$BiVO_4$-Decorated Graphite Felt as Highly Efficient Negative Electrode for All-Vanadium Redox Flow Batteries

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Abstract : With the development and utilization of new energy technology, people's demand for large-scale energy storage system has become increasingly urgent. Vanadium redox flow battery (VRFB) is one of the most promising technologies for grid-scale energy storage applications because of numerous attractive features, such as long cycle life, high safety, and flexible design. However, the relatively low energy efficiency and high production cost of the VRFB still limit its practical implementations. It is of great attention to enhance its energy efficiency and reduce its cost. One of the main components of VRFB that can impressively impact the efficiency and final cost is the electrode materials, which provide the reactions sites for redox couples (V_{2+}/V^{3+} and VO^{2+}/$VO_2{}^{+}$). Graphite felt (GF) is a typical carbon-based material commonly employed as electrode for VRFB due to low-cost, good chemical and mechanical stability. However, pristine GF exhibits insufficient wettability, low specific surface area, and poor kinetics reversibility, leading to low energy efficiency of the battery. Therefore, it is crucial to further modify the GF electrode to improve its electrochemical performance towards VRFB by employing active electrocatalysts, such as less expensive metal oxides. This study successfully fabricates low-cost plate-like bismuth vanadate ($BiVO_4$) material through a simple one-step hydrothermal route, employed as an electrocatalyst to adorn the GF for use as the negative electrode in VRFB. The experimental results show that $BiVO_4$-3h exhibits the optimal electrocatalytic activity and reversibility for the vanadium redox couples among all samples. The energy efficiency of the VRFB cell assembled with $BiVO_4$-decorated GF as the negative electrode is found to be 75.42% at 100 mA cm−2, which is about 10.24% more efficient than that of the cell assembled with heat-treated graphite felt (HT-GF) electrode. The possible reasons for the activity enhancement can be ascribed to the existence of oxygen vacancies in the $BiVO_4$ lattice structure and the relatively high surface area of $BiVO_4$, which provide more active sites for facilitating the vanadium redox reactions. Furthermore, the $BiVO_4$-GF electrode obstructs the competitive irreversible hydrogen evolution reaction on the negative side of the cell, and it also has better wettability. Impressively, $BiVO_4$-GF as the negative electrode shows good stability over 100 cycles. Thus, $BiVO_4$-GF is a promising negative electrode candidate for practical VRFB applications.

Keywords : $BiVO_4$ electrocatalyst, electrochemical energy storage, graphite felt, vanadium redox flow battery
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