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Performance and Electrochemical Characterization of Nickel-Hydroxide Electrodes in Nickel Metal Hydride Battery

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Abstract

The recently commercialized nickel metal hydride (Ni-MH) battery is well suited to applications where high energy density, high rate charge/discharge and good service life are required. In order to achieve charge-discharge and cycle life characteristics of Ni-MH cells a new high energy density positive electrode is required. In this work the electrochemical properties of foam nickel electrode and sintered nickel electrode are studied by using life cycle tests and cyclic voltammetry techniques. It is evident from the results that the foam nickel electrode is suitable for high-energy applications and the sintered nickel electrode is suitable for high rate applications.

Key words: Ni sintered electrode; Ni foam electrode; Ni/MH batteries

Introduction

The demand for nickel-metal hydride cells is increasing rapidly, as a result of the proliferation of portable and cordless equipments. Technological innovation to enhance battery capacity is in great demand. Therefore, with development for practical use in mind research into increasing the energy density of nickel positive electrodes was undertaken. Nickel hydroxide exists in different polymorphic modifications differing from one another in their structure, compsosition, and microstructure. The different polymorphs of nickel hydroxide exhibit a wide variation in their electrochemical performance. In this work sintered nickel and foam nickel electrodes are studied by life cycle and CV tests.

Sintered nickel positive electrode

Sintered electrodes were prepared from the previously prepared electrode mix. The powder was spread over the grids in a graphite die. The powder was sintered at the temperature of 1173 K in a muffle furnace for 30 min. under cracked ammonia atmosphere. Then the electrodes are soaked in nickel nitrate solution, then the electrodes are polarized in sodium hydroxide solution. After completion of these two steps the electrodes are washed in de-ionized water and finally dried. The above steps are repeated until the desired weight gain is obtained.

Foamed nickel positive electrode

Highly porous foamed nickel matrix is used as substrate. In considering the use of this matrix for nickel positive electrodes, the mechanical strength, electronic conductivity and efficiency of active material impregnation were adequate and also the extent to which the shedding of active material powder was prevented. As a result, matrices with a porosity of ~ 90% were used. Ni foamed electrode was made by filling the foamed porous substrate with a fluid paste containing 30% organic solvent. The paste composed of a mixture of 80% nickel hydroxide, 12% nickel carbonyl, 7% graphite and 2% binder. The filled body was dried in oven for 16 h.

Experimental

Large size AB_5 MH electrodes were used as counter electrode for cycling the nickel electrodes at C/5 rate. The cells are initially charged for 40 h at 30mA to stabilize the voltage.

The electrochemical behavior of the nickel electrodes was analyzed by using BAS-Zahner IM6(e) CV Analyzer with a Hg/HgO as reference electrode.

Results and discussions

Pasted nickel hydroxide electrodes comprising β-nickel hydroxide deliver a reversible discharge capacity of only 200 mAh/g corresponding to a 0.5e exchange in the absence of Co.

Typical discharge data for nickel sintered and nickel foam electrodes at C/5 rate are shown in Fig.1. Both the cells having nickel sintered and nickel foam electrodes exhibits a initial drop of 200 mV and this indicates that its internal resistance is only 50Ω.

Figure 2. shows the capacity characteristics of nickel sintered and nickel foam electrodes at C/5 rate. The cell coupled with nickel sintered electrode delivers the maximum capacity of 1200 mAh and the minimum capacity of 650 mAh for 100 cycles. More fluctuation was observed from initial to final stages.

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The cell coupled with nickel foam electrode delivers the maximum capacity of 550 mAh and the minimum capacity of 500 mAh for 100 cycles. The capacity variation is not much through the progression of number of cycles.

