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Design, elaboration and characterization of a Ni–MH battery prototype

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ABSTRACT

This paper shows advances achieved in the design and construction of a nickel–metal hydride (Ni–MH) battery prototype. The requirements of the design were to characterize the new variables appearing in a commercially assembled battery, such as limited physical space, electrical contact resistance, the behaviour of the system as a function of the gas evolution during fast charge and overcharge, and others. The electrochemical characterization was performed using laboratory equipment.

In the first design version an anode and a cathode, both embedded in electrolyte, and electrically isolated by means of a separator, were placed inside a reactor. Based on the identification of problems detected in the structural performance analysis and the electrochemical characterization of the different prototype models, the versatility and usefulness of the designs were optimized. The final prototype design was satisfactorily tested in electrochemical cycling and rate capability studies, with different electrode and separator materials and using different weights between electrodes. The internal pressure monitoring of a sealed cell, under different conditions of use, was also demonstrated, thus proving that the design allows the systematic study of different application requirements.

1. Introduction

Most of the works found in the literature concerning Ni–MH batteries focus on the characterization of the hydrogen storage alloy used as a negative electrode active material [1–7], while others study the property enhancement methods of active material in positive electrodes [8,9]. These materials are characterized in a laboratory cell, where other elements of the system are not intended to affect the variable studied.

Some other research groups [10–15] have been able to perform studies of alloys directly on commercial products taking advantage of industrial facilities. Ozaki et al. [10] have studied some Mg-containing AB_5 alloys, in AAA and short-D size Ni–MH batteries, using facilities of the Japan Automobile Research Institute, according to test a HEV procedure. Chen et al. [11] studied the activation and degradation of a hydrogen storage alloy in sealed AA-size Ni–MH battery. Hoshino et al. [12] characterize a 96 V–14 Ah Ni–MH battery for solar vehicle application, which was previously prepared by them in a laboratory. Yan and Cui [13] prepared and characterized an AA-type Ni–MH battery, testing internal resistance, cell potential, cycle life and inner pressure of gases for no-binder electrodes. Kim et al. [15] studied the characteristics of pre-treated negative electrodes and the effects on inner pressure of D-size cylindrical batteries fabricated through a commercial production line.

However, high cost factors and time limitations need to be considered when carrying out a systematic study on a production

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line. Hence, the development of a special device for studying variables arising after the integration of individual elements in a commercial battery can be very useful. Pressure between electrodes, contact resistance, the amount of electrolyte [16] and pressure due to internal gas evolution [17–19] are important points to be considered for a versatile device design [20].

The aim of this paper is to show the advances reached in the design and construction of a Ni–MH battery prototype. The work presents a final prototype design and two previous models, which were characterized. The work shows which structural problems were detected in the different design versions and how they were solved in agreement with the application requirements. The battery prototype, together with a proprietary galvanostat design, which is to be published, forms part of an Argentinian national project for academic teaching and research.

2. Experimental procedure

The $LmNi_4Co_{0.31}Mn_{0.31}Al_{0.42}$ (Lm = lanthanum rich mischmetal, 84 wt% La, 8 wt% Ce, balance other elements) intermetallic alloys from two different preparation batches were used as the active material of the negative electrodes. The first batch alloy produced was obtained by melting the constitutive elements (purity > 99.9%) inside an electrical arc-furnace [2], while the second was obtained inside an induction furnace in a boron nitride crucible [3,4], both under an inert atmosphere (Ar). In order to ensure the sample homogeneity, the samples were re-melted twice during each preparation. They were labelled as AB5-1 and AB5-2.

Table 1 – Properties of glass-based material tested as battery separator.

