Lead Acid-MH Hybrid System Using Gel Electrolyte

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Introduction

To overcome the limitation of conventional batteries, such as maintenance cost and acid stratification for lead acid battery, and high self discharge and short life cycles for high current discharge for nickel metal hydride (Ni-MH) battery.

Using gel electrolyte instead of aqueous electrolyte is a successful way to extend the battery life. In addition, it has many other advantages like spill proof, maintenance free, no corrosion and low cost, etc.

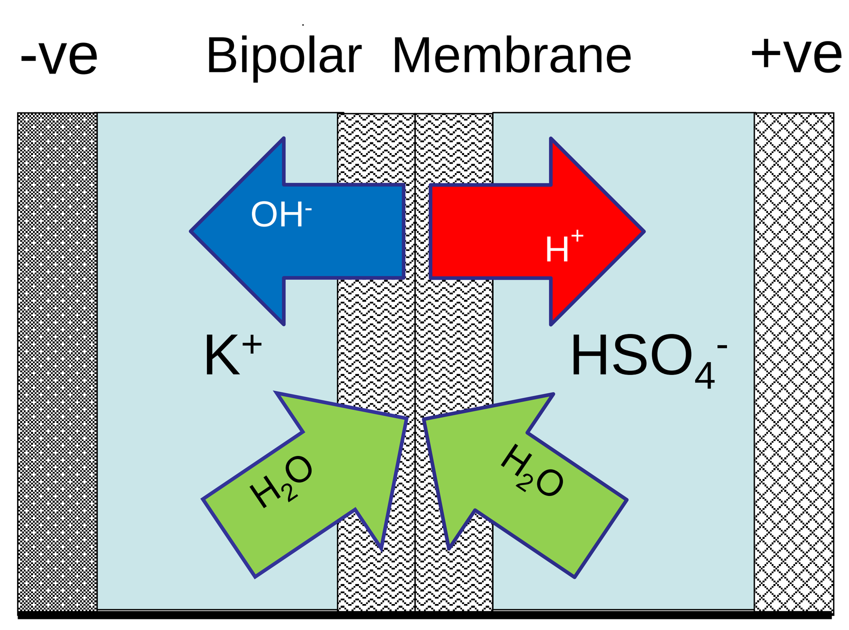
High voltage multiple-electrolyte battery consists of a lead acid positive electrode and a metal hydride negative electrode, which are operated in H_2SO_4-silica-gel and KOH-poly acrylic acid (PAAK) gel electrolytes, separated by a bipolar membrane or two monopolar ionic membranes. The hybrid system demonstrates higher voltage and higher capacity than the individual lead acid or metal hydride cells.

Theory

Thermodynamics of the dual-electrolyte battery

$PbO_2/PbSO_4$ (Acid) – MH (Alkaline) Battery

During Discharge



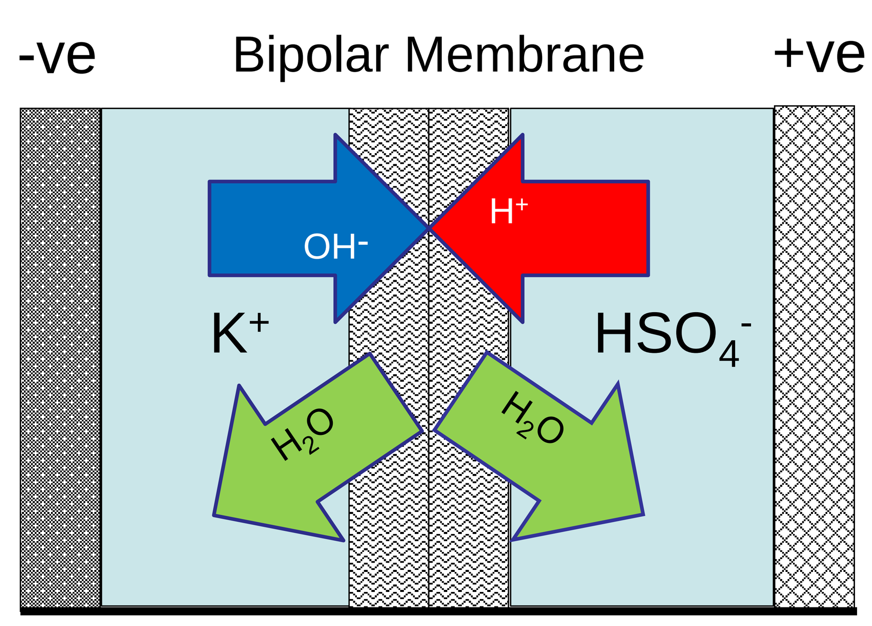
Cathode in H_2SO_4:

$PbO_2 + 3H^+ + HSO_4^- + 2e^- \rightarrow PbSO_4 + 2H_2O$

Anode in KOH:

$2MH_x + 2OH^- \rightarrow 2MH_{x-1} + 2H_2O + 2e^-$

During Charge



Cathode in H_2SO_4:

$PbSO_4 + 2H_2O \rightarrow PbO_2 + 3H^+ + HSO_4^- + 2e^-$

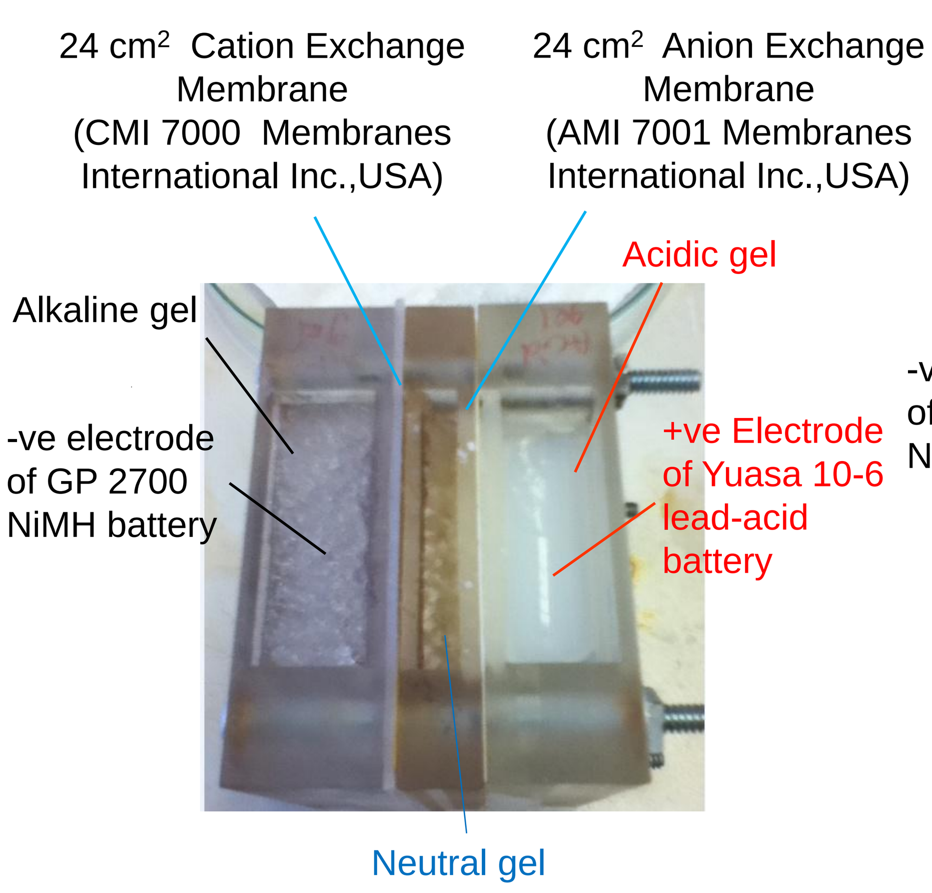
Anode in KOH:

$2MH_{x-1} + 2H_2O + 2e^- \rightarrow 2OH^- + 2MH_x$

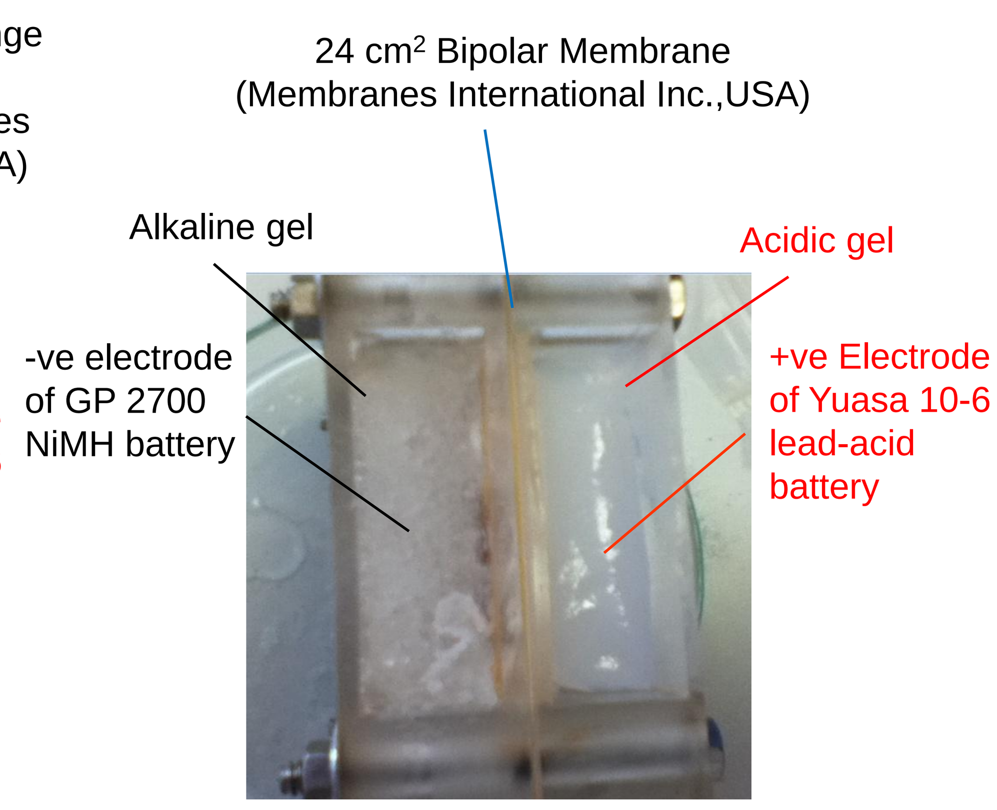
Overall:

$$PbO_2 + 3H^+ + HSO_4^- + 2MH_x + 2OH^- \underset{\text{Charge}}{\overset{\text{Discharge}}{\rightleftharpoons}} PbSO_4 + 2MH_{x-1} + 4H_2O$$

Proposed Schemes of Hybrid Battery



Scheme 1. Three-electrolyte battery



Scheme 2. Dual-electrolyte battery

Major Findings

As observed from Figure 1, the lead acid-MH hybrid battery shows a higher theoretical energy density at around 350 Wh/kg. (The calculation is only based on the active material in the electrochemical battery)

