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Improved cell performances in Ni/Zn redox batteries fabricated by ZnO materials with various morphologies synthesized using amine chelates

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ABSTRACT

ZnO materials of various shapes and sizes were synthesized by a facile hydrothermal method using amine chelates like ethylenediamine (en), diethylenetriamine (dien), and triethylenetetramine (trien) as additives. The synthesized ZnO powders were used in Zn/Ni electrochemical cells to investigate how the size and shape of ZnO can influence the Zn/Ni cell performance. Special attention was given to Zn dendrite growth on the negative electrode, and the cells were constructed as follows: $Ni_{(s)}$ | Zn$(OH)_4{}^{2-}{}_{(aq,\ 0.5\ mol\ in\ 6\ M\ KOH)}$ | $Ni(OH)_{2(s)}$ | $Ni_{(s)}$. As a result, the largest-sized ZnO active material, made using the dien chelate, had the best cell performance because dien could affect the formation of the Zn dendrite and suppress its growth. However, the other cells with smaller-sized particles could not suppress dendrite growth. Therefore, the reversibility of the redox reaction, particularly the anodic reaction ($Zn(s) \rightarrow Zn^{2+}{}_{(aq)}$), was inhibited because the large Zn dendrite growth made Zn ion diffusion more difficult, and resulted in poorer performance. Hence, the diffusion rate of Zn ions was slower the larger the Zn dendrite was. The cell using DIEN, ZnO material synthesized with dien, had the highest retention of efficiency, and the best cell performance.

Introduction

According to the Global Energy Statistical Yearbook 2016, electricity consumption is expected to increase rapidly, especially in Asia where China, India, and South Korea have seen marked growth between 2013 and 2015 [1]. However, conventional power generation is confronted with environmental problems such as CO_2 emission, radioactive waste disposal, and fine dust. Renewable energy technologies have been developed to partially substitute conventional means since they are less harmful to the natural environment. These technologies also directly convert diverse, natural, and sustainable energy sources, such as sunlight, wind, geothermal heat, ocean waves, and rivers, into electricity. One of the disadvantages of renewable energy is its relatively intermittent capacity for supplying electricity. For this reason, combining renewable energy generation and an energy storage system (ESS) can improve the efficiency of the overall system and help balance the electricity load, whether from renewable or conventional sources [2]. Even though the breadth of ESSs is diverse, large-capacity batteries occupy the most important part of the system, especially in middle-scale ESS. The structure of the electric grid places smaller size, volume, weight, and shape limitations on batteries than those used for portable devices. Therefore, the development of batteries for electric grid and transportation is not yet commercially available due to the limits of battery capacity, charging time, capacity per weight, safety, and infrastructure for using them. Additionally, large-capacity batteries must maintain durability after large numbers of charge–discharge cycles, respond rapidly to change input and output, and have a reasonable cost [3,4]. Much of the research into ESS has focused on lithium ion batteries [5], alternatives to lithium batteries, such as, sodium ion batteries [6], sodium-sulfide batteries [7], lead-acid batteries [8], and redox flow batteries (RFBs). RFBs are promising storage devices that can satisfy the requirements listed above. The RFB can be made up of two electrolytes, called the anolyte and catholyte, in which soluble active materials like metal ions are dissolved. Therefore, the redox reaction occurs in the electrolyte separated by a separator, and all chemical species involved in the redox reaction can be soluble in the electrolyte, which can be stored in external tanks. Therefore, the capacity of RFBs depends mainly on the concentration and amount of electrolyte, and the power depends

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