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Characteristics of Test Fuel Cell Using Hydrogen Storage Alloy

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In utilizing a fuel cell, higher cost and deterioration of a catalyst are important subjects. Catalysts relevant to electrolytes have been, therefore, studied and developed from these aspects. In this study, a test fuel cell using $LaNi_5$ as a part of electrode was made from viewpoints of reducing the Pt catalyst and obtaining a new catalytic electrode surface. In this fuel cell, parfluoro carbon sulfonic acid, Pt, Graphite (extruded) and $LaNi_5$ powder or film were used as electrolyte, additional catalyst, cathode and anode, respectively. After the activation of $LaNi_5$ film, the output of test fuel cell exhibited almost the same value as the output of a standard cell using only Pt. Additionally, test fuel cells using $LaNi_5$ powder exhibited higher output than test fuel cell using $LaNi_5$ film. These results indicates a possibility that hydrogen storage alloy of $LaNi_5$ as an electrode may substitute at least partially the higher cost of Pt catalyst. If the electrode of $LaNi_5$ was properly pretreated and activated, diffusion of atomic hydrogen was the rate-determining step. This indicated an adequate performance of $LaNi_5$ for the dissociation of H_2 molecules in the test fuel cells under the test conditions. Thus $LaNi_5$ can be selected, as an ECOMATERIAL because of not only stabilizing the output of the cell but also reducing the consumption of higher cost of Pt.

Key words: Polymer electrolyte Fuel cell, Hydrogen storage alloy, $LaNi_5$

1. INTRODUCTION

Today, increasing consumption in great quantity of fossil fuel has aggravated the global environment. System using natural energy has been desired as a new clean energy system, which may take the place of fossil fuel energy system. However, the natural energy is characterized by low energy density and unstableness. Recently, fuel cell has been expected as a new energy system device using natural and renewable energy resources, which may substitute some part of the fossil fuel energy system. Polymer electrolyte fuel cell is expected as a power supply for movement, since electrolyte contributes to the things into film-like and a miniaturization. In utilization of a fuel cell, cost and decrease of the performance of a catalyst are important factors[1]. Especially, the platinum used as catalyst occupies the most all price. Catalysts in relevance to electrolyte have been, therefore, developed from various kinds of aspects.

For the meanwhile, the hydrogen storage alloy, such as $LaNi_5$, has been expected and used as useful materials, which enlarges the possibility of the system utilities in renewable energy systems. Especially, since $LaNi_5$ is easily activated and also readily keeps the surface activated in hydrogen gas even after exposures of the alloy to air [2].

Figure 1 shows the influence of change of hydrogen supplying pressure upon the output of the cells with and without $LaNi_5$ layer on the electrode. Aforetime, we demonstrated the possibility that the hydrogen storage $LaNi_5$ layer could be expected as hydrogen storage buffer, which resulted in decreased use of Pt and more stable output under unstable fuel supplying. The catalytic effect can be expected, however, after some activation of the electrode, where the output once drops but recovered after several ten minutes of power generation [3].

Then, in this study, the fuel cell using $LaNi_5$ powder alloy as a part of negative electrode was made as a test cell from viewpoints of reducing Pt catalyst by substituting some Pt by $LaNi_5$.

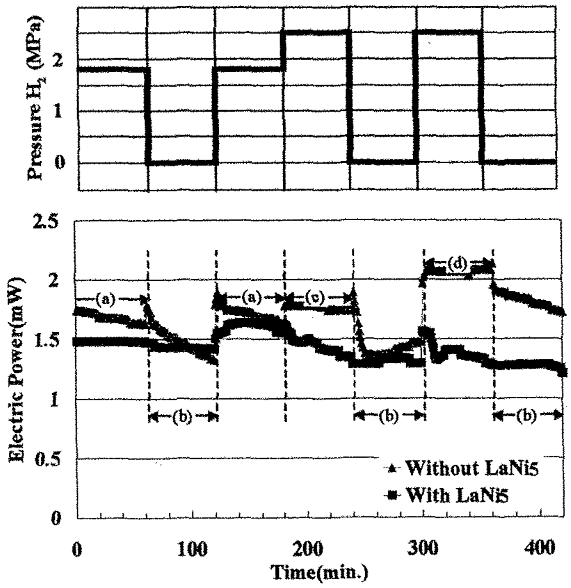

Fig. 1 The influence of change of hydrogen supplying pressure upon the output of the test fuel cell and the standard polymer electrolyte fuel cell measured at RT. (a): the hydrogen gas was supplied at 0.18 MPa , (b): the hydrogen gas supplying was stopped, (c): the hydrogen gas supplying pressure changed 0.18 MPa to 0.25 MPa, (d): the hydrogen gas was supplied at 0.25Mpa[3]