Commercial denomination	Type	Glass type	Weight (g/m^2)	Thickness (μm)	Label
RT200	Woven roving	E	204	150	ER
AI40-C	Veil	C	40	300	CV
AG-40AR	Veil	AR	40	400	ARV

For the negative electrode preparation, 100 mg of active alloy were freshly crushed between a 44 and 74 μm sieve; the resultant particles were then mixed with an equal amount of teflonized black carbon (Vulcan XC-72 + 33 wt% PTFE), therefore rendering available the electrical, mechanical and conductive supports. For the first prototype, this mixture was assembled with a Ni mesh connected to a Ni wire in order to act as a current collector. This set was pressed at 300 MPa within a cylindrical matrix. The electrodes obtained are disk-shaped, with a diameter of 11 mm and an approximate thickness of 1 mm.

The crystalline structures of AB5-1 and AB5-2 were examined using X-ray diffraction spectroscopy (RXD) with Philips PW3710 equipment. Energy dispersive X-ray spectroscopy (EDS) integrated in a Philips 515 scanning electron microscope (SEM) was used in order to verify the homogeneity of the samples.

The positive electrodes used in battery prototype measurements were provided by INIFTA (La Plata, Argentina). Some of these were commercial grade and others laboratory made,

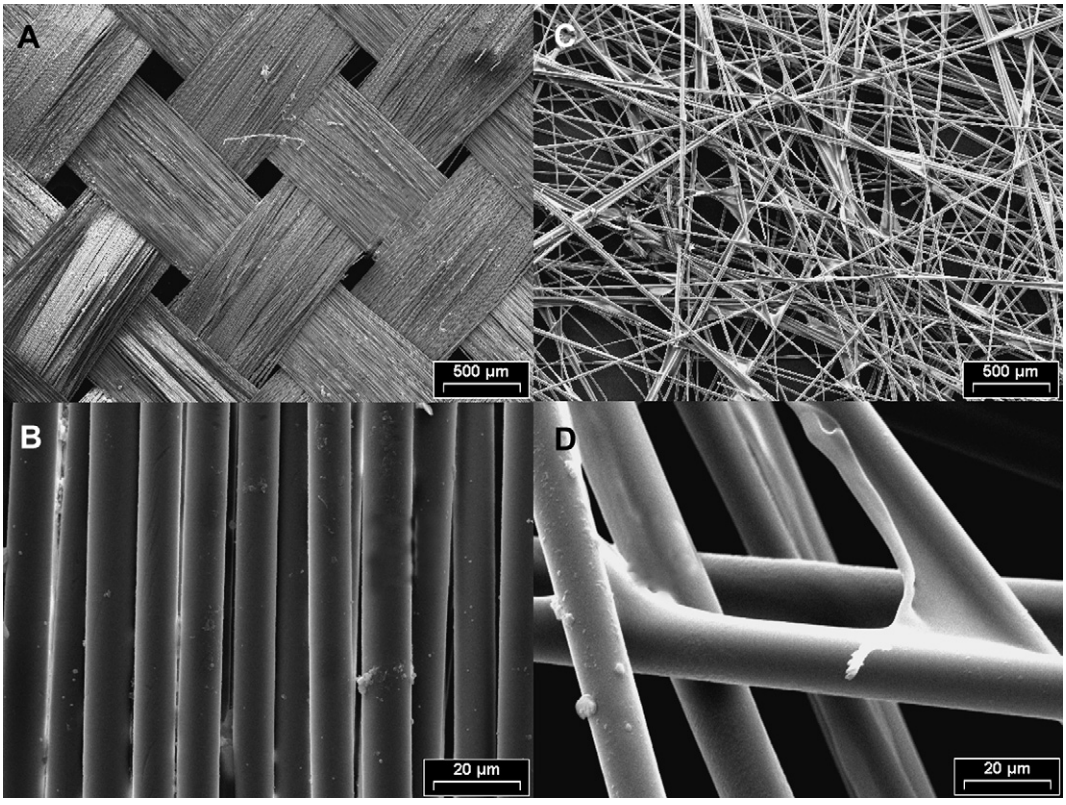

Fig. 1 – SEM images of different separator's fibre structure.