Synthesis, hydride and electrochemical properties of $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$ alloy as a candidate for anode of nickel metal hydride battery

Salighe Zohre[1,2], Arabi Hadi[*1,2], Ghorbani Shaban Reza[2], Komeili Mojtaba[1,2]

[1] *Renewable energies, magnetism and nanotechnology laboratory, Faculty of science Ferdowsi university of Mashhad, Mashhad*

[2] *Department of Physics, Faculty of science, Ferdowsi university of Mashhad, Mashhad*

**Corresponding author E-mail: arabi-h@um.ac.ir*

Abstract

Li-Ion and Ni-MH batteries are the best candidates for Electric Vehicles. Despite higher energy densities of Li-Ion batteries, because of economical reason Ni-MH batteries are still attractive for scientist. In this study, the intermetallic compound $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$ based on $LaNi_5$ structures, which is a suitable absorbent for hydrogen storage in the solid phase, was produced by vacuum arc melting (VAR). The hydrogen properties of this alloy have been measured using the Sievert volumetric method. Based on the results, absorption and desorption of hydrogen with high kinetics (less than 5 minutes) and with a maximum hydrogen storage of 1.8 wt% at room temperature for $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$ alloy were obtained. Electrochemical analysis shown that the energy density which the alloy can reversibly deliver is about 300 mAh/g.

Keywords: *Nickel metal hydride battery, Hydrogen storage alloy, vacuum arc melting, Electrochemical stability, High-rate dischargeeability*

Introduction

With the reduction of fossil fuel reserves and the increase in the price of petroleum products, the development of electric and hybrid cars has become the focus of attention of car manufacturers. In order to achieve this object, it is inevitable to develop rechargeable batteries with high energy storage capacity and reasonable price [1,2]. Although lithium batteries have a greater capacity for energy storage, the use of these batteries in electric vehicles is not economical due to their high price, and other batteries such as nickel-metal hydride batteries are proposed as alternatives. Metal hydrides are widely used as hydrogen storage material for use in fuel cells and internal combustion engines, energy converters, and as electrodes in nickel metal hydride batteries [3,4]. Meanwhile, $LaNi_5$-based alloys with easy activation conditions, high kinetics, almost good cyclability in absorption and desorption, hydrogen storage capacity in the range of 1.4 to 1.6 wt% and also excellent electrochemical properties are one of the suitable options [5]. The purpose of the present research is to synthesize a hydrogen absorbent alloy with the composition of $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$, and then investigate the microstructure, hydride and electrochemical properties of this alloy.

Experimental

After the synthesis of $La_2Y_{0.1}Ni_{10}Mn_{0.5}$ pre-alloy by arc furnace, it is placed in the glow box environment, and powdered by an agate pounder followed by combing with a certain amount of magnesium. Then, for further homogenization, we put the powder in the ball mill apparatus. After that, the powder is put in an autoclave for 4 hours for heat treatment at 900^0C. In order to prepare a pellet-shaped sample for use as an anode's battery, the resulting alloy powder was mixed with nickel powder in a ratio of 2:1 respectively under a pressure of 300 MPa. 6M KOH solution was used for electrochemical experiments. The prepared pellet was used as a working electrode, Ag/AgCl as the reference electrode and nickel hydroxide as a counter electrode [6].

Results and discussion

The XRD analysis of $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$ alloy shows that all peaks are related to $LaNi_5$ phase with hexagonal structure and P6/mmm symmetry. Also no impurity or oxide phase are observed in the X-Ray pattern (Figure 1). The hydrogen absorption and desorption curves for the alloy synthesized in the fifth cycle is shows in figure 2. The alloy has reached its maximum absorption value (1.8% wt), which for the $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$ alloy is higher than the expected maximum absorption for $LaNi_5$, which is due to the presence of magnesium and yttrium in the alloy structure. The absorption curve shows that after about 300 seconds, this process is completed, the absorption kinetics is very good, and in the desorption stage, almost all the absorbed hydrogen is removed from the sample. Therefore, no stable hydride phase is formed in the system, ie heating is not required for desorption and only with a vacuum, we can remove the hydrogen from the sample.