2. EXPERIMENTAL

The test fuel cell was made as shown in Fig. 2. In the test fuel cell, parfluoro carbon sulfonic acid (Nafion117, Dupont Co.) was used for electrolyte. Pt of about 0.3mg/cm^2 (with $LaNi_5$) or 0.6mg/cm^2 (without $LaNi_5$) was deposited on electrolyte and electrodes as catalyst by using an ion sputter (E-1010, HITACHI). Graphite (extruded) was used for both the anode and cathode. Electrolyte on anode side was made to adhere $LaNi_5$ powder or $LaNi_5$ of 1-2 micron-m thick thin film deposited by flash evaporation. Ultra high purity hydrogen gas (7N) and high purity oxygen gas (4N) were supplied to anode and cathode, respectively. Output of the cell, load resistance and current were measured by voltmeter 1, 2 and ammeter, respectively. Output was measured under constant hydrogen and oxygen gas pressures of 0.5Mpa as base pressures. The quantity of the water added to polymer electrolyte was first set to 0.05ml/cm^2. A standard cell using only graphite was also made and compared with the test cell. All the experiments were carried out at RT.

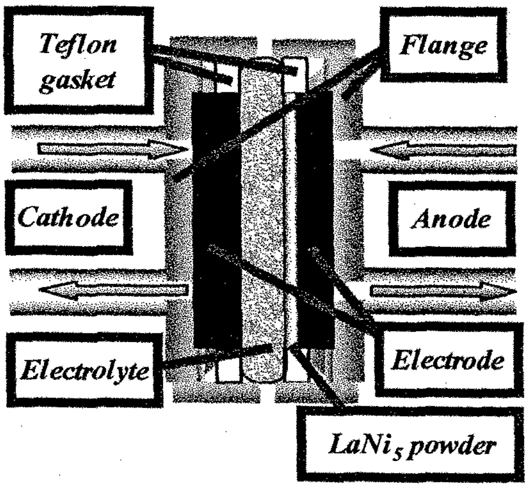

Fig. 2 Schematic diagram of test fuel cell

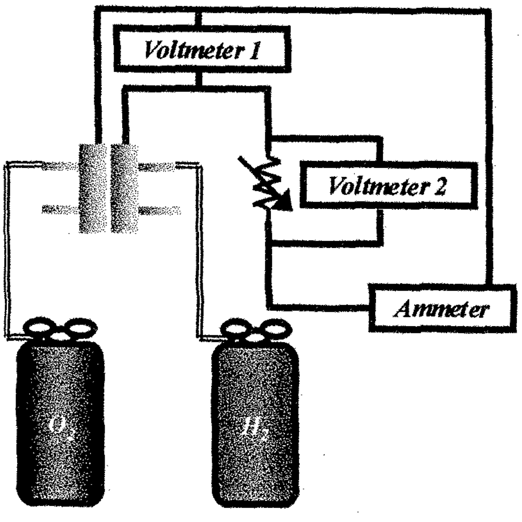

Fig. 3 Schematic diagram of measuring system

The pressure dependence of initial H_2 reaction rate was measured in standard fuel cell and test fuel cells with $LaNi_5$ film. The oxygen initial pressure was set to 0.5 MPa constant. The hydrogen pressure was changed with 0.2MPa, 0.5MPa, and 1.0MPa. The load resistance was controlled under 0.75ohm. The current value in power generation was considered as a penetration reaction velocity of hydrogen.

V-I characteristics of the test fuel cell was measured at the initial stage and after the activation. After 10 minutes of output generating, the current, the electromotive force and the load resistance were measured by varying the load resistance gradually at the initial stage. After 6 hours of activation, the subsequent measurement was carried out.

3 RESULTS and DISCUSSION

3.1 Pressure dependence of initial H_2 reaction rate

Figure 4 shows Pressure dependence of hydrogen reaction rate of test fuel cells at RT. The initial reaction rate, V at RT can be denoted as follows.

$$V = A \cdot P^n \quad (1)$$

Where A, P and n are constant, applied pressure and pressure dependence factor, respectively. In Fig.4, the factor n is denoted as the target of the lines. The factor n of the line indicates the rate determining step, If n=1.0, dissociation of H_2 molecules is the rate determining where as H diffusion is determining if n=0.5. The reaction rates of both fuel cells were proportional to square root of hydrogen pressure. The reactions of both fuel cells were controlled by diffusion permeation of H. This indicates the possibility that hydrogen storage alloy of $LaNi_5$ may substitute at least partially the high cost Pt catalyst.

