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Journal of Power Sources 118 (2003) 44–46
JOURNAL OF POWER SOURCES
www.elsevier.com/locate/jpowsour

Bipolar plates for PEM fuel cells

E. Middelman[a,*], W. Kout[a], B. Vogelaar[b], J. Lenssen[b], E. de Waal[b]

[a]*NedStack Fuel Cell Technology BV, Arnhem, The Netherlands*
[b]*NedStack Fuel Cell Components BV, Arnhem, The Netherlands*

Abstract

The bipolar plates are in weight and volume the major part of the PEM fuel cell stack, and are also a significant contributor to the stack costs. The bipolar plate is therefore a key component if power density has to increase and costs must come down. Three cell plate technologies are expected to reach targeted cost price levels, all having specific advantages and drawbacks. NedStack has developed a conductive composite materials and a production process for fuel cell plates (bipolar and mono-polar). The material has a high electric and thermal conductivity, and can be processed into bipolar plates by a proprietary molding process. Process cycle time has been reduced to less than 10 s, making the material and process suitable for economical mass production. Other development work to increase material efficiency resulted in thin bipolar plates with integrated cooling channels, and integrated seals, and in two-component bipolar plates. Total thickness of the bipolar plates is now less than 3 mm, and will be reduced to 2 mm in the near future. With these thin integrated plates it is possible to increase power density up to 2 kW/l and 2 kW/kg, while at the same time reducing cost by integrating other functions and less material use.

Keywords: Bipolar plates; Carbon–carbon composite; Two-component molding process

1. Introduction

Bipolar plates have to accomplish many functions in the fuel cell stack.

Main functions are:

- distribution of fuel gas and air uniformly over the active areas;
- heat removal from the active area;
- conduction of current from cell to cell;
- preventing leakage of gasses and coolant.

For uniform gas distribution tight tolerances on channel dimensions have to be met. Small deviations lead to reduced efficiency, reduced power output and poor gas utilization and should therefore be avoided.

Heat removal requires preferably integrated cooling channels.

To minimize ohms losses the material needs to have low bulk resistance, and low contact resistance.

The material may not contain components that can poison the membrane and catalysts.

2. Available plate materials

Today several types of materials are being used in bipolar plates.

The main materials are:

- electro graphite;
- carbon–carbon composite;
- sheet metal;
- flexible graphite foil;
- graphite polymer composite.

High purity electro graphite is an excellent material for machining prototype plates, but material costs and process costs are generally considered to high for mass production.

Carbon–carbon composite is not expected to achieve ambitious cost price targets, and needs expensive post processing (CVI).

Sheet metal, graphite foil and graphite polymer composites are potentially low cost materials, and in principle suitable for mass production.

Thin sheet metal, for example, 125 μm (5 mil) stainless steel can be stamped to plates in an established mass production process, but has a drawback, increase of contact resistance and ionic contamination of membrane and catalyst, thus limiting life of the stack.

* Corresponding author. Tel.: +31-26-351-119; fax: +31-26-442-3450.
E-mail address: erik.middelman@nedstack.com (E. Middelman).

0378-7753/03/$ – see front matter © 2003 Published by Elsevier Science B.V.
doi:10.1016/S0378-7753(03)00070-3

Table 1
Properties of three conductive composite materials developed and produced by NedStack

Properties (unit)	Product		
	Conduplate LT-X	Conduplate MT-X	Conduplate HT-X
Operation temperature (max) (°C)	100	125	225
Electrical resistance (Ω m)	53×10^{-6}	60×10^{-6}	46×10^{-6}
Thermal conductivity (W/(m K))	28	38	40
Coefficient of thermal expansion (K^{-1})	28×10^{-6}	25×10^{-6}	12×10^{-6}
Density (kg/m^3)	1600	2000	1800
Hydrogen permeability (m^2/s)	50×10^{-12}	80×10^{-12}	50×10^{-12}
Flexural strength (Pa)	40×10^6	40×10^6	45×10^6

Flexible graphite is a thin, low density, inexpensive material made from expanded natural graphite. Being based on natural graphite, purity and consistency of quality are real concerns for this material. Another drawback of graphite foil is the very limited formability and poor dimensional stability.

Graphite filled polymer composite can offer a combination of inexpensive material and economical processing. Table 1 shows the properties of three conductive composite materials developed by NedStack.

3. Processing of composite plates

Several methods of processing have been developed for composite bipolar plates.

