Contents lists available at SciVerse ScienceDirect

Electrochimica Acta

journal homepage: www.elsevier.com/locate/electacta

Performance gains in single flow zinc-nickel batteries through novel cell configuration

Yuanhui Cheng^{a,b}, Huamin Zhang^{a,*}, Qinzhi Lai^{a,**}, Xianfeng Li^a, Dingqin Shi^a

^a Division of Energy Storage, Dalian Institute of Chemical Physics, Chinese Academy of Sciences, No. 457 Zhongshan Road, Dalian 116023, PR China ^b University of Chinese Academy of Sciences, Beijing 100039, PR China

ARTICLE INFO

Article history: Received 14 March 2013 Received in revised form 3 May 2013 Accepted 3 May 2013 Available online 17 May 2013

Keywords: Batteries Electrochemistry Energy storage Cell structure Positive electrode

ABSTRACT

Rapid charge–discharge rate is an important feature of energy storage devices, but causes dramatic reduction in battery performance. In single flow zinc–nickel batteries (ZNBs), large polarization of nickel hydroxide electrode is an obstacle to realizing high charge–discharge rate without compromising battery performance. A novel cell structure with a serpentine flow field is designed to reduce the polarization of the positive electrode through enhancing mass transport. The power density is improved nearly fourfold by elevating charge–discharge current density from 20 mA cm⁻² to 80 mA cm⁻² for the first time. Compared to traditional structure cell, the energy efficiency is improved 10.3% reaching to 75.2% at 80 mA cm⁻², which has a remarkable improvement. No obvious decrease of efficiencies is presented in the 70 charge–discharge cycles. This provides a feasible method to improve the charge–discharge rate with high performance and boosts the practical application progress of ZNBs.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

To resolve the lack of fossil fuel and rapid demand of electricity, intermittent renewable energy resources are being integrated into electric grids. However, the existing services cannot satisfy the requirements and energy storage devices must be introduced to the electric grid systems. Redox flow batteries (RFBs) have found special applications in rapidly expanding requirements for energy storage due to their ability to store large amounts of electrical energy relatively steady, cheaply, flexibly and efficiently [1,2]. RFBs use two soluble redox couples stored in electrolytes circulated by pump that are oxidized or reduced to store or deliver energy. The well developed battery systems are polysulphide–bromine [3,4], vanadium–vanadium [5] and zinc–bromine [6]. However, the high cost of ion-exchange membrane and intercrossing contamination of electrolyte limit their further development.

Single flow batteries are proposed by Pletcher [7] in 2004. This novel system, constructed without membranes, simplifies the batteries' system and reduces the cost. Since then, numerous publications regarding single flow systems are found in the literature [8–13]. Single flow zinc–nickel batteries (ZNBs) developed by Cheng [12] in 2007 are a promising energy storage system for its high energy density (60–80 Wh kg⁻¹), low cost,

security, innocuity and stability. However, as the positive reaction $(Ni(OH)_2 + OH^- = NiOOH + H_2O + e)$ is a surface conversion between $Ni(OH)_2$ and NiOOH, it has a poor kinetics and contributes the main polarization during charge–discharge processes compared to the negative reaction $(Zn(OH)_4^{2-} + 2e = Zn + 4OH^-)$ and IR drop in the electrolyte. Moreover, the oxygen evolution, along with positive reaction, is serious especially under high charge rate. Therefore, ZNBs have been operated at low current densities (below 20 mA cm^{-2}) since proposed [12,14–16] and have not gained any practical acceptance.

To the best of our knowledge, no study has focused on improving the charge–discharge rate with high battery performance. Hydroxyl transfer in the interface is one key element to improve the kinetic of nickel hydroxide electrode. To porous electrodes, the polarization distribution is usually non-uniform due to the electronic and electrolytic resistance and has a strong relationship with the utilization of electrode surface area as described in Refs. [17,18]. Accordingly, this article provides a novel cell structure with a serpentine flow field to reduce the polarization of the positive electrode through enhancing hydroxyl transfer. The effect of electrolyte transfer on positive reaction under high operated current density has been investigated.

2. Experimental

2.1. Cell structures

A novel cell structure and a traditional cell structure are shown in Fig. 1. For traditional cell structure, positive and negative







^{*} Corresponding author.

^{**} Corresponding author. Tel.: +86 41184379669; fax: +86 411 84665057. E-mail addresses: qinzhilai@dicp.ac.cn, Zhanghm@dicp.ac.cn (Q. Lai).

^{0013-4686/\$ -} see front matter © 2013 Elsevier Ltd. All rights reserved. http://dx.doi.org/10.1016/j.electacta.2013.05.024



Fig. 1. Schematic diagram of single cell structures for (a) traditional structure and (b) novel structure.

electrodes were attached to end plates and the electrolyte only passed through the gap between two electrodes as presented in Fig. 1(a). For novel cell structure, there was a serpentine flow field between the positive electrode and the end plate. Only negative



Fig. 2. Hydroxyl ions and polarization distribution on nickel hydroxide electrode based on (a) traditional cell structure and (b) novel cell structure.



Fig. 3. (a) Charge–discharge curves for traditional structure cell and novel structure cell and (b) positive potential during charge–discharge under various current densities.

electrode was attached to end plate. The electrolyte not only passed through the gap between two electrodes but also passed through the gap between the positive electrode and the end plate as presented in Fig. 1(b).

2.2. Electrochemical measurements

A sintered nickel hydroxide $(30 \text{ mm} \times 30 \text{ mm} \times 0.7 \text{ mm}, \text{ area})$ capacity, 25 mAh cm⁻², Jiangsu Highstar Battery Manufacturing, China) was employed as positive electrode and a nickel sheet $(30 \text{ mm} \times 30 \text{ mm} \times 0.1 \text{ mm}, \text{Shanghai Jinchang Alloy Co. Ltd., China})$ as negative electrode. The gap between them was 5 mm in both cell structures. A 8 mol L⁻¹ KOH containing 0.4 mol L⁻¹ ZnO was circulated through gap and reservoir by a circulation pump. All solutions were made with analytical grade chemical reagents and deionized water. Arbin BT-2000 (Arbin Instruments, America) was used to evaluate the cell performance under constant current charge-discharge tests. The cell was charged to 80% full capacity based on the sintered nickel hydroxide electrode, and discharged to 0.8 V. In order to measure potential change of the positive electrode, the Hg/HgO reference electrode (0.98 V vs. NHE) was inserted in the gap between positive and negative electrodes during charge-discharge processes. All above experiments were performed at room temperature.

3. Results and discussion

A critical difference between the traditional structure and novel structure is our use of a serpentine flow field. We flow electrolyte Download English Version:

https://daneshyari.com/en/article/6617842

Download Persian Version:

https://daneshyari.com/article/6617842

Daneshyari.com