Implantable Nickel Hydrogen Batteries for Bio-Power Applications

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Neural stimulation/prosthesis programs require power sources with exceptional cycle life, safety, and reasonable energy and power density. Nickel hydrogen batteries, currently used in space applications are remarkable for their long cycle life (over 60,000 cycles), high power density and low maintenance; however they utilize high hydrogen pressures (55-70 atm) [1] making them unsuitable for implantable applications.

The present work involves developing a nickel hydrogen battery designed to operate at lower pressures by utilizing low-pressure metal hydride to store hydrogen only, rather than as the negative electrode as in a conventional nickel metal hydride (NiMH) battery. This approach separates the metal hydride from the alkaline electrolyte and eliminates the metal hydride corrosion [2] that leads to short cycle life in NiMH batteries. As significant amounts of hydrogen are stored in the onboard metal hydride, only a low pressure of hydrogen (about 1 atm) is required, which greatly increases safety, design flexibility and is particularly well suited for biomedical applications requiring implantation of the battery in the human body.

A nickel hydrogen rechargeable battery is a hybrid combining a nickel oxide positive electrode from the nickel-cadmium cell and the hydrogen negative electrode from the hydrogen-oxygen fuel cell. A bolt-nut type Ni:H_2 cell of 1 inch diameter and 61.3 mAh capacity, schematic shown in Fig. 1, was assembled and tested in a stainless steel compartment filled with hydrogen. The electrodes are in contact with nickel chromium mesh current collectors. A separator impregnated with 26 wt. % KOH separates the electrodes. The cell at about 2 atmospheric pressure demonstrated excellent cyclability and the voltage profile for 3 charge and discharge cycles are shown in Fig. 2. Other interesting electrode configurations such as bipolar cells in a common pressure vessel are being investigated.

To meet the distributed power needs of implantable systems, a prototype nickel-hydrogen micro-battery with all the components from the current collector to the electroactive material to the electrolyte is being microfabricated using thick film printing (Fig. 3). No external supply of electrolyte is required. The substrate in this design is porous to allow hydrogen diffusion into the negative electrode and was studied earlier for microfabricated fuel cells [3]. Positive and negative electrode inks were obtained by mixing the electrode material with KOH and polyacrylic acid (binder). Aq. KOH mixed with fine alumina (for providing stiffness) and polyacrylic acid was used as electrolyte ink. Low temperature cured porous gold paste was used as current collectors. Modified $LaAl_{0.3}Ni_{4.7}$ hydride material as used in previous work on microfabricated fuel cells [3] will be applied in this study. The modified hydride powder has been shown to be resistant to passivation even in humid environments

With the improved battery design using low-pressure metal hydride for hydrogen storage, the 61.3 mAh battery (Fig. 1) and the microfabricated battery (Fig. 2) will provide reliability with long cycle life, and will serve large power and distributed power requirements for electrostimulators in biomedical applications.

References:

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2. M. Ikoma, K. Komori, S. Kaida, C. Iwakura, J. Alloys Comp., 284, 92 (1999).
3. J.S. Wainright, R.F. Savinell, C.C. Liu, M. Litt, Electrochim. Acta, 48, 2869 (2003).

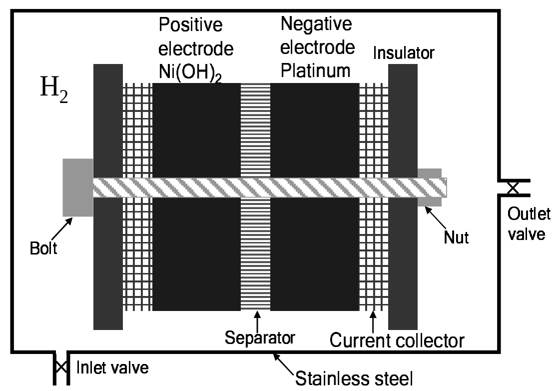

Fig. 1: Schematic representation of the experimental setup. Ni H_2 cell is hosted in a stainless steel compartment filled with hydrogen gas.

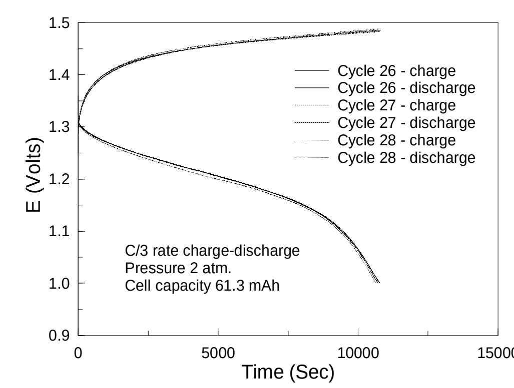

Fig. 2: Battery voltage as function of time during 3 charge-discharge cycles. C/3 charging and discharging rate were used.

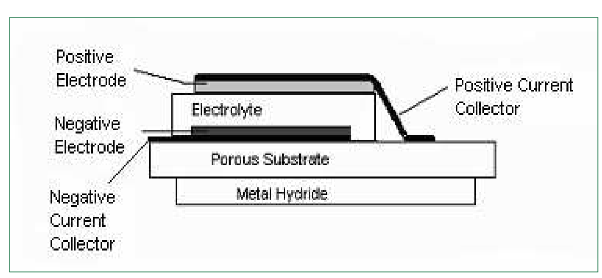

Fig. 3: Fundamental nickel-hydrogen micro- battery design