Improved performance of vanadium flow batteries by bonded graphite felt electrode-bipolar plate assemblies

Gaurav Gupta[1], Nambi Krishnan Nagappan[1], Lisa M. Uhlig[1], Leif-Arvid Schillert[1], Wiebke Germer[1], Barbara Satola[1], Marco Zobel[1], Alexandra Ploner[2], Hermann Block[3], Burak Caglar[2] and Alexander Dyck[1]

[1]DLR Institute of Networked Energy Systems, Carl-von-Ossietzky-Straße 15, 26129 Oldenburg, Germany
[2]SGL Carbon GmbH, Werner-von-Siemens-Straße 18, 86405 Meitingen, Germany
[3]Polyprocess GmbH, Am Wald 15, 97348 Rödelsee, Germany
Email: gaurav.gupta@dlr.de, +49 441 999 06 464

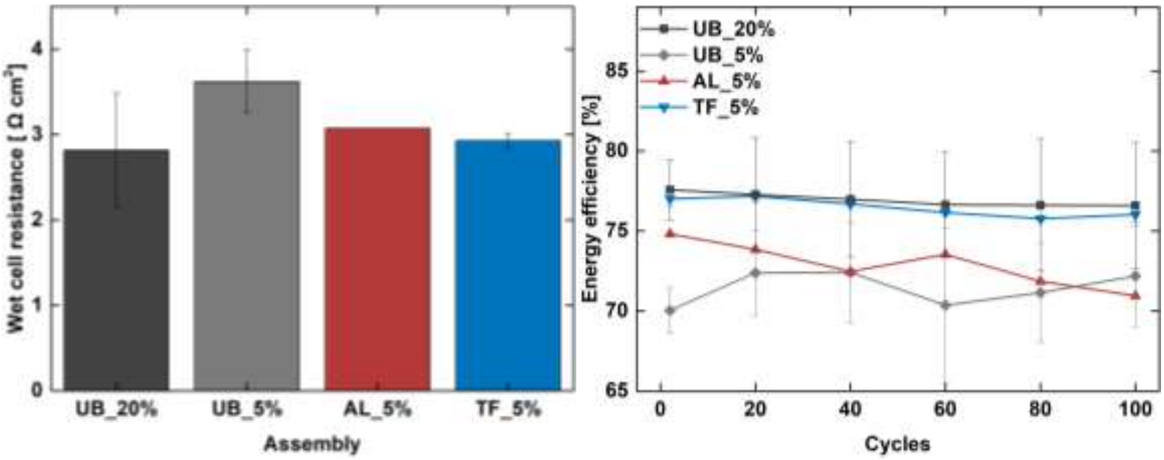
A vanadium flow battery (VFB) stack consists of bipolar plates (BPPs), porous electrodes-graphite felt electrode (GFE) and ion exchange membranes. The GFE provides the site for conduction of current between adjacent cells, physical separation of each cell [1} and support the the mechanical integrity of the VFB stack. In a conventional arrangement the GFE lies in direct contact with the BPP. The contact resistance between the GFE and BPP components is the primary contributor to the internal ohmic resistance (IOR) of the VFB [2]. The current state of the art (SOA) recommends application of high compression force to reduce the contact resistance; the optimum electrode compression rates reported are 20% [3] and 25% [4]. In general, a high compression rate can reduce the electrode porosity and lead to increased resistance to the flow of electrolyte through the electrode. This phenomenon causes higher pumping losses and a decline in the overall VFB system efficiency. Another approach to reduce the contact resistance is to ond the electrode and BPP into a single assembly via (i) an adhesive conductive layer [2] or (ii) a local thermostatic bonding process. [1]. J.W. Lim et al. and P. Qian et al. reported that the novel bonded assemblies improved the VFB performance in comparison to the conventional unbonded GFE-BPP [1, 2].

Under this research project two different bonding methods have been developed. The GFE and BPP have been bonded through application of (i) an adhesive layer (AL) [5] and (ii) thermal fusion (TF). These bonded assemblies have been studied in a 2-cell VFB stack at 5% compression. The obtained VFB results have been compared to unbonded (UB) GFE-BPP at 20% and 5% compression. They are referred as UB_20%, UB_5%, AL_5% and TF_5%.

A 2-cell VFB (SCHMID Group, Germany) with an electrochemical active area of 6 cm x 4 cm, interchangeable frames with varying thicknesses to control the compression of the GFE was designed for the electrochemical performance. The thermally activated SGL GFE 4.6 EA used as GFE, PV-15 was applied as BPP (SGL Carbon group, Germany) while Nafion 117 membrane (Dupont, USA) acted as the separator. The copper plates and steel frames were the current collectors and end plates (Schmid Group, Germany) respectively. The electrolyte was 1.6 M $V^{3+/4+}$ / 4 M sulfate (GFE, Germany), with a volume of 100 ml each on the positive and negative side and was pumped at a flow rate of 60 ml min^{-1} (KNF, Germany) through each half-cell. The stack was studied for 100 charge-discharge cycles at a current density of 80 mA cm^{-2} with cut off voltages of 3.2 V and 1.6 V. All tests were done at room temperature and the electrolyte(s) were purged with nitrogen gas throughout the measurement.

When the compression force is increased from 5 to 20% for unbonded GFE-BPP the wet stack resistance is reduced due to lower IOR (Figure 1a) and the VFB efficiency is improved (Figure 1b). Also the wet stack resistance is discernibly lower for both the AL_5% and TF _5% assemblies when compared to UB_5%. The energy efficiency of the 2-cell stack (Figure 1b) using the AL_5% was better than UB_5%. Concurrently, the energy efficiency of the TF_5% is comparable to that of UB_20% compression and exhibited a stable performance.

The ready-made electro conductive connection allows battery operation at lower GFE compression, resulting in higher GFE porosities, improved electrolyte permeability and increased overall system performance. The bonding of GFE-BPP into a single component shows great promise to provide the prerequisites to simplify the industrial fabrication process and advance the performance of not only vanadium based but other flow batteries in general.



(a) (b)

Figure 1: (a) Wet stack resistance and (b) Energy efficiency of graphite felt electrode-bipolar plate, unbonded at 5 and 20% compression compared to that of graphite felt electrode-bipolar plate assembly bonded through adhesive layer and thermal fusion at 5% compression in a 2-cell VFB.

Acknowledgements

The project "Development of integrated bipolar plate felt components for redox flow batteries" is funded by the German Federal Ministry for Economic Affairs and Energy under the 6th Energy Research Programme "Research for an environmentally friendly, reliable and affordable energy supply" (funding code: 03ET6136C).

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