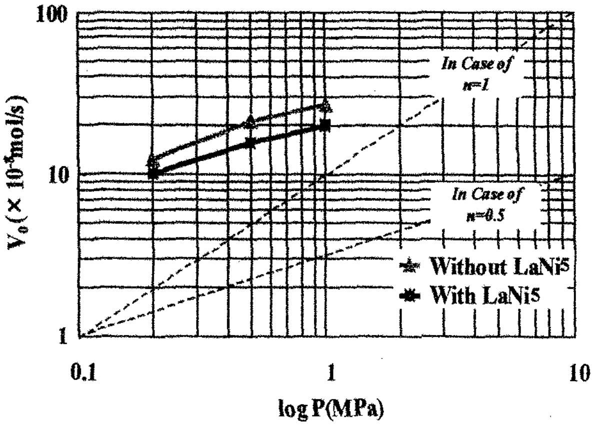

Fig. 4 Pressure dependence of initial hydrogen reaction rate of test fuel cells at RT

3.2 V-I characteristics of the test fuel cell

Figure 5 shows the V-I characteristics of the test fuel cell with $LaNi_5$ powder and $LaNi_5$ film. In both test fuel cell, the output after activation exhibited the high V-I characteristics as compared with the output at initial stage. This result can be considered as follows. The $LaNi_5$ layer is activated and also the surface structure is modified by the output generation. H.Uchida et al. reported the reaction probability; r, of H_2 on the surface of $LaNi_5$. The value r, ranging from 1 to 10^{-6}, changes drastically depending on the amount of oxide layer and heat treatment [1]. This result suggests that if the surface is covered with less amount oxide, the surface may exhibit relatively higher reactivity, which can be obtained by activation through hydrogenation.

Additionally, $LaNi_5$ with some H_2O pretreatment exhibits drastically modified absorption reactions [4]. After the H_2O treatment the surface can be kept as activated even after strong air oxidations. Surface Ni clusters on La oxide segregated by oxidation yield accelerated catalytic reaction. This modified surface structure may be obtained by some oxidation of the $LaNi_5$ surface[4].

When the test fuel cell using $LaNi_5$ powder is compared with the another cell using $LaNi_5$ film, the test fuel using $LaNi_5$ powder exhibited higher output than that of using $LaNi_5$ film. The electrode surface area related to the reaction increased by using $LaNi_5$ powder than film. Consequently, dissociation of hydrogen was promoted and as a result the output increased.

The maximum outputs measured by changing load resistances were also strongly different for the cells with and without $LaNi_5$ as shown in Fig.6. Commonly, the output is higher it the internal resistance of a cell is low[5]. Among these fuel cells, the difference of the internal resistance influenced the output.

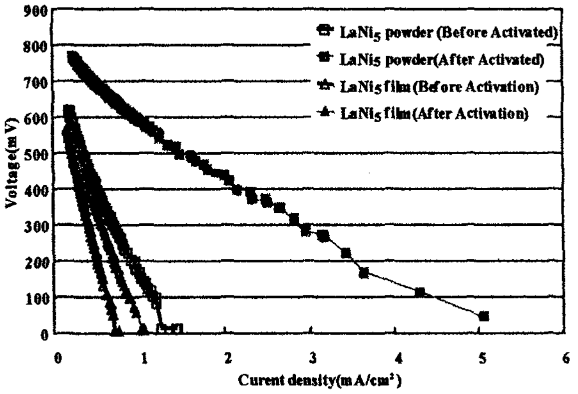

Fig. 5 V-I characteristics of test fuel cells

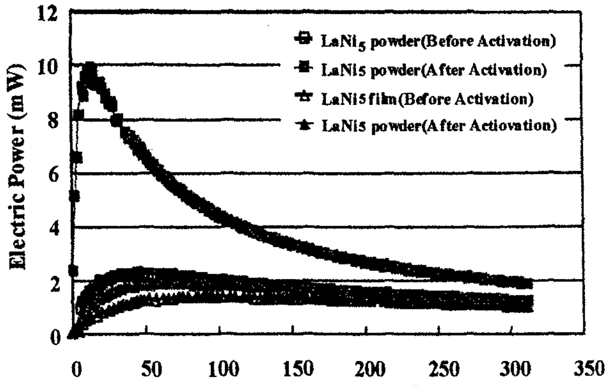

Fig. 6 The relationship between the electric power of the test fuel cells and the load resistance at RT

4. CONCLUSION

In this paper, a test fuel cell with $LaNi_5$ powder on the anode was constructed. We measured Pressure dependence of hydrogen reaction rate of test fuel cells at RT. In both cells, the reaction rates were proportional to square root of the hydrogen pressure. The reaction was, therefore, not controlled by the dissociation of H_2, but H-diffusion. This results in that in both cases $LaNi_5$ functions as catalysts for the dissociation.

In this study, We demonstrated the possibility that the hydrogen storage layer of $LaNi_5$ can be expected as a part of catalyst which leads a decreased use of Pt.

When the test fuel cell using $LaNi_5$ powder is compared with the another cell using $LaNi_5$ film, the test cell using $LaNi_5$ powder indicated higher output. The electrode surface area was relating to a reaction. Consequently, dissociation of the hydrogen was promoted and the output increased.

More quantitative investigations are necessary for more detailed characteristics of a fuel cell using $LaNi_5$ hydrogen storage alloy.

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