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Fabrication and investigation of the charge/ discharge characteristics of zinc/PVA-KOH-H_2O-Iodine/carbon cell

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Electrochemical properties of a zinc/PVA-KOH-H_2O-Iodine/carbon cell have been investigated. In this cell, PVA-KOH-Iodine gel was used as electrolyte with PVA/KOH wt.% ratio of 60:40 and PVA aqueous solution/Iodine ratio 2:1, while zinc and carbon rods serve as electrodes. The cylindrical glass vessel of length 3.0 cm and of diameter 2.0 cm is used as a cell compartment. The current-voltage characteristics and open circuit voltage-time, charge voltage/current-time and discharge voltage/current-time studies are made. The open circuit voltage has been observed for 100 hours. It is found that the cell is stable and also rechargeable.

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1. Introduction

The study of structural, optical, electrical and electrochemical properties of organic electrolytes remains an area of frontier research and is influencing the modern and future technologies of solid state and electrochemical devices. This is mainly due to low cost, ease of device fabrication, interesting electrical, optical and electro-chemical properties.

Many potential applications of organic electrolytes may be realized via investigation of electrochemical properties and modification of their conductivity.

The electrochemical behavior of Zn/orange dye aqueous solution/carbon cell has been studied by Karimov et al. [1]. The cell has been found to be rechargeable. The open-circuit voltage and short-circuit of the fresh and fully charged cell have been reported 1.5 V and 0.45 mA, respectively. The discharge characteristics voltage/current-time of this cell exhibited stable and constant behavior.

Solid polymer electrolytes (SPEs) have been studied extensively in recent years for application in many electrochemical devices, such as cellular phones, thin credit cards, and laptop computers [2].Polymer electrolytes have been extensively studied [3]. To improve the ionic conductivity of polymer electrolytes, hybrid films composed of the polymer, salt and a plasticizer have been prepared [4]. Ionic conductivity studies of poly(vinyl alcohol) alkaline solid polymer electrolyte has been investigated by Mohammad et al. [5] for different wt.% ratio of PVA and KOH. The X-ray diffraction (XRD) patterns revealed that the crystalline nature of PVA based polymer electrolytes were disrupted and converted them into an amorphous phase. This study has reported the highest room temperature conductivity of 8.5×10^{-4} Sm^{-1} of the PVA-KOH alkaline solid polymer electrolyte system with PVA/KOH wt.% ratio of 60:40.

The nickel-zinc cell was fabricated employing this PVA-KOH alkaline solid polymer electrolyte (ASPE) system. Charge-discharge studies of this cell proved that an all solid-state Ni-Zn cell can be prepared with the utilization of PVA-KOH solid polymer electrolyte. Yang and Lin [6] investigated Zn–air cell consists of an alkaline composite PEO–PVA polymer electrolyte combined with a zinc gel anode and an air diffusion cathode and reported that the composite polymer electrolytes have excellent mechanical strength and electrochemical stability (±1.2V). The electrochemical performance of solid state Zn–air battery has also been examined by ac impedance spectroscopy and a galvanostatic discharge tests.

In an earlier study [1], we reported a rechargeable zinc/orange dye aqueous solution/carbon cell. Zinc carbon cells are the most popular primary cells. Despite the fact that zinc-based batteries have been around for a long time, various zinc-based systems, including some rechargeable ones, have been under significant and increasing R&D efforts in recent years [7]. The voltage and current generated by an electrochemical cell is directly related to the types of materials used in electrodes and electrolyte. This paper reports an investigation of the electrochemical properties of a Zn/PVA-KOH-H_2O-Iodine/carbon cell.

2. Experimental

Poly vinyl alcohol (MERCK), [-CH2CHOH-]$_n$, with molecular weight 72000 and density 0.4 – 0.6 gcm^{-3} at room temperature, potassium hydroxide (KOH) and iodine were used for preparation of the poly vinyl alcohol (PVA)-based polymer electrolyte for zinc/ PVA-KOH-H_2O-Iodine /carbon electrochemical cell. The wt.% ratio of PVA and KOH in the polymer electrolyte gel was 60:40 and PVA aqueous solution/iodine were in ratio 2:1. At this ratio the potassium hydroxide disrupts the crystalline nature of the poly vinyl alcohol (PVA)-based polymer electrolyte and converts it into an amorphous phase [5].

In order to make poly vinyl alcohol (PVA)-based polymer electrolyte gel, 3.0 g of PVA was placed in 100 ml of distilled water in a 250 ml beaker and put it onto hot plate at 80°C. Added KOH and iodine, when PVA was fully dissolved in distilled water and the porous [8] alkaline polymer electrolyte gel was prepared.

