Gas Diffusion Layer for Polymer Electrolyte Membrane Fuel Cell Electrodes*
——Preparation of Carbon Fiber Paper

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Abstract: The principle and structure of proton exchange membrane fuel cell(PEMFC) were discussed and a processing flow of preparing high-performance carbon fiber paper was designed by analyzing the performance requirements of gas diffusion layer for PEMFC electrodes. The microstructure was observed by optical microscopy and the integrative performance test was carried out. The results indicated that the carbon fiber paper prepared using this method satisfied basically the application requirement.

Key words: PEMFC; fuel cell; gas diffusion layer; carbon fiber paper
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1 Principle and structure of PEMFC

Polymer electrolyte membrane fuel cell (PEMFC)[1] contains an "ion-exchange membrane" that acts as an electrolyte. The ion-exchange membrane is sandwiched between two "gas diffusion" electrodes, an anode and a cathode, each commonly containing a metal catalyst supported by a gas diffusion layer. The gas diffusion electrodes are exposed to the respective reactant gases, the reductant gas and the oxidant gas. An electrochemical reaction occurs at each of the two junctions (three phase boundaries) where one of the electrodes, electrolyte polymer membrane and reactant gas interface.

For example, when oxygen is the oxidant gas and hydrogen is the reductant gas, the anode is supplied with hydrogen and the cathode with oxygen. The electrochemical reactions that occur at the metal catalyst sites of the electrodes are as follows:

anode reaction:

$$H_2 \longrightarrow 2H^+ + 2e^-$$

cathode reaction:

$$1/2O_2 + 2H^+ + 2e^- \longrightarrow H_2O$$

During fuel cell operation, hydrogen permeates through the anode and interacts with the metal catalyst, producing electrons and protons. The electrons are conducted via an electronic route through the gas diffusion layer and the external circuit to the cathode, while the protons are simultaneously transferred via an ionic route through the polymer electrolyte membrane to the cathode. Concurrently, oxygen permeates to the catalyst sites of the cathode, where the oxygen gains electrons and reacts with the protons to yield water. Consequently, the products of the PEM fuel cell reactions are water and electricity. From Fig. 1 we can see the key parts of PEMFC are polymer electrolyte membrane, metal catalyst, gas diffusion layer and bipolar plate.

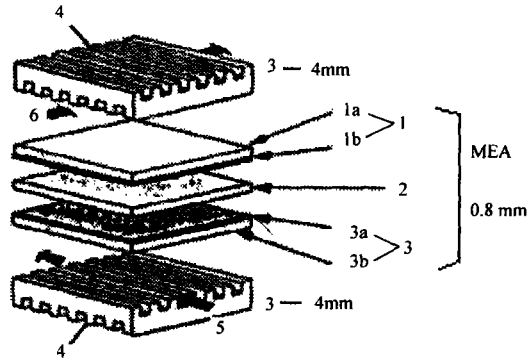

Fig. 1 Schematic diagram of PEMFC structure
1: anode; 2: electrolyte; 3: cathode;
1a, 3a: gas diffusion layer;
1b, 3b: catalyst layer; 4: bipolar plate;
5: oxide; 6: fuel

2 Preparation of carbon fiber paper

2.1 Performance requirements of carbon fiber paper

Gas diffusion electrodes play an important role in PEM fuel cells. While gas diffusion layer is a key part in

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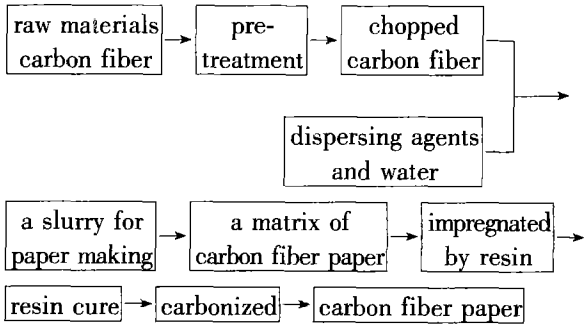
the electrode. Carbon fiber paper[2] is a widely used gas diffusion layer in PEMFC electrode. It must satisfy the following performance requirements: ① low diffusion resistance of the gas to reaction sites; ② high electronic conductivity; ③ mechanical strength for long-term operation; ④ proper hydrophilicity/hydrophobicity balance; ⑤ stability; and ⑥ low cost in favor of mass production.

2.2 Schematic flow sheet of processing carbon fiber paper[3]



2.3 Dispersing ability of chopped carbon fiber

Uniformly dispersing the chopped carbon fiber in water and maintaining the stability of paper making slurry are the most important processing conditions during the preparation of carbon fiber paper. Because carbon fiber is different from natural plants fiber, which doesn't have hydrophilicity, it is liable to assemble. A study indicates that the length and its distribution of chopped carbon fiber, the surface state of carbon fiber, the kind of dispersing agents and its amount used will all influence the dispersing ability of chopped carbon fiber in water.

