

# Vanadium/Water Electrolyser to Recharge Vanadium/Oxygen Flow Batteries and Rebalance Vanadium-Redox-Flow-Batteries

Jens Noack<sup>1,2,3</sup>, Nataliya Roznyatovskaya<sup>1,2</sup>, Chris Menictas<sup>2,3</sup>, Karsten Pinkwart<sup>1,2,4</sup>, Maria Skyllas-Kazacos<sup>2,3</sup>, Jens Tübke<sup>1,2</sup>

1 – Fraunhofer Institute for Chemical Technology ICT, 76327 Pfingztal, Germany

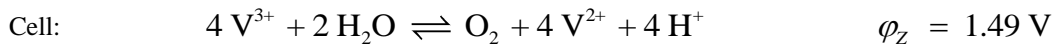
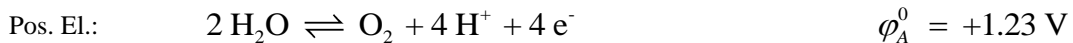
2 – German-Australian Alliance for Electrochemical Technologies for Storage of Renewable Energy (CENELEST), UNSW Sydney NSW 2052, Australia

3 – University of New South Wales, UNSW Sydney NSW 2052, Australia Affiliation

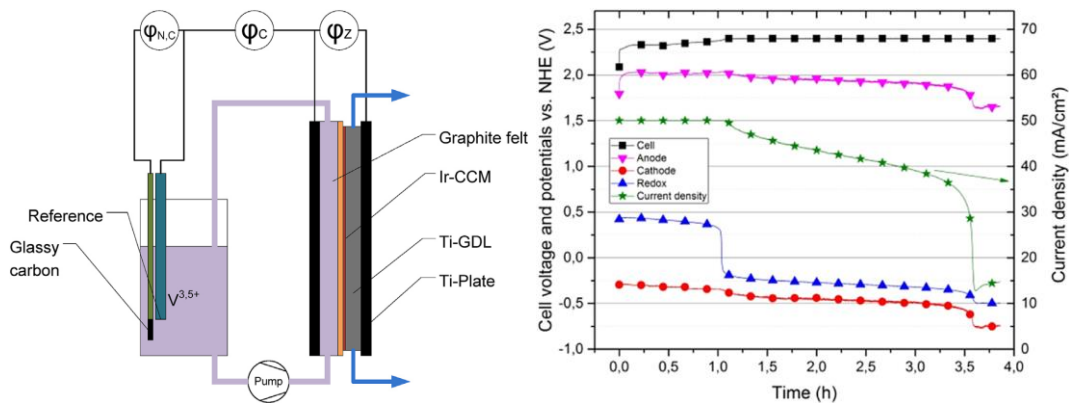
4 - Hochschule Karlsruhe – Technik und Wirtschaft, Moltkestraße 30, 76131 Karlsruhe, Germany

jens.noack@ict.fraunhofer.de

The vanadium/oxygen fuel cell (VOFC) has evolved from developments to vanadium redox flow batteries (VRFB) for storage of renewable energy and perhaps for mobile applications. In VOFCs, oxygen is used to oxidise divalent vanadium ions to trivalent ions instead of the redox reactions of V(IV)/V(V) to achieve potentially higher energy densities and eliminate temperature stability problems associated with the energy storage medium compared to VRFBs. To charge a VOFC as an energy storage system, the discharge reactions have to be reversed with as few side reactions as possible. This process involves reducing trivalent vanadium ions to divalent vanadium ions through the application of electrical energy. The cathodic water generated during the discharge is used as the reductant. The water itself is oxidised to oxygen to keep the cycle between the charge and discharge processes as short and efficient as possible:



This process is also exactly the reversal of the process which happens in VRFBs when atmospheric oxygen oxidizes divalent vanadium ions in vanadium electrolytes. As a synergistic effect, vanadium/water electrolysis can be also used to regenerate oxidized electrolytes and increase the life time of the batteries.



**Figure 1: left) Scheme of the test set-up for investigating a V/Water electrolyser, right) Cell voltage, potentials and current density of a vanadium/water electrolyser (1.6 M V<sup>3.5+</sup>, 2 M H<sub>2</sub>SO<sub>4</sub>, 40 cm<sup>2</sup>).**

Using a cell with a commercial and iridium-based catalyst coated membrane, it was possible to fully reduce V<sup>3.5+</sup> and V<sup>3+</sup> solutions to V<sup>2+</sup> with the formation of oxygen and with coulomb efficiencies of over 96%. The process was followed by introduction of an additional reference electrode to measure the redox potential of the electrolyte, the negative electrode potential and to calculate the positive redox potential. The cell achieved a maximum current density of 75 mA/cm<sup>2</sup> during this process and was limited by the proximity of the V(III) reduction to the hydrogen evolution reaction. Due to the specific reaction mechanisms of V(IV) and V(III) ions, V(III) solutions were reduced with an energy efficiency of 61%, making this process nearly twice as energy efficient as the reduction of V(IV) to V(III). Polarisation curves and electrochemical impedance spectroscopy were used to further investigate the losses of half-cell reactions and to find ways of further increasing efficiency and performance levels.