



ELSEVIER

Journal of Alloys and Compounds 293–295 (1999) 734–736

Journal of
ALLOYS
AND COMPOUNDS

Development of fast kinetics metal hydride alloys and battery electrodes for high power applications

Andreas Otto*, Volker Güther Dr.

GfE Metalle und Materialien GmbH, Höfener Strasse 45, D-90431 Nuremberg, Germany

Abstract

Since 1991, rechargeable Nickel–Metal Hydride Batteries as an alternative to Nickel–Cadmium batteries have been very successful for consumer applications with low discharge rates and long cycling stability (e.g., cellular phones). The main advantages of NiMH batteries in comparison to NiCd batteries are their higher specific energy densities, the elimination of the memory effect and the absence of toxic Cadmium. For high power applications a lasting increase of electrochemical reaction kinetics inside the NiMH battery is important. The combination of both the general advantages of the NiMH battery and the high power performance will lead to a new battery generation which will be able to fulfil the demands of cordless tool and electric vehicle applications. The goal of a Brite Euram Project is the development of such advanced Ni–MH batteries for high power applications. This article gives a brief mid term summary on some provisional results of the running project. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Metal hydride battery; Kinetics; Brite Euram project

1. Introduction

The target of the project is to manufacture a NiMH battery which supplies a continuous peak power output larger than 10 C (discharge rate of about 2.4 A/g). The charging time will be less than 6 min up to 80% of the nominal capacity. The energy densities of the final batteries should be higher than 60 Wh/kg and $>200 \text{ Wh/dm}^3$ respectively combined with a peak power capability $>400 \text{ W/kg}$. Furthermore, a high cycle life (more than 1000 cycles with 80% depth of discharge) shall be approached.

To gain these goals, an increase of the specific electrochemical capacity as well as the electrochemical reaction kinetics of the Metal Hydride Alloys is necessary. The optimised alloy properties have to be transferred into real Metal Hydride Batteries. The battery performance will be demonstrated in common applications with special attention to their high power behaviour as well as the required charging times.

2. Research approach

With regard to kinetic properties the influence of composition of the metal hydride alloy as well as the

crystal structure is investigated. Furthermore the manufacturing process for metal hydride powders will be optimised. By modifying the surface structure of the metal hydride alloy catalytic effects are investigated. To improve the battery itself an optimised design of the negative electrode as well as the whole battery is developed.

The project runs in iterative steps. At the beginning, investigations on model metal hydride alloys with a standard composition $\text{LaMM}(\text{NiCoMnAl})_5$ as well as standard battery electrodes have been carried out. The charge transfer mechanisms and the rate limiting steps at the negative electrode were determined. Also several electrode preparation methods were investigated. As a result optimised alloys and electrode processings are defined and further improved. The manufactured new electrodes are tested in real batteries.

3. Results

During the first two years of the project the influence of alloy composition, alloy and powder preparation techniques as well as surface treatments on the kinetics of standard AB_5 type alloys has been investigated. A significant improvement of the kinetics can be achieved by optimising the manufacturing process as well as special surface treatments. Based on these optimised manufactur-

*Corresponding author.

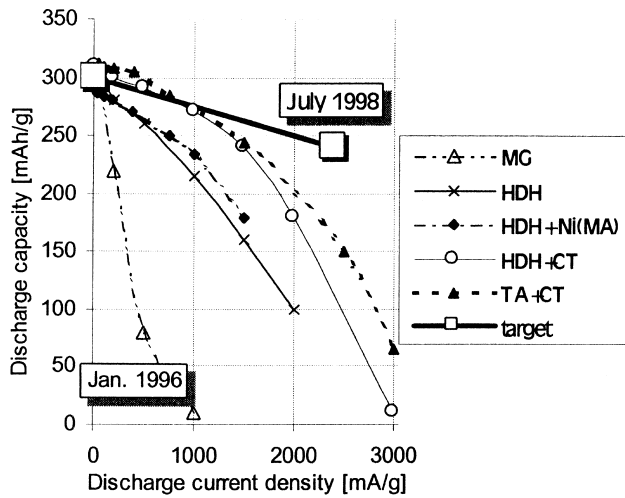


Fig. 1. Deep discharge measurement of an AB₅ alloy powder after different treatments.

ing processes alloys with modified surface as well as crystal structures have been prepared and tested in half cell tests (Fig. 1).

There are big differences in kinetic properties between the alloy powders prepared by mechanical grinding (MG), Hydriding/Dehydriding process (HDH), HDH combined with mechanical alloying with Ni (HDH+Ni/MA) as well as chemical treatment (HDH+CT) and additional thermal annealing (TA+CT). Fig. 2 shows the increase of the discharge rates due to the processes and treatments developed during the project. The main reason for the higher reaction kinetics is the surface modification of the alloy powders. The generation of a large surface area as well as catalytic particles (e.g., Nickel clusters) on the surface seem to be most important in order to get improved kinetic [1–3].

These improved properties of the alloy powders have been transferred successfully to real batteries. As shown in Figs. 3,4 nearly the full capacity is available also at high

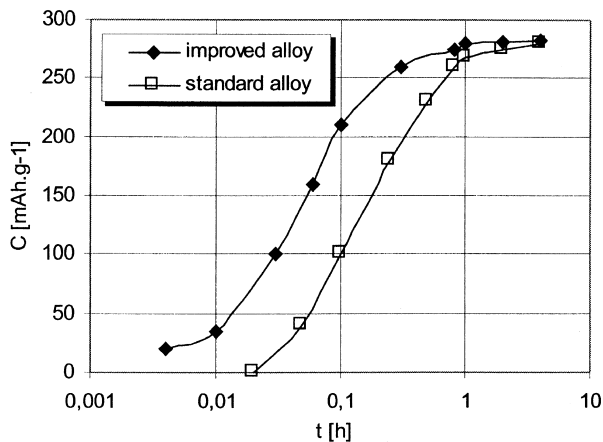


Fig. 2. Capacity vs. discharge time for a standard AB₅ alloy as well as an improved AB₅ alloy powder.

