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ELEMENTARY TECHNOLOGY DEVELOPMENT : DEVELOPMENT OF HIGH PERFORMANCE CELLS

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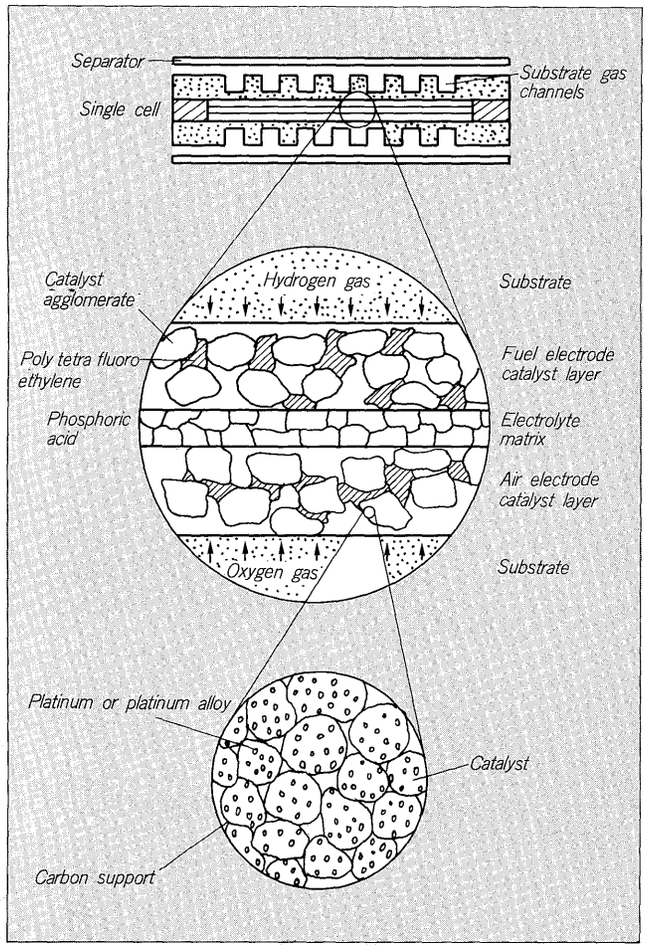
1. FOREWORD

To make phosphoric acid fuel cells practical, it is essential to develop cheap, reliable cells.

Especially, because the cost per kW reduction effect is large and miniaturization of the cell is possible, development of a high performance cell aimed at increasing the cell power density was promoted energetically. Because the reliability of the cell itself is especially important in the entire power unit, development in conjunction with improvement of cell reliability was promoted.

Fig. 1 Structure of phosphoric acid fuel cell electrode



The cell structure, electrode structure, and catalyst structure of a phosphoric acid fuel cell are shown in *Fig. 1*. At the air electrode, the electro-chemical reaction of the cell is:

$$\frac{1}{2}O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

The oxygen in the air which flows through the gas channels of the electrode substrate passes through the gas diffusion part of the electrode and is diffused to the electrode catalyst layer. The electrode catalyst layer is constructed by dispersing the catalyst agglomerate which is platinum or platinum alloy supported on carbon black and polytetrafuoroethylene bonder. Phosphoric acid is also maintained at the catalyst agglomerate so that the hydrogen ions migrate. The diffused oxygen is dissolved and transported to the platinum surface by the catalyst agglomerate surface phosphoric acid. Thereupon, the hydrogen ions and oxygen in the phosphoric acid react with the electrons propagated through the electrode substrate and carbon black and water is generated. The generated water is fleed to the electrode substrate gas channels and is carried to the outside of the cell over a reversed path of the oxygen path. This air electrode reaction and fuel electrode reaction are performed via an ion conductive electrolyte and power is generated by flowing electrons through an outside circuit. At this time, a voltage drop corresponding to the extracted current is generated by activation polarization by catalyst activity, diffusion polarization by diffusion resistance, and resistance polarization by electric resistance of structural material at the electrodes. This voltage drop generates thermal energy.

