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Short Communication

Electrochemical characterization of magnesium/silver chloride battery

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Abstract

A study is made of the effect of de-ionized water and 3.3% NaCl solution on the activation time of a magnesium/silver chloride battery. The influence of electrolyte concentration, temperature, and current density on the cell performance is investigated. By using Shepherd's model, various battery parameters such as polarization coefficient, amount of active material used and internal resistance, are calculated. Finally, the temperature coefficient of the internal resistance of single cells is evaluated.

Keywords: Magnesium; Silver chloride; Batteries

1. Introduction

Magnesium/silver chloride batteries are reserve-type systems and are used in a wide range of underwater applications such as sonobuoys, lifebuoys, life raft, torpedoes, and detection devices [1,2]. The batteries possess long shelf-lives in the unactivated state because of physical separation of the electrodes and electrolyte. Activation requires less than a second to deliver the desired power output. In this cell system, AZ 31 magnesium alloy is used as the anode and has a high efficiency. The work reported here examines the effect of variation of electrolyte concentration, temperature and current density on battery performance.

2. Experimental

Magnesium/silver chloride cells were assembled using two magnesium alloy plates (AZ 31) and one sintered silver chloride plate, all with dimensions 2 cm × 2.5 cm. The plates were separated mechanically by plastic spacers. The outer faces of the magnesium plates and the edges in the vertical position of the cell were covered with poly(vinyl chloride) (PVC) tape. The terminal lead wires were lacquered to avoid electrolyte contact [3]. The effect of de-ionized water and salt water (3.3% NaCl solution) on the activation time of a battery consisting of two cells connected in series with a fixed load was also studied.

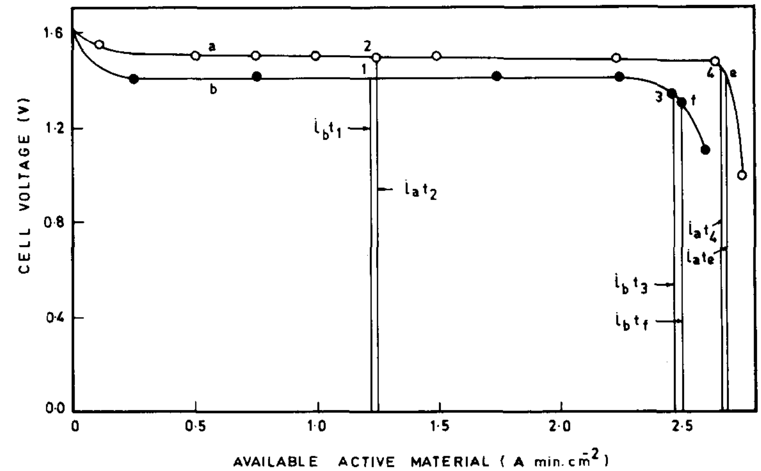

Fig. 1. Discharge curves used in calculation of internal resistance by Shepherd's method. Current drain: (a) 100 mA; (b) 1000 mA.

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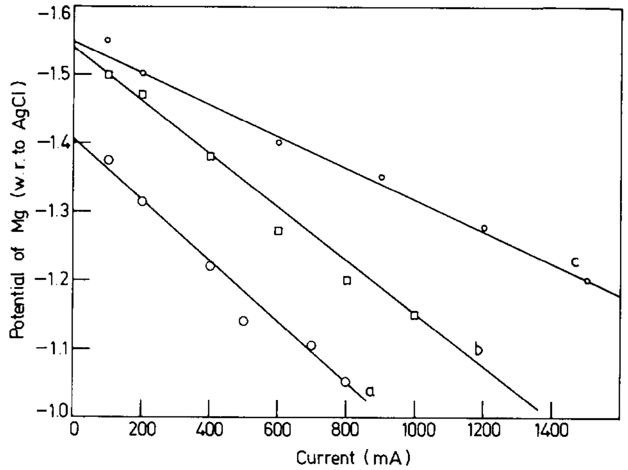

Fig. 2. Variation of potential of magnesium with current: (a) 0.125 M NaCl; (b) 0.25 M NaCl; (c) 0.5 M NaCl.