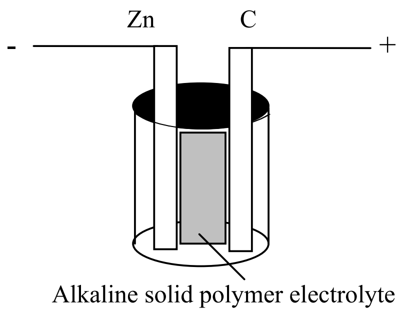

Fig. 1. Schematic of zinc/PVA-KOH-H_2O-Iodine/carbon cell.

Experimental cell assembly for the polymer gel electrolyte- based zinc/carbon cell is shown in Fig. 1. The cell was sealed in cylindrical glass vessel and cell's length and diameter were 3.0 and 2.0 cm respectively. Thickness of gel electrolyte layer between carbon and zinc electrodes was 1.0 cm. The length of both electrodes was 4.0 cm. Used volume of alkaline polymer electrolyte gel was 3.0 cm^3.

The discharge voltage-current, open circuit voltage-time, charge voltage/current-time and discharge voltage/current-time characteristics of cell was measured at room temperature by Keithley 196 Digital Multimeter.

3. Results and discussion

Fig. 2 shows the discharge voltage-current (V-I) relationship of zinc/PVA-KOH-H_2O-Iodine/carbon cell. The zinc electrode's potential has negative polarity with respect to the carbon electrode [1]. For electrochemical cells, the V-I relationship is typical [9]. The values of open circuit voltage and short circuit current of fully charged cell are 1.421 V and 71.1 mA, respectively.

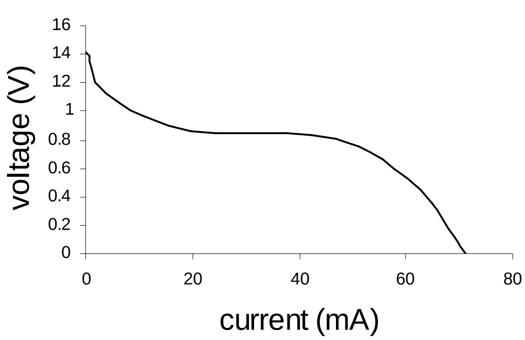

Fig. 2. Voltage versus current discharge characteristic of zinc/ PVA-KOH-H_2O-Iodine/carbon cell.

The charging curves of the cell are shown in Fig. 3. It is found that the cell is rechargeable and attains saturated values of current and voltage during initial 40 minutes of charging. Fig. 4 shows the discharging curves of the cell. The cell was discharged at a load of 100 Ω. Initially, the current drops very sharply and then become stable. This behavior could be due to small value of load resistor.

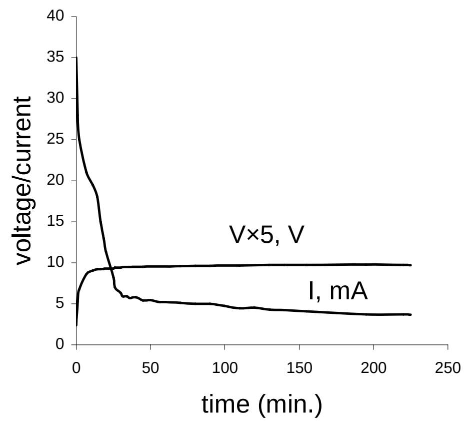

Fig. 3. Charge voltage/current-time curves for zinc/PVA-KOH-$_{H2O}$-Iodine/carbon cell.

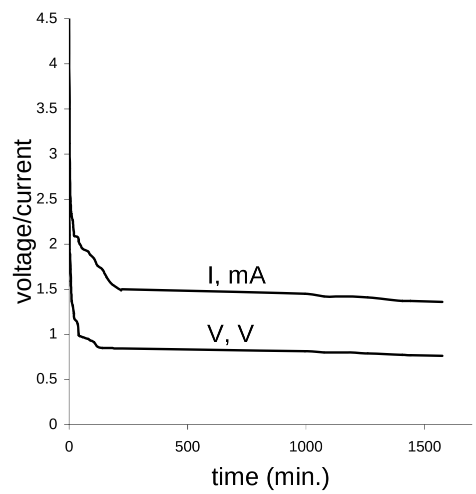

Fig. 4. Discharge voltage/current-time behavior for zinc/PVA-KOH-$_{H2O}$-Iodine/carbon cell.

Fig. 5 shows open circuit voltage of the polymer gel electrolyte- based zinc/carbon cell during 100 hours of storage. The cell was in the discharged mode then again charged for three hours and the voltage of about 1.9 V was obtained. After charging, the open circuit voltage measured for 100 hours. It can be seen from plot that the open circuit voltage of the cell dropped to ~1.3 V during first 40 hours and then remain constant for next 60 hours, which shows excellent stability of the cell. The initial drop in open circuit voltage might be due to zinc cathode oxidation during charging.