To develop a high performance cell,

(1) Cell high power densification
  (a) High activation of air electrode catalyst
  (b) Current densification by improvement of the air electrode structure.
  (c) Increase of heat conductivity, high electric conduction, and improvement of other performances of the electrode substrate material
(2) Improvement of cell reliability
  (a) Improvement of air electrode catalyst corrosion resistance and aggregation resistance
  (b) Improvement of the air electrode hydrophobicity

Fig. 2 Improvement of catalyst for air electrode

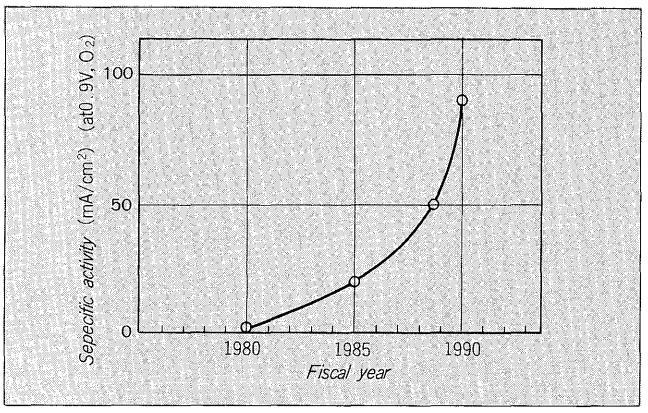


Fig. 3 TEM photograph of carbon supported platinum catalyst

Fig. 4 SEM photograph of catalyst layer of air electrode

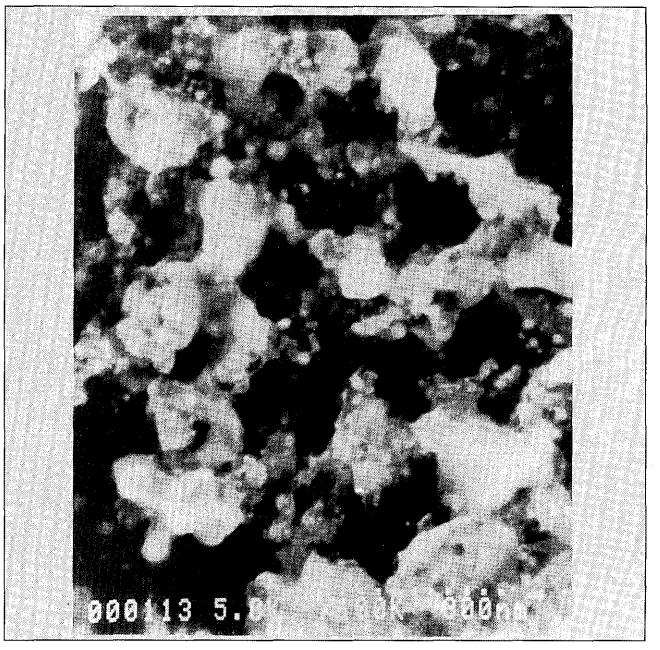
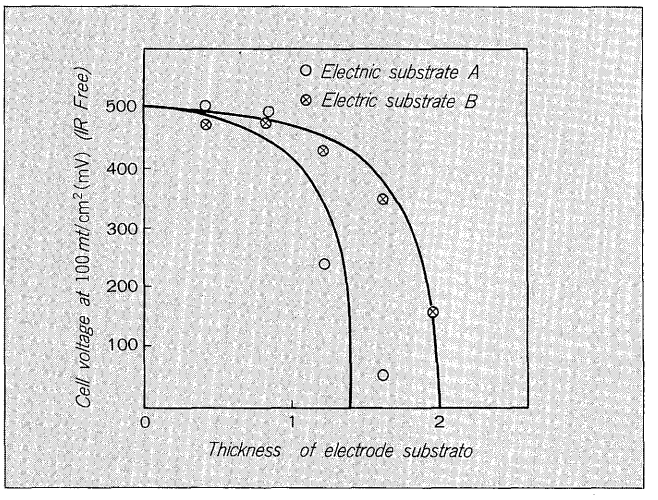


Fig. 5 Electrode substrate thickness vs cell voltage



(c) Development of acid refill structure

must be achieved.

The development status, with emphasis placed on cell power densification and reliability improvement technology, is introduced here.

2. HIGH ACTIVATION OF AIR ELECTRODE CATALYST

To increase performance, a high voltage must be maintained even when a larger current is extracted. Since the voltage drop by activation polarization at the air electrode of a phosphoric acid fuel cell is large, high activation of the air electrode catalyst is an especially important development problem.

