TECHNICAL NOTE

PEM FUEL CELL BIPOLAR PLATE MATERIAL

BALLARD®

GRAPHITE CARBON PROVIDES SUPERIOR COST AND DURABILITY – NEW STUDY RESULTS

FUEL CELL ELECTRIC VEHICLES

On the Path to Commercialization

Today, a growing numbers fuel cell buses, trucks and cars are being deployed in our cities. With no emissions at the tailpipe, fuel cell vehicles will play an important role in meeting the air quality improvement goals set by communities.

Fuel cell technology has moved beyond the prototype stage, and fuel cell vehicles are now on the road for real-world operation. OEMs and technology providers have an eye towards the future, designing fuel cell engines suitable for mass production volumes.

FUEL CELL BIPOLAR PLATES

An important fuel cell design consideration is the material selected for the bipolar plate for the proton exchange membrane (PEM) fuel cell. The bipolar (or flow field) plate is a key component, connecting each cell electrically, supplying reactant gases, and removing reaction by-products from the cell.

Bipolar plates can be made from various materials, with the most common being graphite carbon or metal. Each type of material has its strengths and weaknesses. Tradeoffs must be evaluated with the goal of balancing both material performance and cost effective manufacturing processes. A new cost study has shown that graphite carbon based plates are edging out metal for the plate material of choice, particularly when durability requirements are considered.

Considerations in Bipolar Plate Material Selection

When assessing a technology for mass production, manufacturers must take into account a variety of technical and strategic material attributes.

Technical

- **Corrosion:** electro-chemical stability to meet lifetime requirements
- **Durability:** strength and ability to meet shock and vibe requirements
- **Freeze-start:** capability to manage liquid water and minimize effective thermal mass
- **Heat rejection:** strength to operate at >100°C
- **Power density:** minimize thickness and maximize area utilization
- **Weight:** minimize stack weight (including fluids)

Strategic

- **Cost:** raw material cost, bipolar plate cost at mass production volumes
- **Recyclability:** strategy to meet recyclability requirements as defined by government directives
- **Supply:** development of raw material suppliers and bipolar plate suppliers
- **Competition:** competitive landscape, assessment of technology used by competitors

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Ballard's Perspective

At Ballard, our engineers are leveraging years of experience and extensive collaborations with Tier 1 automotive manufacturers to support critical areas of fuel cell design, including extensive work with both metal and graphite bipolar plates. We continually conduct analysis based on the latest materials and information to ensure we have the most up-to-date assessment.

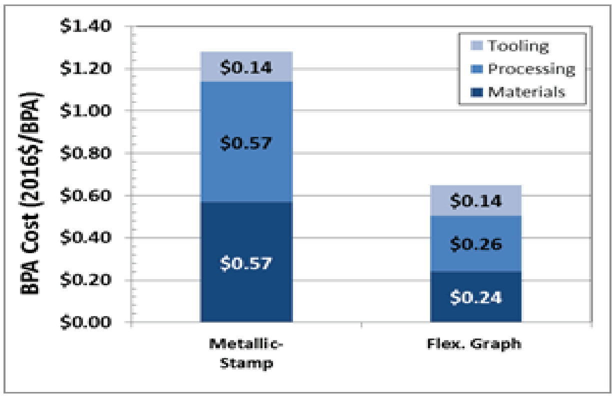
Historically, the higher mechanical strength of metal compared to carbon enabled a thinner bipolar plate design and subsequently a higher power density (kW/L). However, the corrosion behavior of conventional metal bipolar plate options compared to carbon in the fuel cell environment required either (i) the addition of corrosion resistant coatings for metal bipolar plates or (ii) the use of more expensive metallic materials that are stable in the fuel cell environment. Both options lead to an increase in cost of a metal bipolar plate.

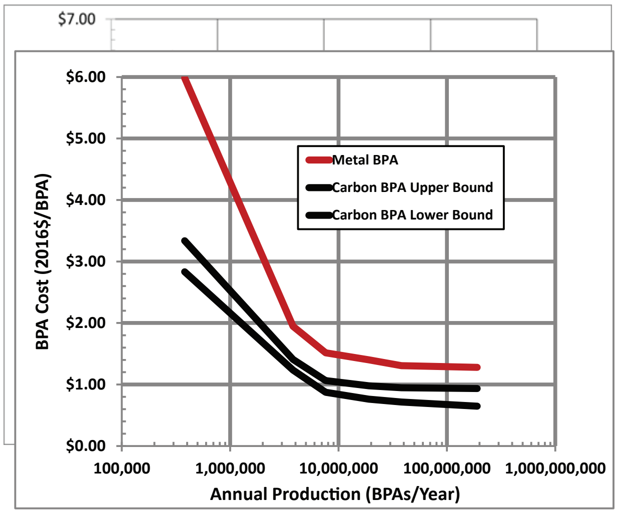
A recently published, third party study by Strategic Analyis Inc., indicates that the findings indicated that flexible graphite carbon plates are amenable to high volume production, and the estimated plates costs are substantially lower than stamped metal plates at all production volumes. The graphite plates are estimated to save US$5/kW for medium duty vehicles at 100,000 units per year but also provides significant saving for passenger car fuel cells at volume of 500,000 units per year ($3/kW). The total cost for the processed carbon plates (including tooling, processing, and materials) is just slightly higher than the material costs alone for the stamped metal plates, even at the higher volume production rates.

In addition to the cost advantage, the inherent stability of the carbon material over that of the metal provides a distinct advantage, particularly for long life applications. Carbon based plates have been proven beyond 30,000 hrs lifetime in London bus operation and in 1000's of stacks operating in the material handling application beyond 10,000 hours.

In addition, recent improvements to graphite bipolar plate design and material mechanical strength led to plate thickness and corresponding stack power density comparable to metal bipolar plates. Ballard designs metal and graphite fuel cell stacks that exceed intermediary automotive technical targets on the path to commercialization. Our industry-leading technical achievements include stack power >100kW, power density (including compression hardware) >4.0kW/L, and plate assembly thickness <1.0mm, with either carbon or metal based designs. There are different options for carbon plate materials, and depending on the plate requirements, Ballard can optimize the plate attributes and processes to meet cost and power density objectives. Typically high power density bipolar plates are slightly more expensive, but are still cheaper than a metal plate version of equal power density.

A bipolar plate assembly, or BPA, consists of two bipolar plates bonded together to form a cooling cell, inclusive of flow fields and all necessary coatings, but not including any sealings.





Flexible Graphite Plates are estimated to Shift Bipolar Plates Closer to $3/kW DOE Target for LDVs at 500k Systems per Year

[1] Brian James, Strategic Analysis Inc., Fuel Cell Systems Analysis, Project ID# FC163, US DOE Annual Merit Review, May 1, 2019.

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