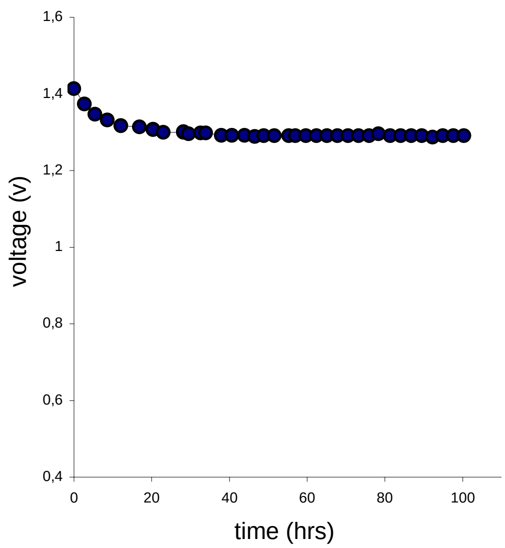

Fig. 5. Open circuit voltage of zinc/PVA-KOH-H_2O-Iodine/carbon cell during 100 hrs of storage.

The current efficiency (E_i) for a fixed time (t) of 3 hrs is 52% at 100 Ω load resistor as calculated by the following formula [10].

$$E_i = \frac{\int_0^t I_d dt}{\int_0^t I_c dt} \qquad (1)$$

where I_d is discharging current and I_c is charging current.

In the zinc/PVA-KOH-H_2O-Iodine/carbon cell, when the zinc electrode was replaced by carbon and charged the cell, it was found that in the discharge mode the operating voltage dropped from 182.7 to 6.3 mV and current from 0.34 to 0.008 mA, during 12 hours. This indicates that in the zinc/PVA-KOH-H_2O-Iodine/carbon cell, the zinc electrode is active with respect to that of carbon.

The electrical energy of the cell as a change of free energy (ΔG), was found to be -274 $kJmol^{-1}$ by using following expression [9].

$$\Delta G = -nFE \qquad (2)$$

where n is the number of electrons transferred per mole (it is equal to 2), F is Faraday constant (96487 C), and E is the electromotive force of the cell (1.421 V).

The capacity of the cell (C) was calculated using the expression [9]:

$$C = \frac{nFW}{(MW)} \qquad (3)$$

where W is the weight of the active electrode material (zinc in this case): its weight is equal to 2.106 g; MW the molecular weight of the material (for zinc it is equal to 65.37). The calculated value of the C is 6.22 kC = 1.72 Ah.

4. Conclusions

The experimental zinc/carbon cell assembled using alkaline polymer electrolyte gel have been fabricated and its electrochemical properties have been investigated. The cell is rechargeable. The values of open circuit voltage and short circuit current of the fresh and fully charged cell are 1.941 V and 50.28 mA, respectively. The large value of short circuit current indicates that the polymer gel prepared from potassium hydroxide have high ionic conductivity.

Zinc/PVA-KOH-H_2O-Iodine/carbon cell exhibits good charge-discharge characteristics. The current discharge/charge efficiency is 52 %. The stable and constant behavior is observed for discharge voltage/current-time characteristics and quick charging response is noted for this cell. The alkaline polymer gel electrolyte used in this study seems to have potentialities of being applied in secondary batteries.

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References

[1] Khasan S. Karimov, Muhammad H. Sayyad, Mukhtar Ali, Muhammad N. Khan, Syed A. Moiz, Khurram B. Khan, Humera Farah and Zioda M. Karieva, J. Power Sources **155**, 475-477 (2006).
[2] F. M. Gray, Solid Polymer Electrolytes: Fundamental and Technological Application, VCH, New York (1991).
[3] P. V. Wright, Electrochim. Acta **43**, 137 (1998).
[4] A. Lewandowski, K. Skorupska, J. Malinska, Solid State Ion. **133**, 265 (2000).
[5] A. A. Mohamad, N. S. Mohamed, M. Z. A. Yahya, R. Othman, S. Ramesh, Y. Alias, A. K. Arof, J. Solid State Ion. **156**, 171-177 (2003).
[6] Chun-Chen Yang, Sheng-Jen Lin, J. Power Sources **112**, 497-503 (2002).
[7] Hui Ye, Jun John Xu, J. Power Sources **165**, 500-508 (2007).
[8] S. Chandra, S. S. Sekhon, Ritu Srivastava, Narinder Arora, J. Solid State Ion. **154-155**, 609-619 (2002).
[9] D. B. Hibbert: Introduction to Electrochemistry, Macmillan Press Ltd., London, UK, 294 pp. (1993)
[10] D. R. Crow: Principles and Applications of Electrochemistry, Third Edit. Chapman and Hall, London, 202-206 pp. (1988).

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