# Nickel-Metal Hydride Batteries: A New Generation of Secondary Storage

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Interest in secondary batteries suitable for use in electric vehicles has increased rapidly in the last decade, as restrictions on vehicle emissions in urban areas have become more stringent. Combustion of fossil fuels in large power plants and storage of the energy electrochemically is more efficient than direct combustion in internal combustion engines [1]. In addition, storage batteries can be charged from alternative sources of electricity, such as solar and hydroelectric plants.

In order to be acceptable for use in an electric vehicle, a battery must meet a number of important criteria. It must have a high energy density to make the travel distance between recharges as long as possible. It must be capable of high power output throughout its discharge cycle to provide the high current necessary to operate a vehicle, and it must be capable of especially high peak power for acceleration. The battery must also have a long cycle life as well as a long physical lifetime. It must not undergo rapid self discharge on standing. Finally, it must not be prohibitively expensive.

Theoretical energy densities of secondary battery systems in common use are listed in Table 1. Most of these systems are not practical for electric vehicle use for a variety of reasons. The lead-sulfuric acid battery cannot be sealed, and cannot be produced with a sufficiently high energy density. The sodium-sulfur cell is undesirable because it contains metallic sodium and operates at 300°C. The nickel-cadmium battery has a high energy density. However, Ni-Cd cells with high capacities and high discharge rates are difficult to produce [2]. In addition, the presence of highly toxic Cd presents a serious disposal problem if high capacity batteries are to be produced on a large scale.

| Electrochemical Couple | Theoretical Energy Density (W·h/kg) |
|---|---|
| $Pb/H_2SO_4$ | 161 |
| $Na/S_2$ | 980 |
| Ni/Cd | 209 |
| $Ni/LaNi_5H_6$ | 275 |

Table 1. Theoretical energy densities of various electrochemical couples [3].

The nickel cathode of the Ni-Cd cell has a high energy density and is capable of very high rates of discharge [4]. Attempts were made in the late 1960's and early 1970's to use metallic alloys to store hydrogen in cells using $Pt/H_2$ electrodes [5-7]. Replacement of the Cd anode in a Ni-Cd battery was first attempted by Justi and co-workers in 1970 [8]. The overall reaction in this system is given in equation 1.

$$NiOOH(s) + MH(s) \rightarrow Ni(OH)_2(s) + M(s) \qquad (1)$$

The Ni-MH cell has almost the same discharge potential as a Ni-Cd cell allowing them to be used interchangeably. The energy density of the metal hydride electrode is slightly higher than that of the Cd electrode, and high discharge rates are easily attainable. Because there is no net change in the electrolyte concentration in this system, sealed cells are easy to construct.

$LaNi_5$ was found to have exceptional hydrogen absorption and physical properties for use in battery applications [9]. Small Ni-metal hydride batteries have been commercially available since 1987. However, the cycle life and self discharge characteristics have been unsuitable for larger scale uses until recently [10].

Recently, two groups have reported development of batteries with sufficient energy density, cycle life time, and self discharge characteristics for electric vehicle use. Ovshinsky, Fetcenko, and Ross at Ovonic Battery Corp. have developed a battery using disordered materials to provide the necessary features for electric vehicle use [11]. Sakai and co-workers have developed a battery with similar characteristics, using doped $LaNi_5$ alloy powders encapsulated in Cu [12,13].

In the Ovonic battery, the composition of the anode alloy is varied to control the hydrogen storage capacity, the metal-hydrogen bond strength, the charge and discharge rates, and the stability of the electrode in the alkaline electrolyte. Long range structural disorder is used to optimize the storage capacity and rate capability by combining regions of high storage capacity with regions of high catalytic activity within the alloy. Intermediate range structural disorder is used to increase cycle life and discharge rate by covering the alloy surface with a porous protective oxide coating [11].

In the Sakai battery, the $LaNi_5$ alloy is substituted with small amounts of other metals to increase cycle life [14,15]. The alloy powder is coated with a thin layer of Cu or Ni according to a procedure first developed by Ishikawa and co-workers [16,17]. This encapsulation decreases the self discharge of the cell [18] and improves the charge [19] and discharge [20] characteristics of the electrode. Complete substitution of La with mischmetal provides a viable low-cost alternative alloy [21].

Recent improvements in Ni-MH battery technology by Ovonic Battery Corp. and Sakai, et al. suggest that a battery which meets the criteria necessary to power electric vehicles may be marketable in the near future. Tests of such batteries in cars are under way [12]. Ovonic projects a vehicle range of 240 miles and a battery life of 120,000 miles using batteries they are developing [11]. Metal hydride anodes also offer the possibility of use in combination secondary battery/fuel cells which can be recharged electrochemically, or alternatively with hydrogen gas [22].

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