Vanadium Redox Flow Batteries Fabricated by 3D Printing and Employing Recycled Vanadium Collected from Ammonia Slag

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We have established the chemical aqueous solution method to prepare vanadium aqueous electrolyte for VRFB from an industrial waste ammonia slag by pH control at a low temperature (< 95°C). The vanadium ions in the extracted solution underwent reversible redox among the V^{5+}, V^{4+}, V^{3+}, and V^{2+} states nicely associated with the color change and without forming precipitates. In the H-cell battery tests, the recycled vanadium solution exhibited almost the same performance as that prepared from commercial pure V_2O_5, although small values of coulombic, voltage and overall efficiency were only achieved due to the electrode material and cell configuration we used. The recycled vanadium faced a serious problem of degradation in the cycle test, caused by the impurity to condense on the negative electrode to hinder the reduction of V^{3+} to V^{2+} during charging. Having solved this problem by identifying the impurity and removing it, the recycled vanadium must become useful for VRFBs to make ammonia slag a new resource.

Significant efficiency improvement was made possible with the miniature flow cell fabricated by a 3D printer. Even though the finally achieved energy efficiency of 40-45.2% with 0.4 M vanadium redox electrolytes is still far below the level of the best examples, 3D printing has proven to afford a very good platform for developing device structures in small laboratory scale experiments. New device designs can easily be developed on a computer, quickly printed and tested. Together with the further chemical refinement of the recycled vanadium from ammonia slag, we should be able to achieve high performance and economical VRFB system for real-world installation.