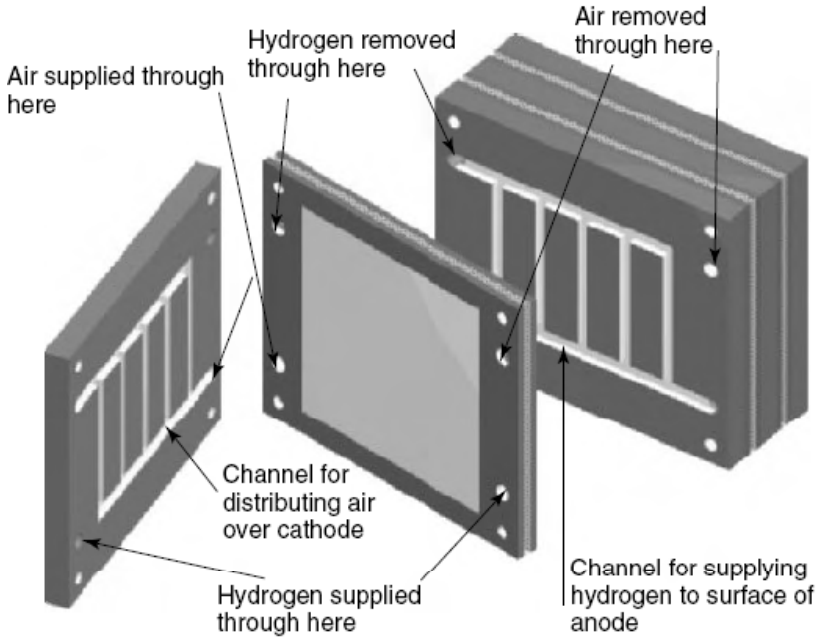
Other Stack Components

INTERNAL MANIFOLDS OR FLOW CHANNELS

- Internal manifolding refers to a means of gas distribution among the cells through channels or ducts within the stack itself,

- The electrolyte matrix itself can be used as a sealant.
- The electrolyte matrix forms a wet seal in the manifold areas around the gas ducts
- It is possible to seal the manifolds with separate gaskets and to extend the matrix only over the active cell area,



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Other Stack Components

Advantage

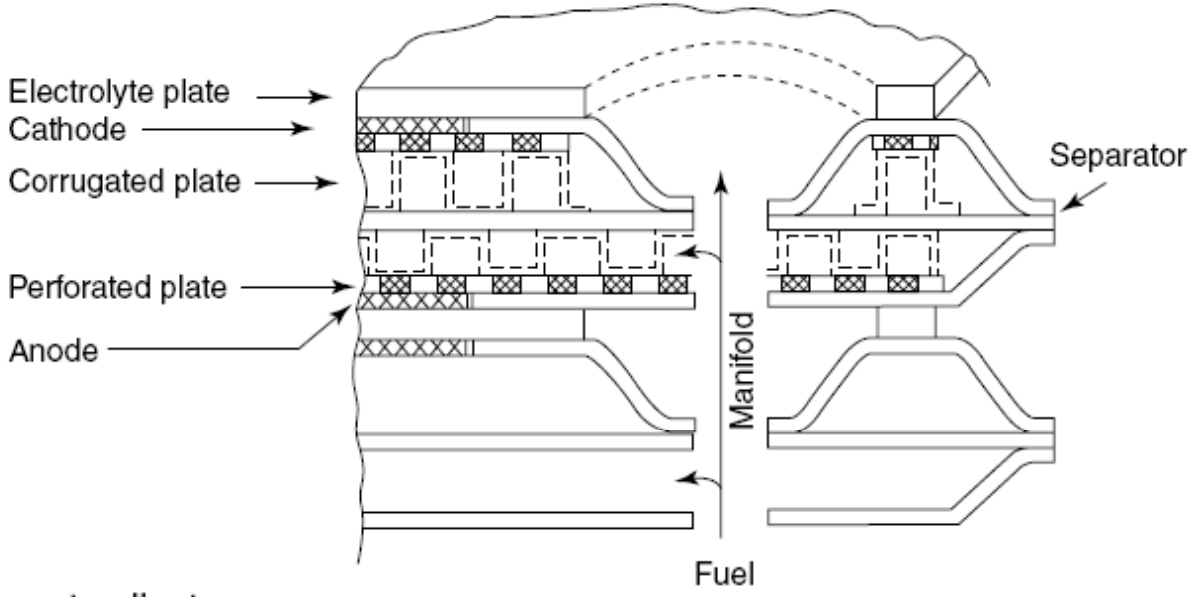
- There is much more flexibility in the direction of flow of the gases.
- The separator plates are designed with various internal geometries (flow inserts, corrugations, etc.), which, as well as providing the walls of the internal manifold, also control the flow distribution across each plate.
- Offers a great deal of flexibility in stack design, particularly with respect to flow configuration.

