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A NEW ELECTROLYSIS METHOD. MAGNETOELECTROLYSIS

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A fundamental work was carried out on the development of a new electrolysis method using a rotating cell and a permanent magnet. As a result, it was proved that the rotation of the conducting cell in an external magnetic field can induce a dc potential difference by which electrochemical reactions are directly brought about.

To date, the effect of a magnetic field on mass transfer in electrolysis,$^{1)}$ including polarography,$^{2)}$ has been studied extensively. And the enhancement of the diffusion limiting currents by an imposed magnetic field is generally interpreted as a result of the magnetohydrodynamic effects.$^{3)}$ Recently, Kelly$^{4)}$ described that a magnetic field might affect the rates not only of mass transfer controlled process but also of activation (charge transfer) controlled process. According to his work, electrochemical reactions in metal/flowing-electrolyte systems are affected by an applied magnetic field as a consequence of the Lorentz forces acting on the charged components of the flowing electrolyte.

From a completely different point of view, we wish to report a preliminary, fundamental work on the development of a new electrolysis method named "magnetoelectrolysis" in which a rotating cell and a permanent magnet are used. This method is based on the concept that the rotation of a conducting cell in an external magnetic field can induce a dc potential difference which will cause electrochemical reactions to proceed. So, no electrical power source is necessary if a mechanical power source, such as wind force, is available for rotating the cell.

The experimental cell assembly is schematically shown in Fig. 1. The cell consisted of a rotating shaft (8 mm ϕ), a rotating drum (44 mm ϕ) and two Teflon caps. Both the shaft and drum which served as electrodes were made of stainless steel, but their surfaces being in contact with electrolyte were covered with an electrodeposited copper layer. The cell was rotated in clockwise direction (looking down at it) by the use of a rotating ring-disk electrode device (Nikko Keisoku, RRDE-1) connected with a motor speed controller (Nikko Keisoku, SC-5). In this work, the magnetic field was produced from a horseshoe permanent magnet (Eclipse, Power Magnet #816, ALCOMAX III), which had a gap width of 47.6 mm and a magnetic flux density of ca. 700-750 G (1 G$\sim 10^{-4}$ T), measured at its center with a gauss meter (Denshijiki Industry, GM-1120). For convenience, the direction of the magnetic field as shown in Fig. 1 will be represented by the symbol "N/S" and the reverse direction by the symbol "S/N". The potential of the drum against shaft was measured by means of a digital multimeter (Takeda Riken, TR-6841).

At the beginning of the experiment, the potential difference between the rotating shaft and drum was confirmed to be virtually zero, independent of the rate of rotation, in the absence of the magnetic field. Furthermore, it was confirmed that no measurable potential difference appeared when the magnet was set horizontally. But, a dc potential difference did appear when the magnet was set vertically as shown in Fig. 1.

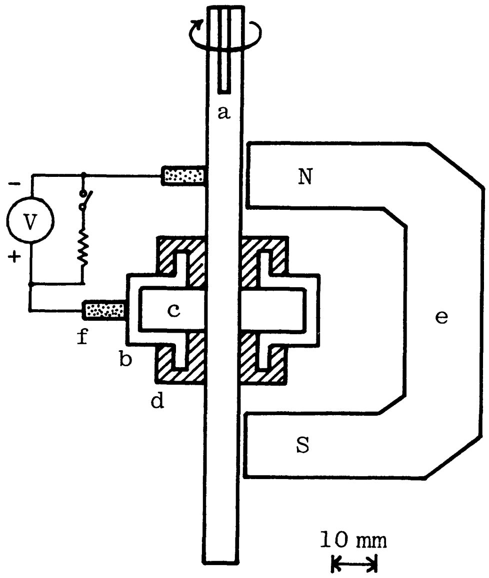

Fig. 1. Schematic representation of the experimental cell assembly.
a : Rotating shaft, b : rotating drum,
c : electrolyte, d : Teflon cap,
e : horseshoe magnet, f : brush.

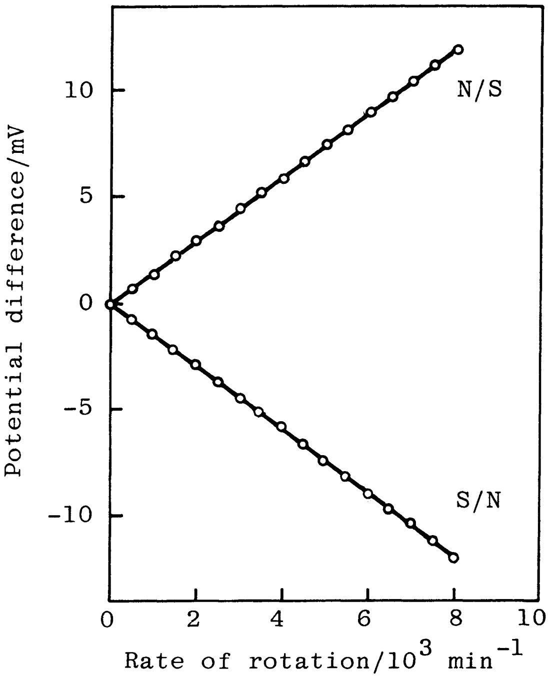

Fig. 2. Variation of potential difference with rate of rotation in 0.5 mol dm^{-3} H_2SO_4 + 0.5 mol dm^{-3} $CuSO_4$.

