ORIGINAL PAPER

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A new method of making a gas diffusion electrode

Abstract A technique is described for production of a gas diffusion electrode by electrophoresis.

Keywords Electrophoresis · Gas diffusion electrodes

Introduction

There are many applications of gas diffusion electrodes. For example, they are fuel cells, the oxygen cathode for chlor-alkali electrolysis [1], the air cathode of the zinc–air battery, etc. This gas diffusion electrode is composed of a dispersion of PTFE and carbon black with a catalyst. The production technique of the electrode is complicated [2, 3]. The electrode materials are dispersed in aqueous solution with a surfactant. The dispersion becomes the electrode sheet by flocculation, filtration, drying and sheeting processes. Afterwards, the sheet is dried, the surfactant removed, and the electrode is finally hot-pressed. Simplification of the process is necessary in order to obtain cheaper gas diffusion electrodes.

A method for simplifying the operation was studied. It was noticed that the carbon black and PTFE dispersion were a disperse system using a non-ionic surfactant. The zeta-potential is almost −30 mV on the PTFE and carbon black in the dispersion. This puts a high voltage in this dispersion, because the conductivity is small. By inserting both silver electrodes in the dispersion, it was electrolyzed. The anode was covered with a mixture of PTFE and carbon black, that is, it was found that a mixture of PTFE and carbon black could be electrodeposited by electrophoresis.

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In this paper, a production technique for a gas diffusion electrode by electrophoresis is reported.

Experimental

The dispersion of the gas supply layer was composed of hydrophobic carbon black (6%) and a PTFE dispersion (4%) in 4% Triton X-100 aqueous solution. The conductivity of the dispersion was 86 μS/cm. The dispersion of the reaction layer was composed of hydrophobic carbon black (4%), hydrophilic carbon black (1.7%) and a PTFE dispersion (3.4%) in 4% Triton X-100 aqueous solution. The conductivity of the dispersion was 55 μS/cm.

The zeta-potential was analyzed by a ELS-6000 (Otsuka Electronics). The electrophoresis cell was home made. Measurement of the composition was by fluorescence X-ray analysis (JSX-3201, JEOL). Evaluation of the electrode performance was carried out in a half-cell test.

The electrophoresis cell is shown in Fig. 1. The electrophoresis voltage was 2–300 V.

Results and discussion

The results from measurement of the zeta-potential are shown in Table 1. The zeta-potential of the carbon black and the PTFE particles were of a value smaller than −30 mV. It was proved that these particles are stably dispersed in aqueous solution and electrophoresis is possible on the anode.
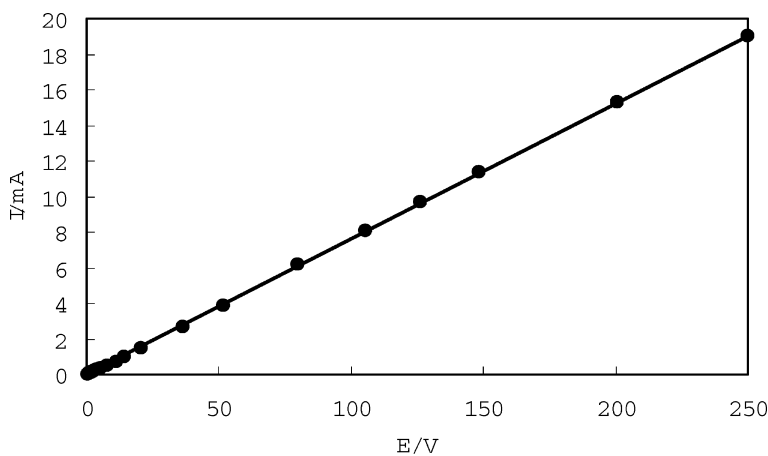
Electrodeposition on Ag plate

The dispersion of the gas supply layer (hydrophobic carbon black + PTFE dispersion) was deposited under various electrophoresis conditions. Figure 2 shows the relation between the electrophoresis voltage and the current. The deposition quantity was proportional to the electrophoresis voltage.