Disadvantages : More complex design of the bipolar plate needed.

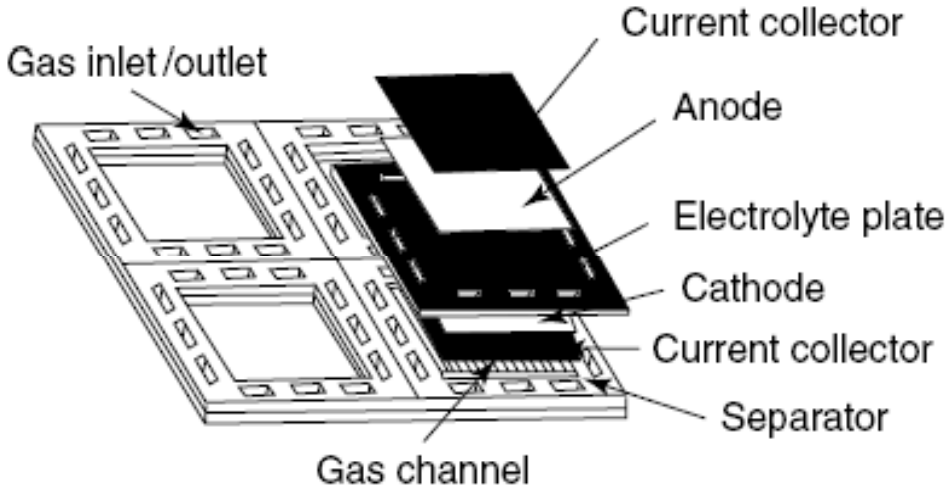
- It is possible to seal the manifolds with separate gaskets and to extend the matrix only over the active cell area,