The potential differences in the open circuit were measured at different rates of rotation. An example of the data obtained is shown in Fig. 2. It is clear that the potential difference is directly proportional to the rate of rotation. The reproducibility of the data was invariably excellent. Such measurements were done in a variety of electrolytes. As a result, the potential difference was found to be little dependent on the kind of electrolytes.

An external standard resistance (1 Ω) was connected in series with the rotating cell to make a closed circuit, and then the currents flowing through the system were measured at different rates of rotation. A typical example of the data obtained is shown in Fig. 3. Although the reproducibility of the current values was relatively poor, the trend of them was well reproduced. The current at a given rate of rotation depended upon the $CuSO_4$ concentration. Based on the data shown in Figs. 2 and 3, the current is plotted in Fig. 4 as a function of the potential difference. This curve is quite similar to the usual current-voltage curve obtained with copper electrodes in $CuSO_4$-containing H_2SO_4 solutions, and hence suggests strongly that electrochemical reactions are taking place in the rotating cell. In the present system, the dissolution and deposition of copper

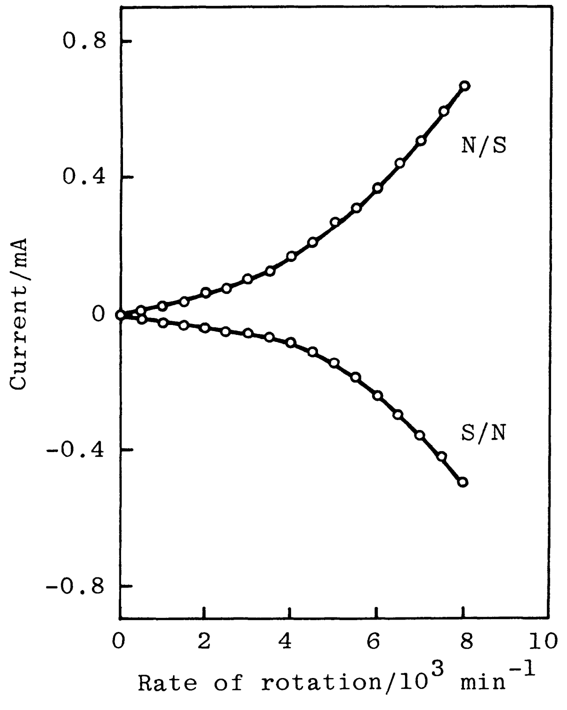

Fig. 3. Variation of current with rate of rotation in 0.5 mol dm^{-3} H_2SO_4 + 0.5 mol dm^{-3} $CuSO_4$.

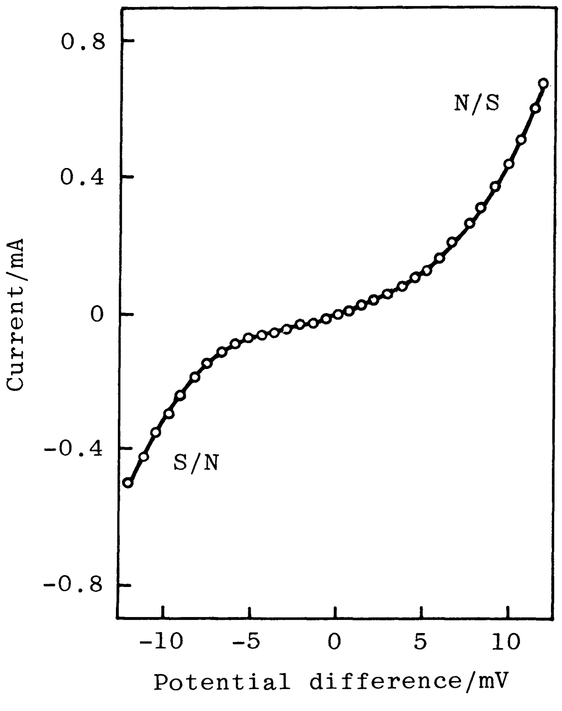

Fig. 4. Plot of current vs. potential difference on the basis of the data shown in Figs. 2 and 3.

probably take place at the anode and cathode, respectively.

In order to get further information, the rotating drum was packed to full with aluminium foil in place of the electrolyte, and then the data corresponding to those shown in Figs. 2 and 4 were obtained. The potential difference to be measured in the present experiment can necessarily be regarded as an induced electromotive force, whose direction should be determined by Fleming's right hand rule. In this case, the plot of the potential difference against the rate of rotation agreed very closely with that shown in Fig. 2, but the current vs. potential difference plot gave a straight line with the slope of 1 A V^{-1}, obeying Ohm's law exactly. The former fact implies that the origin of the potential difference observed in the case of the electrolyte is identical to that observed in the case of the aluminium foil and that the lag in the rotating motion of the electrolyte is negligibly small under the experimental conditions. And the latter fact clearly indicates the distinction between the ionic (electrolytic) and electronic currents flowing in the cell with the electrolyte and aluminium foil, respectively.

On the basis of the above data, one is led to conclude that the rotation of the conducting cell in an external magnetic field can induce a dc potential difference by which electrochemical reactions are directly brought about.

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