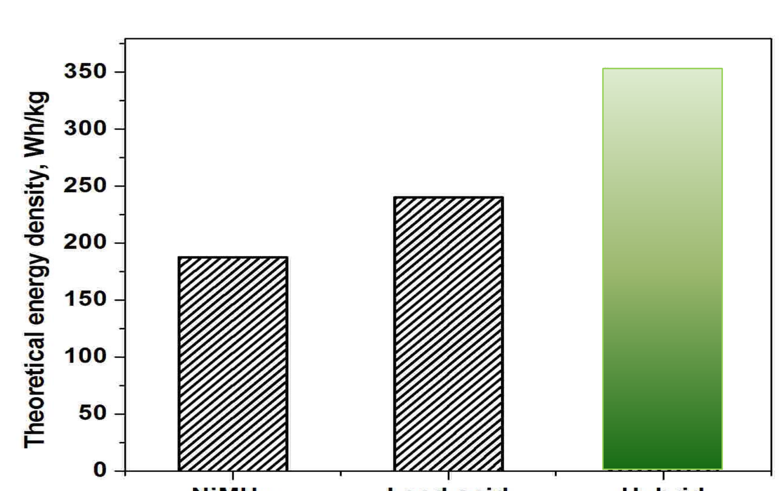


Fig 1. Comparison of different batteries in theoretical energy density

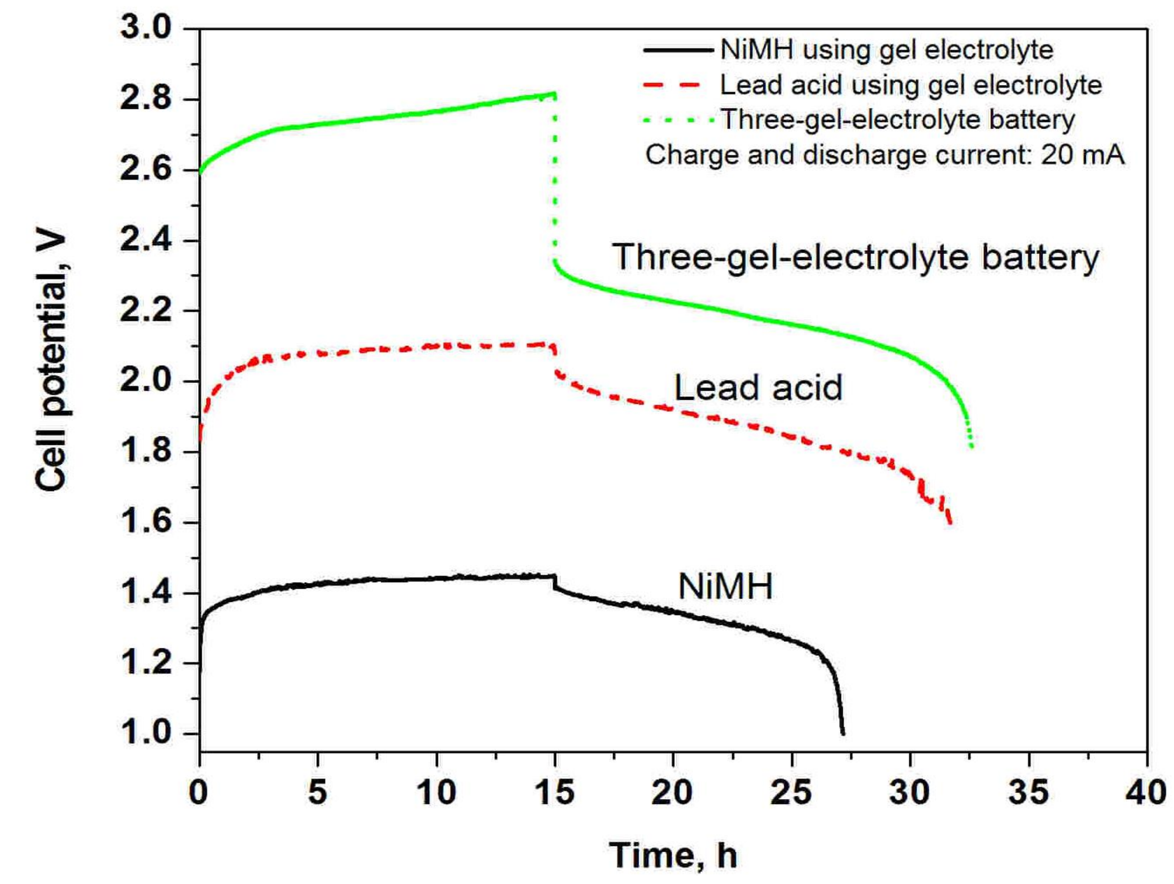


Fig 2. Comparison of the three-electrolyte, lead acid and NiMH batteries using gel electrolyte