Other Stack Components

Cross section of the wet-seal area in an internally manifolded MCFC stack



Multiple cell stack



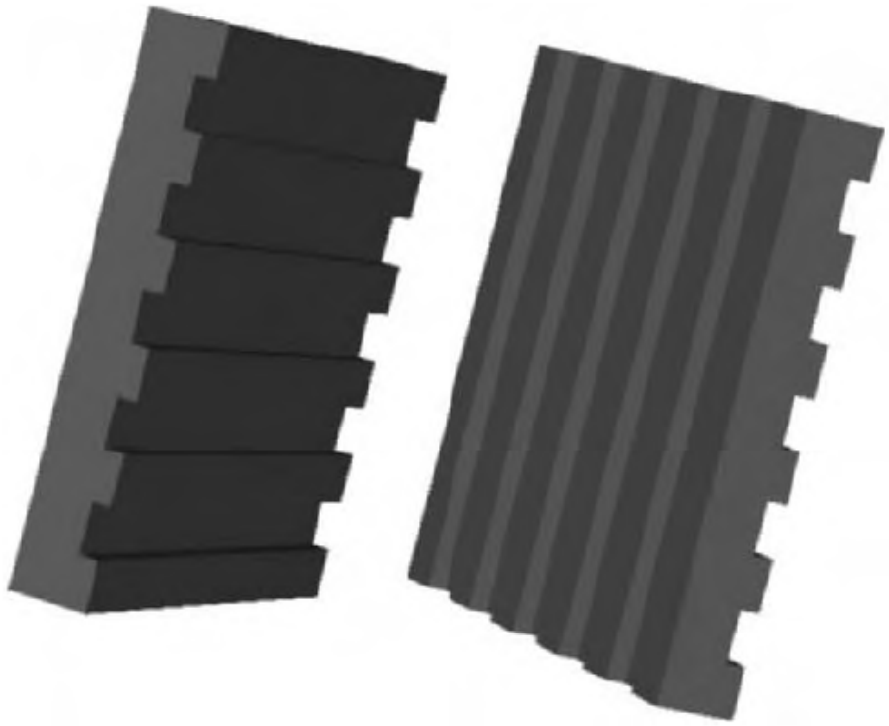
Multiple concepts for integration

- **Integrate with separators, bipolar plates**
- **Integrate with cooling**
- **Integrate with electrodes**

Other Stack Components

Bipolar plate

- The present bipolar plate consists of a separator, current collectors, and the wet seal.
- Used to interconnect cells together
- Serves as a means of feeding oxygen to the cathode and fuel gas to the anode
- Usually have to be further channels through it to carry a cooling fluid.



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Other Stack Components

HEAT EXCHANGERS

Needed to cool fuel cell – maintain operating temperature

Primarily lower temperature fuel cells

- AFC – usually cooled by circulating electrolyte
- PEMFC
- PAFC

Water or coolant (therminol, ethylene glycol) used

- Purity, conductivity issues

Higher temperature cells typically use other mechanisms

- Internal reformation – endothermic
- Higher air stoichiometry (essentially air cooling)

Other Stack Components

Interconnects (SOFC)

Electrically connect anode to cathode of adjacent cells in series and physically separate anode and cathode gas chambers (reducing and oxidizing environments)

- High density (>94%Th.D.)
- High electrical conductivity
- Low ionic conductivity
- Good thermal, mechanical, chemical stability
- Match thermal expansion (electrodes and electrolyte)

Very difficult criteria

Currently use ceramic interconnects

Metal interconnects under development

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Other Stack Components

Interconnects (SOFC) (cont'd)

Acceptor (Mg^{2+}, Sr^{2+}, Ca^{2+}) substituted lanthanum chromite is main candidate material

But, $LaCrO_3$ difficult to sinter to high density in air, poor mechanical strength, unstable under severely reducing environments

Several techniques for sintering high density $LaCrO_3$

- Add sintering aid (e.g., fluorides)
- Highly reactive powders
- Firing $LaCrO_3$ between Cr_2O_3 plates
- Add alkaline earth elements (e.g., Ca, Sr or Mg), or transition metals (e.g., Zn or Cu), or low melting point eutectic compositions

Other Stack Components

Interconnects (SOFC) (cont'd)

Recent development: transient liquid phase sintering in slightly non-stoichiometric Ca-doped $LaCrO_3$ (LCC)

LCC, however, has poor dimensional stability under reducing atmospheres

Perhaps use Sr-doped $LaCrO_3$, but, very difficult to sinter in air

Active area of research since lanthanum chromite is dominant, but, has several problems/issues

- Instability in reducing environments
- Expansion upon reduction
- Mechanical strength reductions
- Phase segregation in microstructure
- Sintering difficulty

Other Stack Components

Interconnects (SOFC) (cont'd)

Metal interconnects

- Lower cost
- Ease of manufacture/forming

Main problem is metal oxidation (degrades conductivity)

- Add protective oxidized layer - slow growing

Matching thermal expansion is difficult

Main candidates

- Ni/NiO - Conductivity good, CTE too high
- Cr_2O_3-forming alloys - relatively low oxide growth rate and relatively high electrical conductivity
- Cr-based alloys such as the plansee alloy Cr-5Fe-1Y_2O_3 wt.%, - designed to match the thermal expansion of zirconia-based electrolyte, cheaper, but limited to lower temperatures for longevity

Other Stack Components

PEMFC stack components

Bipolar plates

- Carbon based
- Recently, injection molded plastics w/ conductor (carbon)
- Bipolar plates usually comprise the flow channels

Current collectors – stainless steel

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