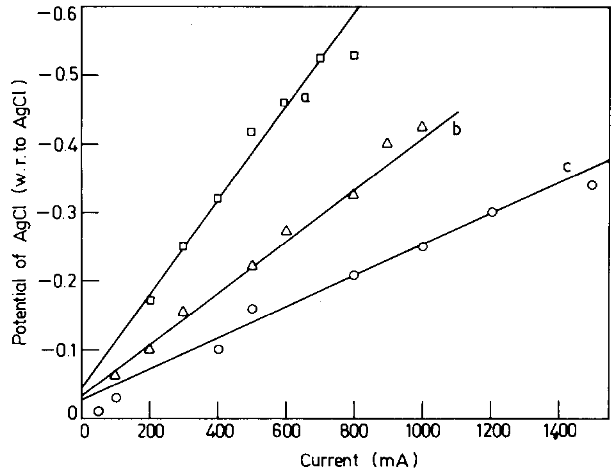

Fig. 3. Variation of potential of AgCl electrode with current: (a) 0.125 M NaCl; (b) 0.25 M NaCl; (c) 0.5 M NaCl.

A de-ionized water-activated battery was assembled using specially treated cotton separators. The latter were made by dipping cotton in saturated solutions of NaCl for 10 min and then drying at 100 °C for 30 min to remove water. The separators were then pressed using a hydraulic press at 1 ton cm^{-2}. The pressed cotton was cut to the required size for the separator.

3. Results and discussion

3.1. Basic parameters from discharge study

Two cells were discharged at constant-current drains of 100 and 1000 mA in 3.3% NaCl solution at 30°C. Fig. 1 shows the variation of cell voltage with available active material. The following parameters were evaluated by adopting the procedure of Shepherd [4]:

- mean available active material = 5.4 A min/cell
- coefficient of polarisation = 0.12 Ω/cell
- internal resistance of the cell = 0.131 Ω/cell

Table 1
Effect of electrolyte concentration on electrode polarization

Concentration of NaCl (M)	Slope of Mg electrode (*E*/*I*)	Slope of AgCl electrode (*E*/*I*)
0.125	0.45	0.70
0.25	0.32	0.38
0.5	0.22	0.23

3.2. Polarization behaviour of cell electrodes

The variation in the potential of the Mg and AgCl electrodes of single unit cell (against a AgCl reference electrode) with different concentrations of NaCl solution at 25 °C are shown in Figs. 2 and 3, respectively. The slopes calculated from these curves are presented in Table 1. The electrode polarization decreases by a magnitude of 0.23 for Mg and 0.47 for AgCl electrodes as the NaCl concentration is raised from 0.125 to 0.5 M. As the concentration of electrolyte increases, the conductivity of the solution increases and this results in a decrease in electrode polarization.

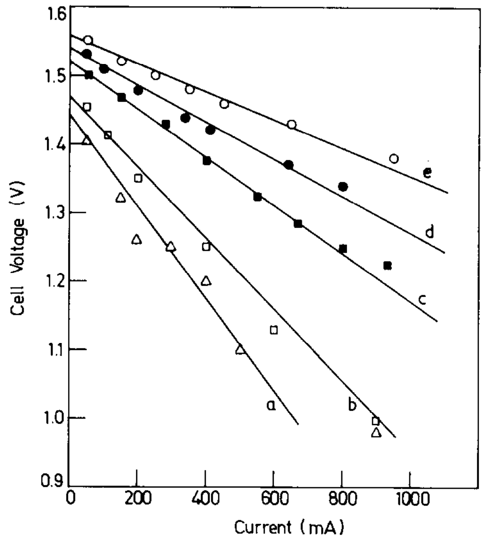

Fig. 4. Voltage vs. current at different temperatures: (a) −10 °C; (b) 0 °C; (c) 10 °C; (d) 20 °C, and (e) 30 °C.

