Generation of Functional Water by Electrolysis with Diamond Electrodes

Kazuki Arihara, Masahiko Ishikawa, Akira Fujishima

Technology Research and Development Department, Central Japan Railway Company

1545-33 Ohyama, Komaki City, Aichi 485-0801, JAPAN

Introduction

By proper electrolysis of aqueous solutions, we can conveniently add some useful properties to plain water to produce so-called electrolyzed functional water. For instance, the electrolysis of a saline solution produces a strongly acidic solution at the anode, which contains hypochlorous acid and serves as a bactericidal water. In addition, ozone-water generated by the electrolysis of pure water can be used for the purposes of sterilization, deodorization, and decolorization, and have already been introduced into food processing, sanitary facilities, medical services, etc. However, it has been known that conventional electrodes gradually dissolve into the solution as the electrolysis continues under large current conditions to produce the electrolyzed functional water.

On the other hand, conductive diamond films are mechanically durable and chemically inert, and are suitable for water electrolysis under quite large current conditions, with no need for concern regarding dissolution. Due to the large overpotential for oxygen evolution as a parasitic reaction, chlorine and ozone evolution conversely may occur efficiently. Here, we will present basic information on the production of different types of electrolyzed functional water such as strongly acidic solutions and ozone-water with the diamond electrode.

Experimental

Polycrystalline boron-doped diamond (BDD) films were deposited on Si(111) wafers in a high-pressure microwave plasma-assisted chemical vapor deposition (CVD) system. The carbon source was an acetone/methanol mixture (9:1, v/v) containing B_2O_3 as the boron source (10,000 ppm B/C atomic ratio). The BDD film, a platinum (Pt) plate, and a platinum-iridium coated titanium (Pt-Ir/Ti) plate were used as the working electrodes. A Pt wire was employed as the counter electrode.

Results and Discussion

Linear sweep voltammetry was performed in a 0.9 M $NaClO_4$ solution containing 0.1 M NaCl with the BDD, Pt and Pt-Ir/Ti electrodes. Large anodic current responses shown in Fig. 1 correspond to the chlorine evolution reaction concurrent with the parasitic reaction of oxygen evolution. However, because the reaction ratio is unknown, we cannot say anything about the current efficiency for the chlorine evolution reaction from the voltammograms.

A 0.1 M NaCl solution was electrolyzed at constant current of 33 mA cm^{-2}. The chlorine generated at the anode changes to hypochlorous acid in the aqueous solution, as follows, depending on the solution pH:

$$2Cl^- \rightarrow Cl_2 + 2e$$
$$Cl_2 + H_2O \rightarrow HClO + HCl$$
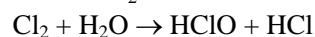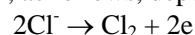
The electrolysis in the one-compartment cell produced the weak alkaline solution, in which HClO dissolved as ClO^-. According to the molar extinction coefficient of ClO^- (351 cm^{-1} M^{-1} at 292 nm), the generated amount and current efficiency were calculated from the UV spectra of the electrolyzed solutions, as shown in Fig. 2.

The result is summarized in Table 1. The current efficiency at the BDD electrode was 63 %, which is exceedingly superior to the value obtained at the Pt electrode. However, it still inferior to the value of 82% obtained at the Pt-Ir/Ti electrode. Nevertheless, considering the mechanical durability and chemical inertness of the BDD electrode, it should be applied especially for long-term electrolyses of saline solutions under large current conditions or for the generation of highly pure electrolyzed functional water.
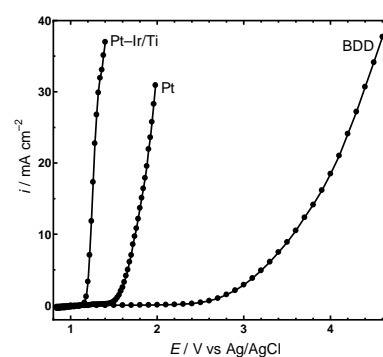

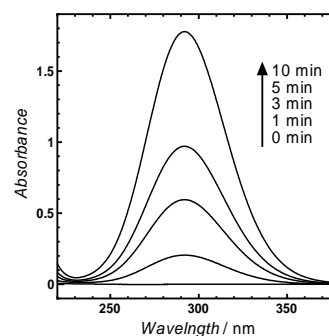Fig. 1 Liner sweep voltammograms obtained in a 0.9 M $NaClO_4$ solution containing 0.1 M NaCl at a scan rate of 10 mV s^{-1}.

Fig. 2 UV spectra of electrolyzed solutions obtained by electrolysis of 0.1 M NaCl at constant current of 33 mA cm^{-2} at a BDD electrode.

Table 1 Current efficiency for the ClO^- generation reaction

Electrode	Current efficiency %
BDD	63
Pt	33
Pt-Ir/Ti	82