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AC Impedance Studies on AB_5 Metal Hydride Electrodes

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The metal hydride battery developed in recent years, is one of the most promising rechargeable batteries because of its attractive features compared with other batteries. The metal hydride electrode is the negative electrode in this battery, with hydrogen being stored in the alloy. The hydrogen-storage alloys, which are utilized in the negative electrodes, tend to be oxidized and pulverized in the alkaline environment such that the ability of absorbing and desorbing hydrogen is lost. The objective of this study is to compare the electrochemical characteristics of metal hydride electrodes of varying composition, by using the electrochemical impedance spectroscopy (EIS) technique. EIS study on MH electrodes is used to develop electrodes with the optimum composition more suitable for high-energy applications

Key words: MH electrode; Ni/MH batteries

Introduction

Now a days, the Ni/MH batteries are used in many applications, mainly for consumer and portable electronic applications. However, the capacity of Ni/MH batteries should be improved to meet the increased interest worldwide for the different types of electric vehicle and other applications. The ultimate acceptance of electric vehicle depends on the performance of the Ni/MH batteries. The metal MH electrode mainly influences the performance of Ni/MH batteries. So research is focused to fabricate a suitable negative electrode to fulfill the demands of Ni/MH batteries. Understanding the processes governing the charge and discharge reactions in metal hydride electrodes is very important for improving the performance of metal hydride batteries. By using Electrochemical Impedance Spectroscopy (EIS), a small sinusoidal signal is used to perturb the electrochemical system and the response of the system is observed. The frequency of the signal is varied over a wide range, which makes it possible to monitor processes in the system with different time constants. EIS is a standard technique for investigation of electrochemical systems. Several groups have given valuable contributions to important issues of modeling impedance response in metal hydride electrodes for battery purposes. It is evident from many authors that the reaction impedance was highest for fully charged AB_5 alloy electrodes.

Experimental

Electrode development

Three different electrodes of different compositions were fabricated as follows for the present work

a) 76% AB_5 alloy, 16% Nickel carbonyl, 6% acetylene black and 2% PTFE
b) 76% AB_5 alloy, 19% Nickel carbonyl, 3% acetylene black and 2% PTFE
c) 76% AB_5 alloy, 10% Nickel carbonyl, 12% acetylene black and 2% PTFE

Alloy powder, nickel carbonyl and acetylene black were well mixed with PTFE by using a organic solvent to form paste, which was pasted into a nickel foam substrate, which was then dried in vacuum and finally pressed to form the negative electrode of Ni/MH battery.

The experiments were carried out using Hg/HgO reference electrode. Prior to each experiment, all the three alloy electrodes were activated by cycling ten times. An over dimensioned nickel hydroxide electrode was used as counter electrode. The experimental procedure was performed as follows. The electrodes were charged under constant current mode until the hydrogen content reached its saturated value. Before conducting the experiments sufficient time (30 min) was allowed for the potential to stabilize. After the voltage stabilized, EIS experiments were carried out.

Results and discussions

EIS studies on metal hydride electrodes of various compositions have been carried out using BAS-Zahner IM6(e) Impedance Analyzer.

Figure1 shows Nyquist plots for the impedance of the electrode of the composition (a) at 10 cycles. Each plot consists of two depressed semicircles, and a Warburg slope W. The semicircle in the low frequency range is state of discharge (SOD) dependent, i.e., the size of semicircle decreases with discharge capacity until about 100 mAh/g is reached, then it begins to increase with further discharge. The semicircle in the low frequency region is attributed to the charge transfer resistance and double layer capacitance, whereas the sloping line is the Warburg diffusion impedance.

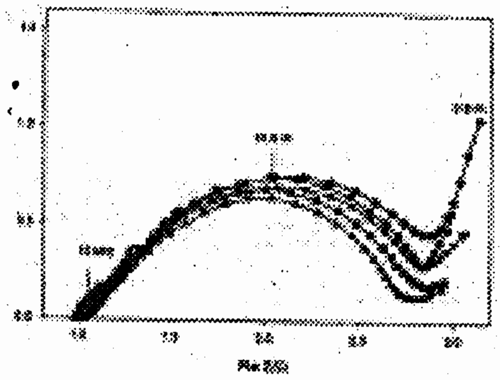

Fig.1 Nyquist plots for impedance of the electrode of the composition (a) at 10 cycles

Figure 2. shows Nyquist plots of the impedance of the electrode of the composition (b). This shows two resistance-capacitance semicircles in series with an inductive resistance. The semicircle in the high frequency region is independent of SOD, but the low frequency semicircle is sensitive to SOD.

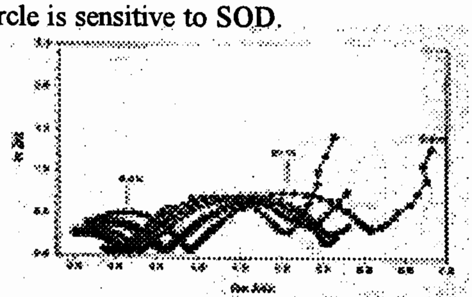

Fig.2 Nyquist plots of the impedance of the electrode of the composition (b).

Figure 3 shows Nyquist plots for the impedance of the electrode of the composition (c). The diameter of the high-frequency semicircle increases and a small increase in solution resistance occurs.

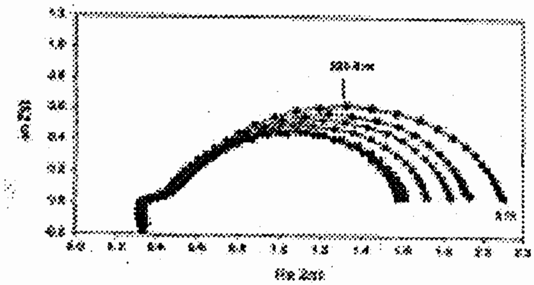

Fig.3 Nyquist plots for the impedance of the electrode of the composition (c).

Conclusion

AB_5 electrodes of various compositions were analyzed using EIS techniques. Electrode resistance have been determined by using this technique. Increase or decrease in nickel carbonyl and acetylene black has no effect in ohmic resistances of the alloy electrode. For electrodes containing optimum percentage of nickel carbonyl (16%) and acetylene black (6%) the total resistance is controlled by the ohmic resistance. It is concluded from the EIS study that the electrode containing the above composition is suitable as MH electrode for the fabrication of Metal Hydride Battery.

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