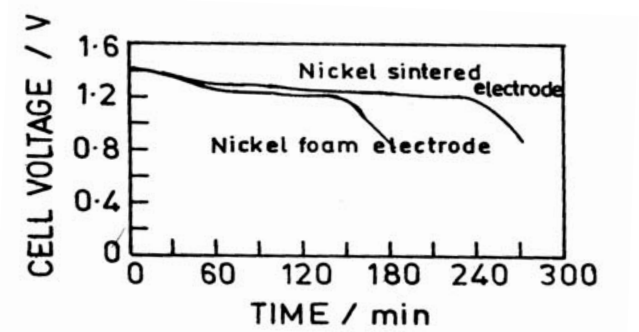

Fig.1. Discharge characteristics of nickel sintered and nickel foam electrodes

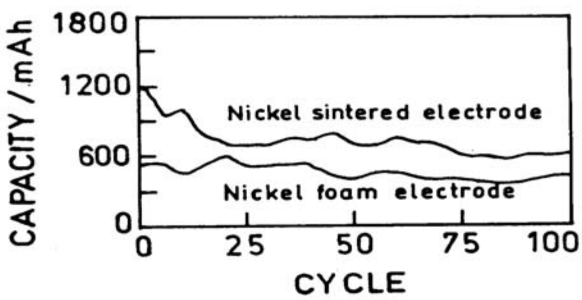

Fig.2 Discharge capacities of nickel sintered and nickel foam electrodes.

A cyclic voltammogram in the 1st cycle for nickel sintered electrode is shown in Fig.3. The two current peaks 0.520 V and 0.049 V constitutes the basis for the operation of Ni oxide

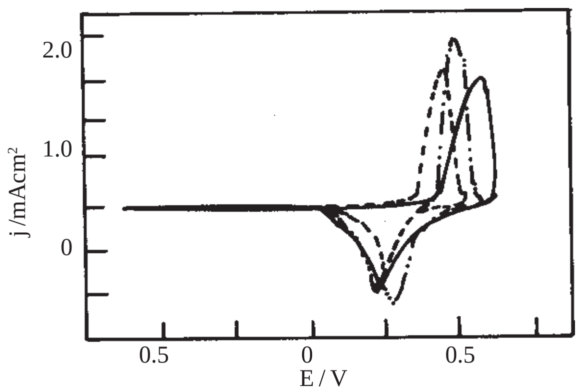

Fig.3 Cyclic voltammograms for nickel sintered electrode.

electrode in a rechargeable battery. The reversibility of the electrode reaction can be measured by ($Eo-E_R$) between the oxidation potential (Eo) and the reduction potential (E_R). The difference ($Eo-E_R$) depicts a good reversibility.

Another cyclic voltammogram in the1st cycle for the nickel foam electrode is shown in Fig.4. The two Current peaks 0.521

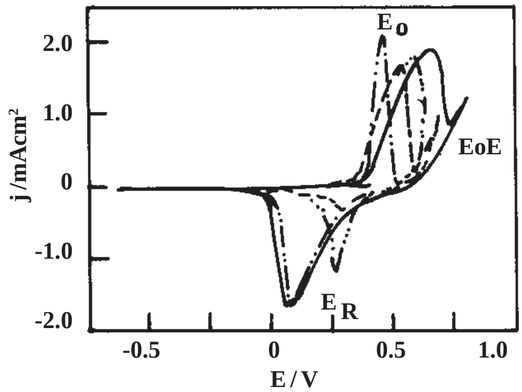

Fig.4. Cyclic voltammograms for nickel foam electrode.

and 0.045 constitute the basis for the electrochemical reaction of Ni Oxide electrode in a rechargeable battery. A large difference (E_{OE}-Eo) between the oxygen evolution and the oxidation potentials (Eo) is beneficial for Nickel electrodes. Also further increase in (E_{OE}-Eo) allow the electrodes to be fully charged, that means the complete oxidation of Ni^{2+} to Ni^{3+}. Consequently long cyclability and larger capacity are the properties that should be expected.

Conclusion

Spectrochemical experiments revealed that both the electrodes are suitable as positive electrode in nickel metal hydride batteries for practical applications.

The discharge characteristics of sintered electrode depicts that the cell voltage is found stabilized for more duration. Also the capacity characteristics shows that the capacity fading is appreciably noticed from initial to later stages of the life cycle in comaparision with the nickel foam electrodes.

The discharege characteristics of the nickel foam electrode falls below the c/o voltage of 1 V quickly compared with the sintered electrode. But the capacity characteristics is found stable while proceeding from the initial to final stages of the life cycle. After analyzing all the above results it is evident to conclude that the sintered nickel electrode is suitable for high rate applications and the nickel foam electrode is suitable for high energy applications.

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