For high activation of the air electrode catalyst, development of a corrosion-resistant carbon support with a large surface area, development of an active platinum alloy catalyst, improvement of the dispersion homogeneity and development of fine granularization of the platinum alloy catalyst on the carbon support are important. Regarding development of the carbon support, several kinds of carbon black and carbon stabilization were studied and the carbon support was optimized. The activity improvement shown in *Fig. 2* was achieved by using the alloyed catalyst. Studies on further activity improvement are progressing. As for homogeneous dispersion and fine granularization, the manufacturing conditions and heat treatment conditions during alloying were studied and the homogeneous dispersion and fine grain alloy catalyst shown in *Fig. 3* was developed and an increase of the reaction surface area

Fig. 6 Test facilities for short stack

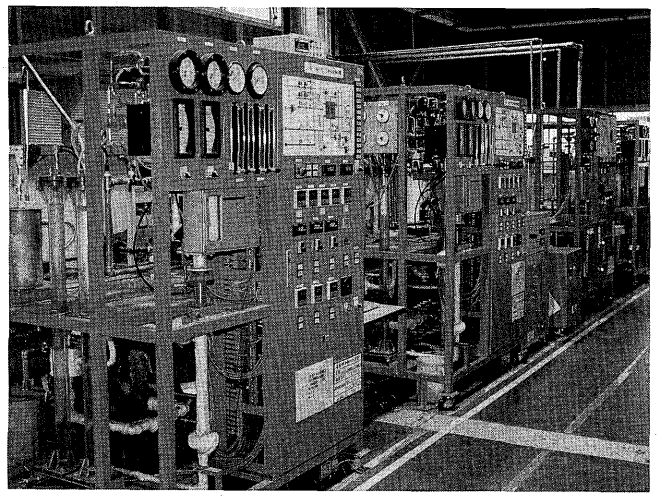
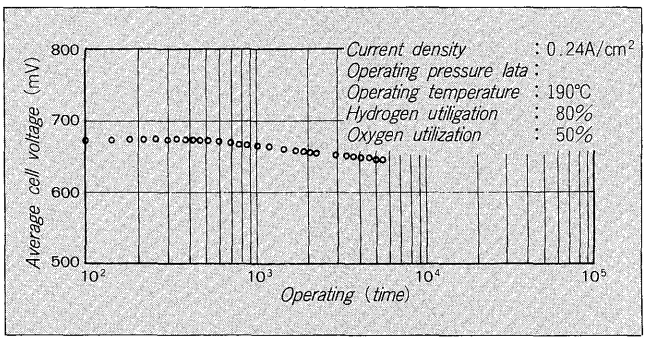


Fig. 7 2000cm² cell endurance test result



and high activation were achieved.

Regarding stability as a catalyst, the change of the surface area, crystalline diameter, and diffraction angle (2θ) was studied by aging test at 0.8V and stability was confirmed.

3. HIGH CURRENT DENSIFICATION BY AIR ELECTRODE STRUCTURE

To increase performance, development of an electrode structure capable of stable operation in the high current region, especially the electrode catalyst layer, is just as important as development of the catalyst. In the high current region, the increase of diffusion polarization related to diffusion of oxygen and removal of the generated water at the air electrode catalyst layer is a problem. The electrode catalyst layer is made up of catalyst agglomerate and the hydrophobic agent polytetrafluorouethylene. Fuji Electric conducted optimization studies on the electrode catalyst layer structure by comparison between simulation result based on the diffusion equation and electrode catalyst layer manufacture method and clarified that improvement of catalyst utilization and securing of ion conductivity by securing gas diffusion channel and improvement of the liquid retention of the catalyst agglomerate are important factors. Based on this result, optimization of electrode catalyst layer manufacture method was conducted. High current densification with homogeneous dispersion of the catalyst agglomerate and polytetrafluoroethylene, as shown in *Fig. 4*, was achieved by improvement of dispersion.

4. DEVELOPMENT OF FUNCTIONAL ELECTRODE SUBSTRATE

Similar to the electrode catalyst layer, the electrode substrate has an effect on gas diffusion in the high current region. Therefore, the structure of the electrode substrate was simulated and the relationship between the electrode substrate structure and the output voltage in the high current region was studied and the results shown in *Fig. 5* were obtained. The solid lines in the figure are the result of simulation. Optimization of the electrode substrate structure and dimensions was conducted based on such studies.

The electrode substrate must also tranfer the heat generated in the cell. Development of electrode substrate is proceeding, aiming improvement of a heat conductivity of three times the conventional value with securing gas permeability.

5. IMPROVEMENT OF CELL RELIABILITY

Regarding the high power densification development items described up to this chapter, reliability is confirmed by performing endurance tests of actual size cells using the short stack test facilities shown in *Fig. 6* concurrently with endurance evaluation by small cell. An example of the endurance evaluation results of a 2,000cm² cell are shown in *Fig. 7*. Besides such endurance evaluation, studies on cell reliability under condition close to actual operating conditions were advanced using a small cell.

6. CONCLUSION

This paper describes the recent development results related to high power densification and reliability improvement regarding development of the high performance cell which is important in practical use of the fuel cell. Development centered about the catalyst and electrodes aimed at increasing cell performance will be promoted in the future and more efforts will be poured into early practical use.

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