

A Novel Bifunctional Electrode for Air Secondary Batteries

T. Ishito, Y. Aramaki, M. Morimitsu, M. Matsunaga
*Department of Applied Chemistry,
Kyushu Institute of Technology
Tobata, Kitakyushu 804-8550, Japan*

K Adachi, S. Taniguchi
*Research Laboratory
Kyushu Electric Power Co., Ltd.
Minami-ku, Fukuoka 815-0032, Japan*

An air secondary cell using metal or hydrogen negative electrodes with an alkaline solution has attractive properties such as high theoretical energy and power densities for a wide variety of rechargeable power supply applications. In this type of cell, the evolution and reduction of oxygen should be able to occur at the positive electrode during charge and discharge, respectively. Therefore, a bifunctional air electrode having gas diffusivity in conjunction with hydrophilicity to an electrolyte is needed. The development of such a bifunctional air electrode has been carried out: The electrode typically consists of different types of catalysts, for charge and discharge, loaded on carbon powders and PTFE particles as a binder. A wide variety of metals, alloys, and oxides have been screened as catalysts for the evolution and reduction of oxygen.

However, carbon powders are not appropriate for this purpose, since carbon powders are consumed during charge through the oxidation to carbon dioxide. In addition, a suitable combination of catalysts for bifunctionality has not been found. This situation motivated us to develop a novel bifunctional electrode for an air rechargeable cell. In this paper, we present the preparation and performance of nickel-PTFE based air electrodes having bifunctional catalysts prepared by thermal decomposition method.

Nickel powders were used as a conductive and catalyst-supporting material for an air electrode. The nickel powder was mixed with platinum chloride or iridium chloride solutions, dried, and heated at appropriate temperature to generate platinum or iridium dioxide on nickel as catalysts for the reduction or generation of oxygen. The catalyst-loaded nickel powder and a PTFE solution were mixed, dried, and pressed on a nickel mesh sheet to make a disk. Then the disk was heated at 645 K for 15 min.

Electrochemical measurements were carried out a conventional three-electrode cell consisting of the air electrode, a platinum plate counter electrode, and a Hg/HgO reference electrode. The electrolyte was a 7 mol dm⁻³ KOH solution. Anodic and cathodic polarization characteristics were examined by constant current method at 333 K. IR compensation for measured potentials was carried out. XRD and EPMA measurements were performed to characterize the catalyst-loaded nickel powder. The loaded amounts of platinum and iridium were determined by ICP and XRF spectroscopies, respectively.

The catalyst preparation conditions, the concentration of precursor solutions dissolving platinum or iridium and thermal decomposition temperature, were examined for the loading of platinum and iridium dioxide,

respectively. Polarization curves of air electrodes using platinum-loaded nickel powders prepared in different conditions were compared to determine the most appropriate condition, and the same procedure was also carried out for iridium dioxide-loaded nickel powder electrodes.

From the results, the preparation conditions for platinum loading were decided to be the concentration of platinum precursor solution of 2 g/L (based on platinum as metal) and the thermal decomposition at 743 K for 2 min, and those for iridium dioxide loading to be the concentration of iridium precursor solution of 1 g/L (based on iridium as metal) and the thermal decomposition at 693 K for 2 min. The existences of platinum or iridium on nickel powder were confirmed by EMPA analyses. The results obtained by XRD also revealed that the oxidation of nickel powder hardly proceeded during the catalyst loading processes.

Considering the above conditions, nickel powders with both iridium dioxide and platinum were also prepared: iridium dioxide was formed on nickel, then platinum was loaded on the iridium dioxide-formed nickel. The polarization curves of the air electrode using the nickel powder with both the catalysts are displayed in Fig. 1. The Ni:Ir:Pt weight ratio of the electrode was 98.1:0.7:1.2. The electrode worked well at high current densities up to 400 mA/cm² for anodic and cathodic polarizations. The overpotential for oxygen evolution reaction (OER) was relatively low, even though the amount of iridium as an OER catalyst was small. The overpotential for oxygen reduction was higher than that for OER. This may be attributable to inadequate catalytic ability of platinum and low gas diffusivity in the air electrode. In this paper, the cycle-life performance of the developed air electrode will be also discussed.

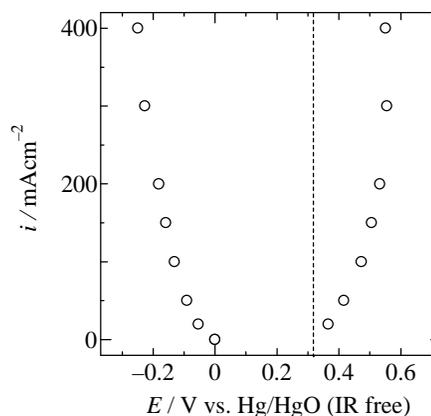


Fig.1 Anodic and cathodic polarization curves of the bifunctional air electrode.