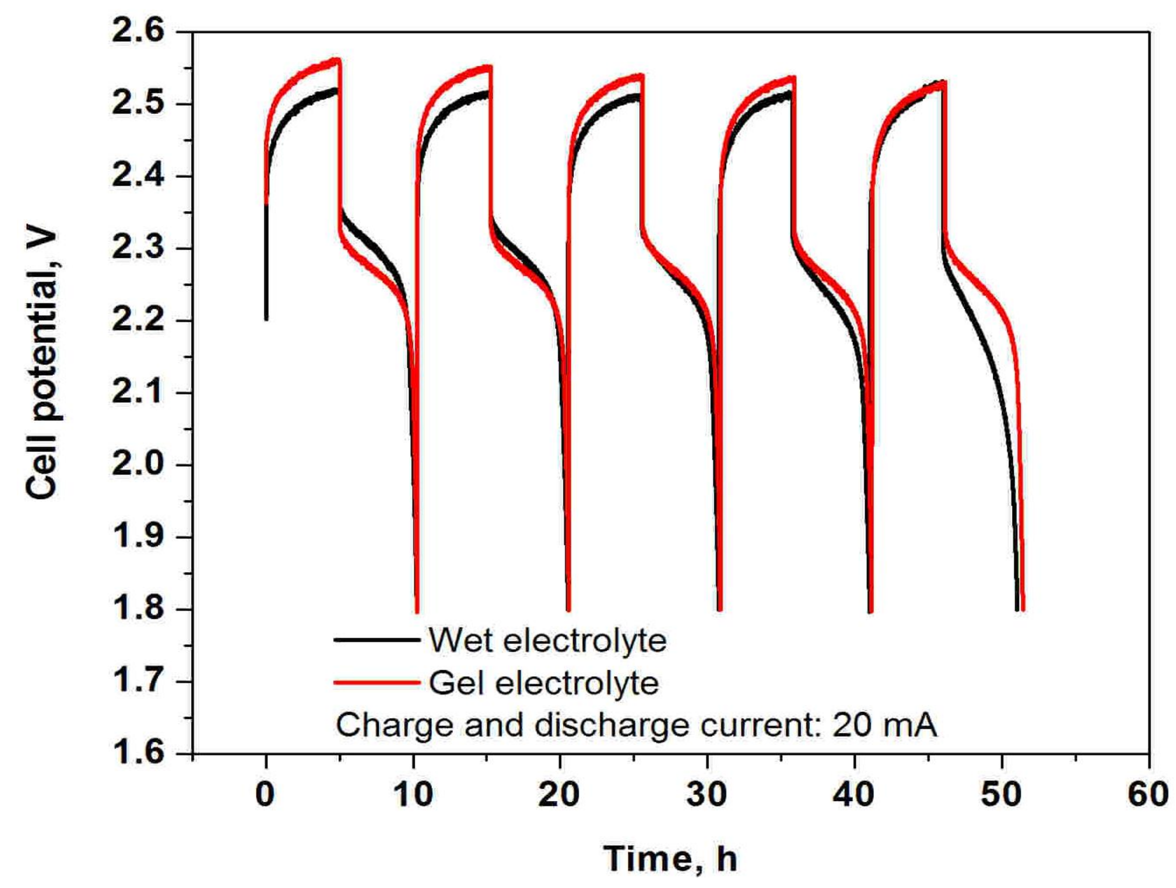


Fig 3. Cycle tests of the three-electrolyte battery

The electrochemical tests were performed by Voltalab at room temperature. Gel electrolytes (1 M H_2SO_4-silica-gel, 1.28 M Na_2SO_4-PAAK-gel and 3.24 M KOH-PAAK-gel) were used in all electrochemical systems. In Figure 2, it can be observed that a higher discharge voltage and discharging capacity can be obtained from the hybrid system than that of the individual batteries (lead acid & NiMH). From Figure 3, hybrid battery using gel electrolyte has a more stable and better battery life, compared to that wet electrolyte. The improved discharge performance is possibly due to the use of gel electrolyte which prevents acid stratification.

Conclusions

The MH(alkaline)/PbO_2 (acid) rechargeable cell using gel electrolyte has higher voltage, and stable discharging voltage over long cycles.

It is expected that the hybrid battery can be used for electrochemical storage system.

References

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