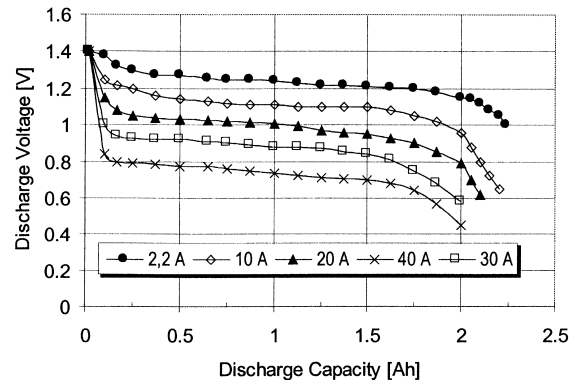


Fig. 3. Discharge voltage vs. discharge capacity of a battery with an improved and activated AB₅ alloy at different discharge currents.

charging and discharging currents (measured in Sub-C-Cells produced by NiMe Hydrid). Merely the cell voltage decreases at high currents which indicates a high internal resistance of the electrodes. Therefore further optimisation of the cell design (electrode technology, current collector, . . .) is required.

4. Conclusions

During the first half of the Brite Euram Project some fundamental results about the influence of AB₅ alloy structure as well as alloy processing on kinetic properties were gained. It was shown, that the chemical composition and the stoichiometry only influence the maximum capacity. The influence on kinetics is mainly caused by the crystallinity (as a function of cooling rate and/or thermal treatments) of the alloys. But even more important in regard to reaction kinetics is the surface state of the metal hydride powders. It can be influenced by powderization techniques as well as subsequent treatments. The production of “surface active species” (e.g., Nickel clusters) improves the kinetics strongly. An optimum surface structure is obtained during powderization by hydriding/dehy-

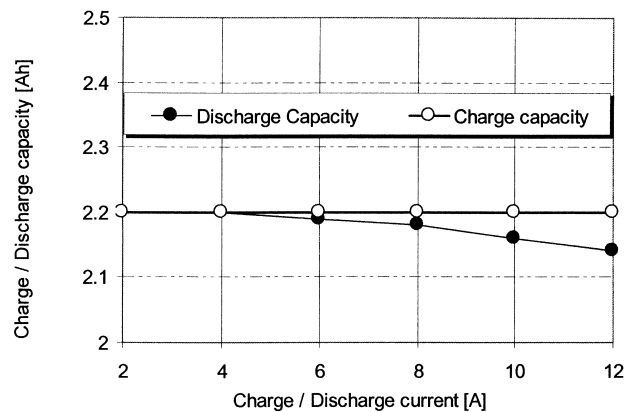


Fig. 4. Charged and discharged capacity vs. charge/discharge current for a Sub-C battery with an improved and activated AB₅ alloy.

Table 1
Provisional results of electrochemical measurements with optimised metal hydride alloys

	AB ₅	AB ₂
Maximum capacity	LaMM (NiCoAlMn) _{4.8–5.0} 350 mAh/g	Zr _x Ti _{1–y} (NiCr, V, Mn) ₂ 382 mAh/g
Maximum capacity at		
300 mA/g	305 mAh/g	276 mAh/g
1000 mA/g	281 mAh/g	48 mAh/g
2000 mA/g	224 mAh/g	0 mAh/g
Cycling stability/activation	Very good	Not sufficient

driding process combined with an chemical treatment in the electrolyte. Table 1 shows some provisional results gained with these optimised alloy powders.

The gained high discharge rates of the metal hydride alloy powders are transferable to real batteries. To get low internal resistance of the battery the battery design has still to be improved.

Acknowledgements

The research has been funded in part by the European Commission in the framework of the Brite Euram III program (contract number BRPR-CT95-0136). The project is based on a cooperation between: GfE Metalle und Materialien GmbH Nuremberg, Germany; CNRS, France; EXIDE Europe, SEA Tudor S.A., Spain; Electrolux Research & Innovation AB, Sweden; Stockholm University,

Sweden; Leclanché S.A., Switzerland; Ni–Me Hydride AB, Sweden; University of Salford, United Kingdom; University of Fribourg, Switzerland.

References

- [1] D. Chartouni, N. Kuriyama, A. Otto, V. Güther, C. Nützenadel, A. Züttel, L. Schlappbach, Influence of the alloy morphology on the kinetics of AB₅-type metal hydride electrodes, *J. Alloys Comp.* to be published.
- [2] A. Züttel, D. Chartouni, Ch. Nützenadel, L. Schlappbach, V. Güther, A. Otto, M. Bürtsch, R. Kötz, Comparison of the electrochemical- and gasphase hydrogen sorption process, *Materials Science Forum* (1999) to be published.
- [3] A. Züttel, V. Güther, A. Otto, M. Bürtsch, R. Kötz, D. Chartouni, Ch. Nützenadel, L. Schlappbach, About the mechanism and the rate limiting step of the metalhydride electrode reaction, *J. Alloys Comp.* (1999) to be published.