Selecting four kinds of chopped carbon fiber with different length in a range from 0.5 mm to 6 mm, putting them together with water to form four different slurries for paper making, then observing the sedimentation speed respectively. The sedimentation time was used to measure the dispersing ability. From the Fig.2 we can see easily the sedimentation time of sample 1 is longest. So the dispersing ability of sample 1, which has appropriate length and uniform distribution, is best.

3 Performance test of carbon fiber paper

The essential properties of carbon fiber paper, as a gas diffusion layer material, are the thickness, density, permeability, porosity and specific resistivity. Thickness was measured by vernier caliper; density was measured by specific gravity balance; porosity was measured by the weight difference between dry and wet carbon fiber paper or by porosity apparatus; permeability was measured by air permeability apparatus and specific resistivity was measured by model SZT-90 digital four-point probe measuring system. The surface microstructure was observed by model BH2-umA Olympus microscope. Two micrographs are shown in Fig.3a and b for cured sample and carbonized sample respectively. The state of charring resin bound carbon fiber and the residue left from resin after carbonization bound carbon fiber can be seen from them. In addition, the pore size and its distribution of carbon fiber paper can also be shown in the micrographs.

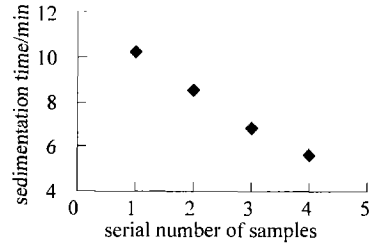
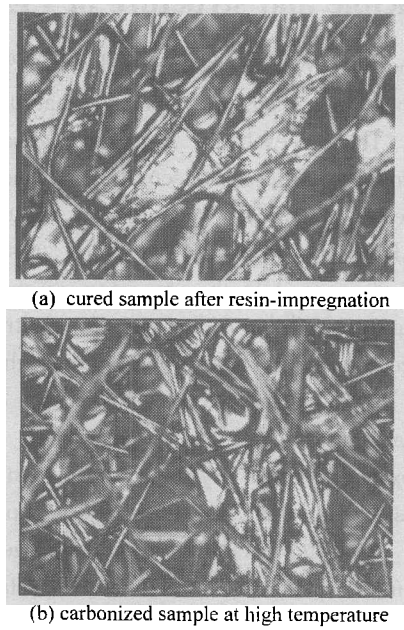


Fig.2 Influence of length on dispersing ability of chopped carbon fiber



(a) cured sample after resin-impregnation

(b) carbonized sample at high temperature

Fig.3 Micrographs of carbon fiber paper

A Chinese patent (No: 01 132 156.3) for invention on the preparation method of carbon fiber paper was authorized in November 2001. Now there are two types of carbon fiber paper, and their dimensions are 125 mm times 135 mm and 220 mm times 220 mm respectively. The performance parameters are as follows:

Thickness: 0.15 ~ 0.25 mm

Density: 0.38 ~ 0.52 g/cm^3

Porosity: 65% ~ 78%

Specific resistivity: 0.06 ~ 0.20 Ω·cm

Shanghai Jiaotong University and Dalian Sunrise Power Co., Ltd have used the carbon fiber papers in

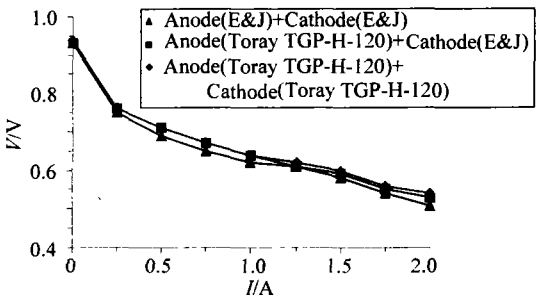


Fig.4 The result of electric performance test

PEM fuel cell to test their integrative performance. The test results are shown in Fig. 4, from which we can conclude that the carbon fiber papers basically satisfied all requirements.

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质子交换膜燃料电池用气体扩散层——碳纤维纸的制备

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摘 要:介绍了质子交换膜燃料电池(PEMFC)的工作原理,并通过分析气体扩散层材料的性能要求,设计了一条制备高性能碳纤维纸的技术路线。对制得的碳纸样品进行了显微结构和基本性能的表征,同时还将它应用于PEMFC的单电池中进行综合性能的测试,测试结果表明,按照这种技术路线制得的碳纤维纸在性能上基本能满足PEMFC的使用要求。

关键词:质子交换膜; 燃料电池; 气体扩散层; 碳纤维纸

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