In Figure 3 (a), the electrochemical stability of the cycles has been investigated by discharge curves, which include the discharge capacity based on the number of working cycles. As can be seen, after 50 working cycles, about 72.54% of the discharge capacity of the first cycle is maintained, which indicates the suitable electrochemical stability of this alloy. the maximum energy storage capacity in this alloy reaches 298.944 mAh/g, for a current of 320 mA/g (1C). Figure 3 (b) shows the value of discharge capacity for this alloy in different discharge currents. in Figure 3 (c), the High-rate dischargeability curve for the $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.9}$ alloy electrode shows very good electrochemical kinetics for this alloy at high currents.

Conclusion

In this research, the synthesis of intermetallic alloy $La_2Mg_{0.9}Y_{0.1}Ni_{10}Mn_{0.5}$, hydrogen storage process in it, and also the fabrication of metal nickel hydride electrochemical cell was done successfully. Suitable hydrogen storage and electrochemical properties, reasonable absorption and desorption kinetics, stability and high electrochemical kinetics were obtained. For this alloy, the weight percentage of hydrogen absorption at room temperature was calculated as (1.8 wt%) and the energy storage capacity was about 300 mAh/g. The results of this research show that this alloy is a suitable candidate for hydrogen storage and application in nickel metal hydride batteries.

References

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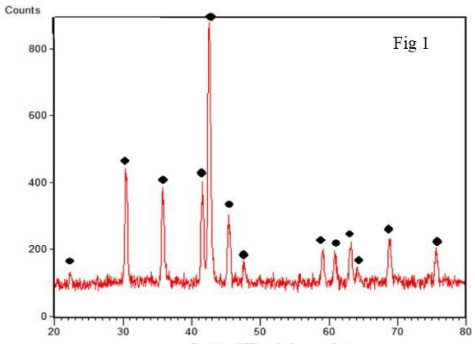

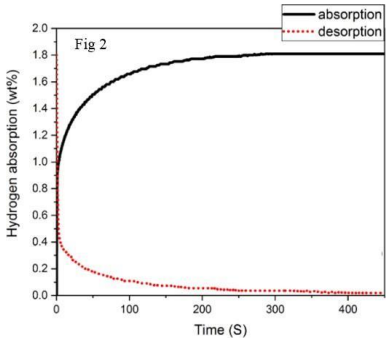

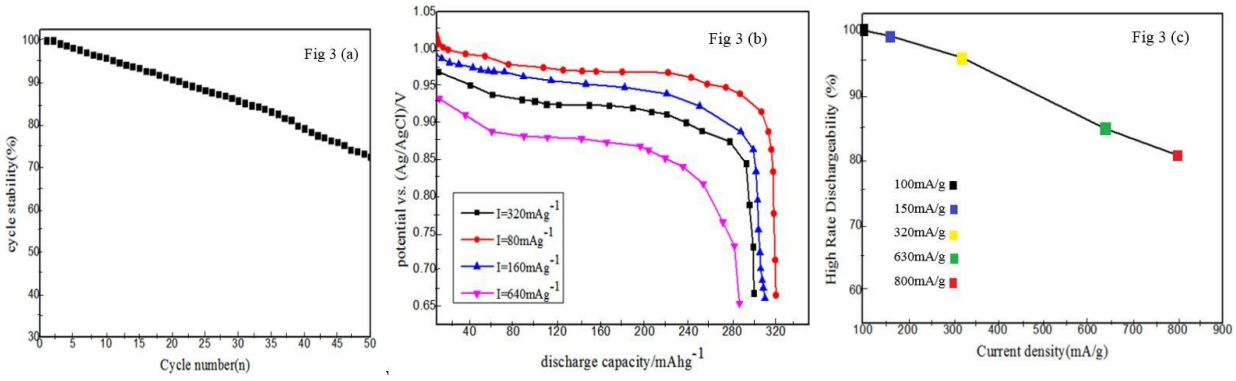

Figure 1: XRD analysis of La2Mg0.9Y0.1Ni10Mn0.5 alloy prepared by electric arc remelting method.
Figure 2 : Adsorption and desorption of hydrogen for La2Mg0.9Y0.1Ni10Mn0.5 alloy at room temperature.
Figure 3: (a): electrochemical stability (b): discharge curves (c): HRD curves for La2Mg0.9Y0.1Ni10Mn0.5 alloy.