Table 2
Slope of voltage vs. current plots

Discharge temperature (°C)	Slope (*V*/*I*)
30	0.22
20	0.28
10	0.34
0	0.52
−10	0.67

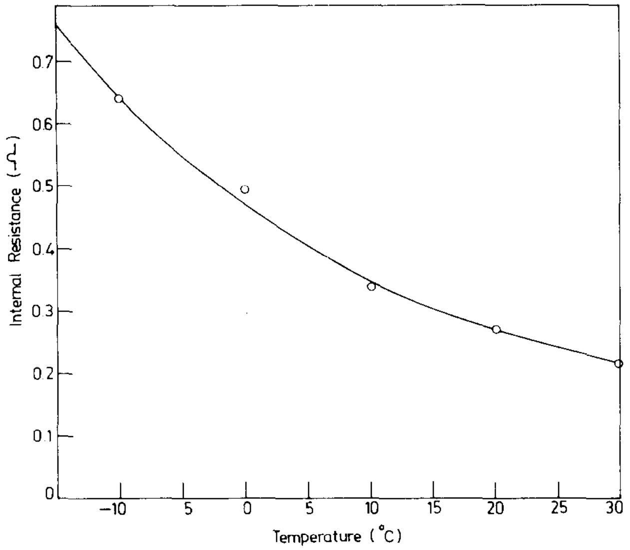

Fig. 5. Variation of cell internal resistance with temperature.

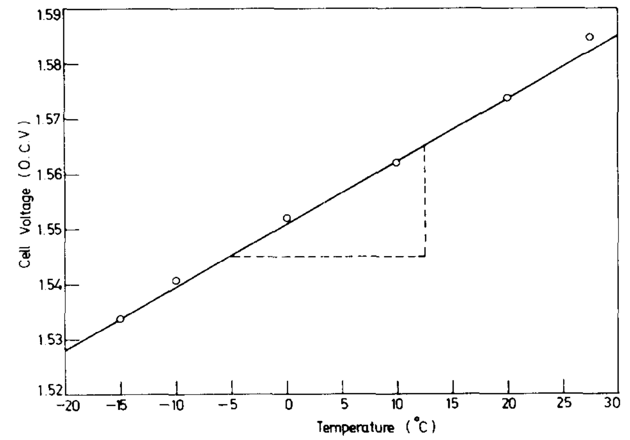

Fig. 6. Variation of cell OCV with temperature in 0.5 M NaCl.

3.3. Voltage–current characteristics

The voltage–current curves of single cells were obtained at different temperatures (Fig. 4). All the plots are straight lines. The slopes increase with decrease in temperature. The linear nature of the plots indicates that the fall in voltage with current is ohmic in nature and is due to an increase in the internal resistance of the cells. The values of the slopes (V/I) for different conditions are listed in Table 2. These values represent the internal resistance of the cells at the corresponding temperature.

3.4. Temperature coefficient of cell resistance

The variation in the internal resistance with temperature is presented in Fig. 5. The slope of the resulting curve represents the temperature coefficient of the cell resistance and has a value of 0.007 Ω per °C. This is a significant parameter when designing a cell for use at a specified temperature.

The dependence of the open-circuit voltage (OCV) on the Mg–AgCl cell with temperature in 0.5 M NaCl solution is given in Fig. 6. The slope has a value of 0.0022 V per °C. The increase in OCV with temperature implies that the temperature coefficient of the cell voltage is positive.

Two batteries were activated, one in de-ionized water and the other in 3.3% NaCl solution. The activation time of the battery to reach the cutoff voltage of 2 V under a 2 Ω load was found to be 1500 and 400 ms in de-ionized water and 3.3% NaCl solution, respectively. The time interval taken for NaCl salt to dissolve from the cotton separator and for the chloride ions to diffuse to the magnesium surface accounts for the difference in the activation time of the two batteries.

4. Summary

Various battery parameters, i.e., mean available active material, coefficient of polarization and cell internal resistance, have been calculated from discharge data obtained at different current drains using Shepherd's equation. The internal resistance calculated using Shepherd's equation is in agreement with that determined experimentally. The internal resistance decreases with increase in either temperature or electrolyte concentration. A battery activated by 3.3% NaCl solution has a shorter activation time than that activated by de-ionized water.

References

[1] P.B. Mathur and R. Balasubramanian, *Proc. 3rd National Conf. Power Sources, SAEST, Karaikudi, India, 1979*, pp. 27–32.
[2] R. Balasubramanian, A. Veluchamy and P.B. Mathur, *Bull. Electrochem.*, *2* (1986) 283.
[3] R. Balasubramanian, A. Veluchamy and N. Venkatakrishnan, *J. Power Sources*, *52* (1994) 305–308.
[4] C.M. Shepherd, *J. Electrochem. Soc.*, *112* (1965) 657.