

ULTRA THIN NICKEL ELECTRODES FOR HYBRID SUPERCAPACITORS

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It is well a well-known fact today that a fuel cell or a traction battery probably can not fully power an electric vehicle. This is due to the high cost and low power density of both the fuel cell and the candidate batteries.. One way of overcoming this problem could be the introduction of super-capacitors, which can take care of the power demand during acceleration. Moreover, they can store the breaking energy. This concept is under evaluation at several research institutes all over the world.

The traditional double-layer capacitor works with two carbon electrodes with no faradic reactions occurring. The Hybrid capacitor has one carbon non-faradic electrode and one faradic battery electrode. In most cases it is the positive capacitor electrode which is replaced with a nickel hydroxide electrode. This choice is rather natural since the nickel electrode is one of the few secondary electrodes, which have any chance to reach the very large requirement for long cycle life, around 100.000 cycles .

The repeated volume changes in all battery electrodes make this task rather difficult to handle. The true double-layer capacitor electrode does not suffer from this problem.

The advantage with the hybrid super capacitor is the higher cell-voltage and the higher volumetric charge capacity of the nickel electrode. This results in an increase of the possible energy density from 1.5 to 10 Wh/kg compared to the double-layer capacitor [1]. Moreover, the replacement of the carbon cathode eliminates the corrosion problem generally seen with carbons at high positive potentials.

This paper presents results from a project aiming at developing a bipolar hybrid super capacitor battery with a nickel-hydroxide electrode as the anode and a rather cheap high surface area carbon as the negative electrode. The bipolar wall in the battery consists of a nickel-foil, 50 μm thick. A porous nickel structure is electroplated, in a new process, on one side of the nickel-foil. This structure is later filled with nickel-hydroxide with cathodic precipitation [2]. The resulting structure has a nominal thickness of 0.1 mm and a nominal capacity of 1 mAh/cm². The other side of the nickel-foil is electroplated with nickel and suspended graphite as a co-deposit. This is done to reduce the contact resistance to the carbon capacitor electrode in the bipolar stacking. The two electroplating steps can be performed in a one step between two roller electrodes. The nickel hydroxide precipitation can be carried out immediately after that in the same apparatus. Thus, the whole process can be automated in one production unit. The performance of the nickel hydroxide electrode is very high: 1 A/cm², 1000 C, causes a polarisation and ohmic voltage drop of 175 mV. So far we have not yet chosen the final carbon material for the capacitor negative. Contact resistance and cost concerns are a part of our evaluation and screening. We have a cost limit for the whole battery of 10 US \$/kW and a performance requirement of at least 2 kW/kg.

The next step will be to incorporate the hybrid single cells in a bipolar stack assembly. The stacking of the bipolar electrodes in our battery (or in any battery of this kind) is a challenge in itself. The parasitic currents have unfortunately very short ways to travel. Our battery has the possibility to reach stack-voltage levels of 30 volts per cm! The driving forces for parasitic currents are therefore enormous. We have good reasons to believe that a halocarbon wax round the borders of the nickel-foils can

suppress these currents to an acceptable level. It is worth to notice that it is good enough if these self-discharge currents are two orders of magnitude smaller than the discharge and charge currents in the battery. This is acceptable due to the working conditions for capacitors as power boosters. For ordinary batteries where the capacity must stay for many days the difficulties are much more severe.

References.

[1] A. Burke, Ultracapacitors: why, how and where is the technology, *Journal of Power Sources* **91** (2000) 37-50.

[2] D. L. Britton, Progress in the Development of Lightweight Nickel Electrode For Nickel-Hydrogen Cell. 34th Intersociety Energy Conversion Engineering Conference. Vancouver, British Columbia, Canada, August 1-5, 1999. NASA/TM-1999-209430.