The main processes are:

- compression molding;
- injection molding;
- two-component injection molding (patented);
- preform molding (patented).

Most compression molding methods start with a powder compound. This powder is fed into a heated mold in which the compound will flow, and fill the mold cavity. If the binder is a thermo-set, several minutes, are typically required to have sufficient chemical conversion (cross linking) of the binder before the plate can be removed from the mold. If a thermoplastic binder is used, the mold has to be cooled to a temperature below the melting temperature of the binder before the plate can be removed. Cycle times of 15–20 min for thermoplastic compounds have been reported [1]. This is far too long for economical mass production.

Injection molding is also considered for mass production of plates. Although the injection molding process in general offers many advantages like automated production, short cycle time and accurate size, processing of conductive composite compounds is difficult. Drawbacks are excessive mold wear, limited size to thickness ratio and poor conductivity.

NedStack developed a two-component molding process especially for fuel cell plates. A highly conductive compound is used for the active area, while for the boarder area a non-conductive injection molding grade polymer is used. Fig. 1 shows two examples of such a bipolar plates. These plates have a total thickness of 3 mm, integrated cooling channels and incorporated molded seals. Channel size is 0.6 mm × 0.6 mm. The two-component injection molding process is preferred for small size plates were the active area is relatively small compared to the total plate area.

NedStack developed a preform molding process for larger bipolar plates. A plate like conductive composite material is heated outside the mold to a temperature above the melting point of the binder, inserted into a cold mold and molded to shape. The molding cycle with this material and process was reduced to less than 10 s. This is 100 times faster than other plate molding processes, and is considered a break trough in productivity and cost reduction.

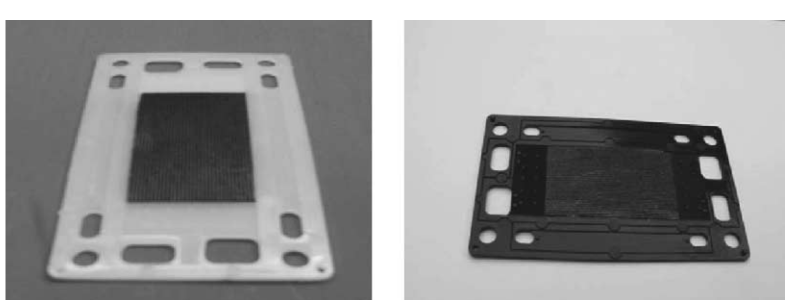

Fig. 1. Two-component injection molded bipolar plates.

4. Costs of plates

NedStack believes it has developed an attractive material and production process for bipolar plates. Low cost raw materials are used, molding is fast and material yield is high because the material is fully recyclable. To evaluate the cost price potential of the material and technology a typical plate design was used:

- *size*: 250 mm × 250 mm (10 in. × 10 in.);
- *thickness*: 2 mm (0.08 in.);
- *channel depth*: 0.5 mm (20 mil);
- *channel width*: 0.5 mm (20 mil);
- *weight*: 0.1 kg;
- including cooling channels and integrated seals.

In the cost price model a capacity of 1,000,000 plates per year was used.

Other assumptions are:

- NedStack Conduplate LT-X material;
- 100% material yield;
- 500,000 cycles per mold;
- 80% up-time of equipment;
- 20% depreciation per year;
- €50,000.- /fte.

The cost price break down (in Euro per plate) will than be:

- *material*: €0.65;
- *molds*: €0.05;
- *equipment*: €0.40;
- *energy*: €0.08;
- *labor*: €0.22;
- *total*: €1.40.

If used in combination with a 7 kW/m^2 MEA, this price per plate will result approximately in a €4.00/kW.

5. Conclusions

The conductive composite material and production process developed by NedStack are suitable for low cost mass production.

High power density of 2 kW/kg and 2 kW/l can be realized.

Ambitious cost targets set by the automotive industry can be met at sufficiently large scale.

Conductive composite is the material of choice for micro cogen PEM stacks, and is expected to be the preferred material for automotive stacks too.

Acknowledgements

We would like to thank Novem (The Dutch Energy Agency), EET and ECN for supporting this development.

References

[1] F.N. Buchi, M. Ruge, Bipolar elements for PE Fuel Cell Stacks based on the mold to size process of carbon/polymer mixtures, in: Proceedings of the First European PEFC Forum, 2001.