Study of the Electrochemical Behavior of High Voltage Vanadium-Metal Hydride Hybrid Flow Battery

Guo-Ming Weng, Chi-Ying Vanessa Li, Kwong-Yu Chan

Department of Chemistry, The University of Hong Kong, Pokfulam, Hong Kong

Coupling the advantages of the vanadium redox flow battery and the acid/alkaline hybrid battery concepts, a novel Vanadium-Metal Hydride (V-MH) hybrid rechargeable flow battery is developed. In principle, this hybrid battery system of V^{4+}/V^{5+} and metal hydride can deliver an overall cell capacity of 110 mAh/g, cell voltage of 1.8 V, and a much higher energy density of 200 Wh/kg than that of the conventional all vanadium redox flow (VRF) battery (60.5 Wh/kg as shown in Fig. 1). The high voltage (1.8 V) reported is among the highest in the Vanadium-based flow systems, about 40% higher than conventional VRF battery and nickel metal hydride battery. The V-MH flow battery consists of graphite felt positive electrode in flowing $VOSO_4$-H_2SO_4 electrolyte and metal hydride negative electrode in flowing KOH, the two flowing streams are separated by a bipolar membrane (as shown in Fig. 2). As an extended study of our previous reports,[1-6] the electrochemical properties (charge/discharge characteristics, cycle test and discharge polarization curves) of this new hybrid flow battery at different flow rates and electrolyte concentrations will be investigated to optimize the current system. This V-MH flow battery has a huge potential to implement as effective electrochemical energy storage system from intermittent energy sources like wind and solar power.

Another configuration is to replace the metal-hydride electrode by hydrogen, resulting in a Vanadium-Hydrogen (V-H_2) flow battery. Hydrogen electrode has an extremely high capacity and energy conversion efficiency, thus further increase the energy and power density. In theory, this V-H_2 battery system can yield an overall cell capacity as high as 164 mAh/g, with a cell voltage of 1.83 V and reach a higher energy density of about 300 Wh/kg (which is five times that of VRF battery). This proposed flow battery system has been undergoing vigorous test in our laboratory and the results will be reported in due course.

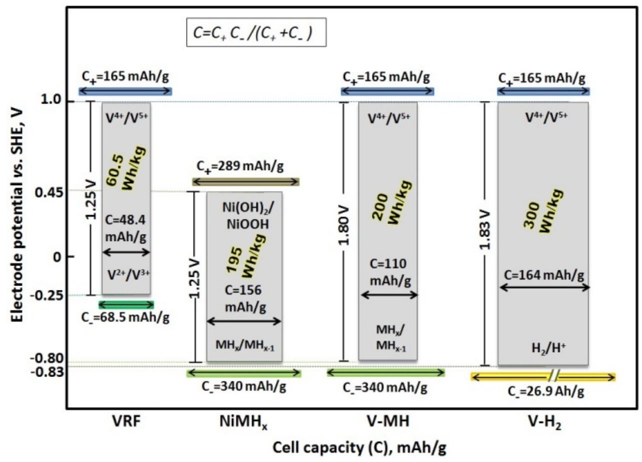

Fig. 1 Cell voltage, cell capacity and specific energy of different batteries pairing positive and negative electrodes/electrolytes. [The theoretical cell capacity is calculated by $C=C_+/(1+C_+/C_-)$,[4] where C_+ and C_- represent the theoretical capacity of positive electrode/electrolyte material (width of bar at the top) and negative electrode material (width of bar at the bottom), respectively. C_+ and C_- are scaled by Faraday's law to their individual active material. In VRF battery, $VOSO_4$ and $V_2(SO_4)_3$ are the active material for V^{4+}/V^{5+} and V^{2+}/V^{3+} redox couples, respectively. The specific energy is calculated as C×cell voltage.]

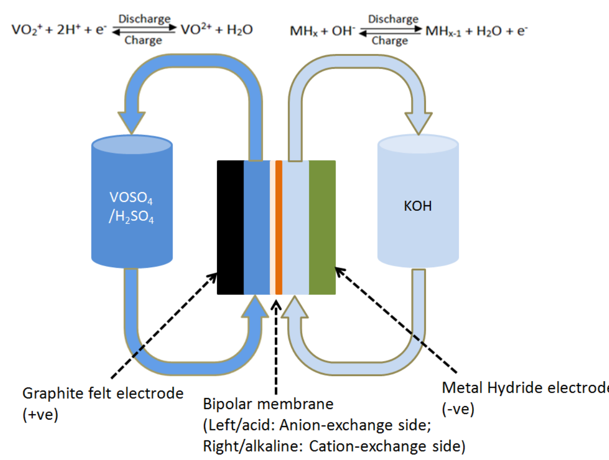

Fig. 2. Set-up and components of the Vanadium-Metal Hydride (V-MH) hybrid flow battery.

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