The gas supply layer and the reaction layer were deposited on Ag plates at 50 V. Table 2 shows the deposition time, the deposition quantity per coulomb
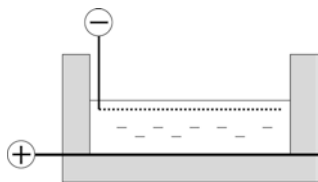
Fig. 1 The electrophoresis cell

Table 1 The zeta-potential of the various particles for the gas diffusion electrode

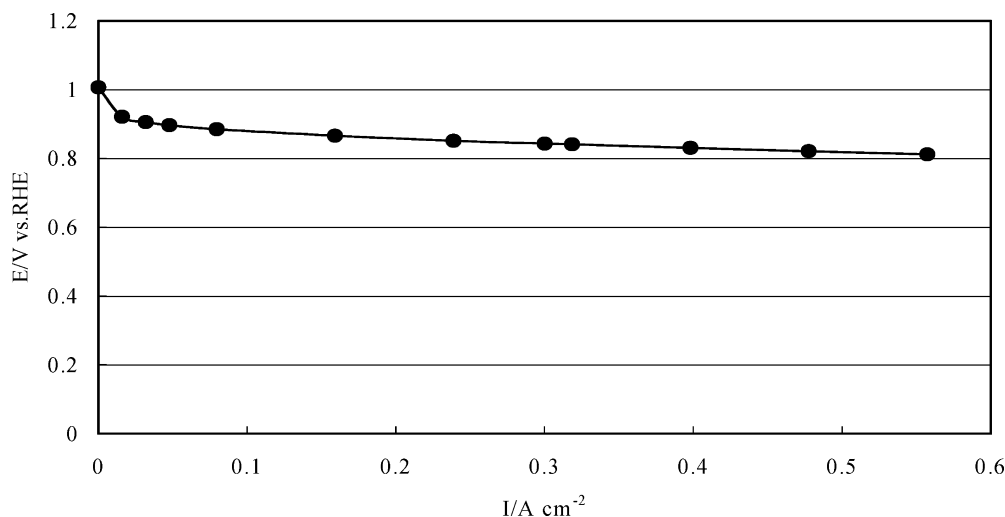| Particle	Zeta-potential (mV)
Hydrophobic carbon black	−31.07
Hydrophilic carbon black	−37.09
PTFE dispersion	−38.00
Hydrophobic carbon black + PTFE dispersion	−34.00
Hydrophilic carbon black + PTFE dispersion	−39.00

and the thickness. It was proved that the gas supply layer is rapid for electrodeposition and that it is slow in the reaction layer.

Table 2 Deposition time, deposition quantity per coulomb and thickness

	Time (s)	Quantity (g/C)	Thickness, d (mm)
Gas supply layer	90	0.623	0.98
Reaction layer	40	0.168	0.20

Evaluation of the electrode performance

The gas supply layer was deposited on Ag mesh at 50 V for 100 s. Continuously, the reaction layer was deposited on the gas supply layer at 50 V for 30 s. After deposition, the sheet was dried, the surfactant removed using a Soxhlet extractor and hot-pressed at 50 kg/cm^2 and 350 °C. The gas diffusion electrode was loaded with platinum catalyst (0.56 mg/cm^2).

The electrode performance is shown Fig. 3. The electrode (12.6 cm^2) performance for oxygen reduction was measured by a half-cell test at 32% NaOH, 80 °C and 1 atm O$_2$. The performance of the gas diffusion electrode obtained was 0.843 V vs. RHE at 30 A/dm^2. The performance of the electrode is higher than

Fig. 2 Relation between the electrophoresis voltage and the current

Fig. 3 The performance of the gas diffusion electrode using electrophoresis

that of the electrode produced by the conventional method [4].

Conclusion

Electrophoresis was able to produce a gas diffusion electrode with good performance. A large electrode can easily be produced by this method. The gas diffusion electrode can also be cheaply produced, because the process is simple.

References

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