Hawai‘i Natural Energy Institute Research Highlights

Electrochemical Power Systems

Transition Metal Carbide Catalysts for Electrochemical Applications

OBJECTIVE AND SIGNIFICANCE: The objective of this project is to develop transition metal carbide catalysts for electrochemical applications. These carbide catalysts have the potential to improve the performance of a variety of electrochemical devices including fuel cells, water electrolyzers, and vanadium redox flow batteries (VRFBs).

BACKGROUND: The commercial application of a number of electrochemical technologies would benefit from the availability of low cost, efficient, and durable catalysts. Pt-group metals-based catalysts are used in most commercially available fuel cells and water electrolyzers. Unfortunately, they have the shortcomings of high cost, low earth abundance, and limited lifetime. VRFBs have recently attracted considerable attention for large-scale energy storage. Carbon-based materials have been the most common catalysts for VRFBs. However, they often show limited activity and reversibility. Transition metal carbides are regarded as attractive candidates because they possess an electronic structure similar to Pt which promotes high activities, good electronic conductivity, low cost, high abundance, and outstanding thermal and chemical stabilities. The catalytic properties of carbide catalysts strongly depend on their surface structure and composition, which are closely associated with their synthesis methods.

PROJECT STATUS/RESULTS: The research team at HNEI is currently focused on the synthesis of carbide catalysts for VRFBs. Rather than applying the conventional carbide synthesis method by carburization of metal precursor with hydrogen as reducing agent and carbonaceous gas (e.g. CH_4) as carbon source, this work is exploring in-situ carburization of metal precursor with carbon material as carbon source and support without using any gaseous carbon source. This simple synthesis method avoids the use of environmentally unfriendly and flammable gases, which are potential safety hazards in the operation. In addition, the use of carbon material as carbon source and support favors the formation of nano-sized carbides that are expected to possess a large specific surface area. Figure 1 indicates that C and V elements are distributed uniformly for vanadium carbide on Vulcan XC72 (VC_{XC72}). VC_{XC72} contains 29 atom% vanadium and 71 atom% carbon, corresponding to 76.5 wt.% V_8C_7 on Vulcan XC72. Figure 2 shows the catalytic activity of graphite and VC_{XC72} after background current subtraction. The peak potential separation ($\Delta E_p=E_{pa}-E_{pc}$) and peak current ratio (I_{pa}/I_{pc}) indicate the reversibility of a redox couple. The vanadium carbide-modified electrode exhibits lower ΔE_p value than the pristine graphite electrode. The I_{pa}/I_{pc} for VC_{XC72} is closer to 1 than that for graphite, which also indicates enhanced reversibility toward V^{3+}/V^{2+} redox reactions. Future studies will include modifications to the catalyst synthesis approach to increase the activity by tuning the catalyst structure and morphology.

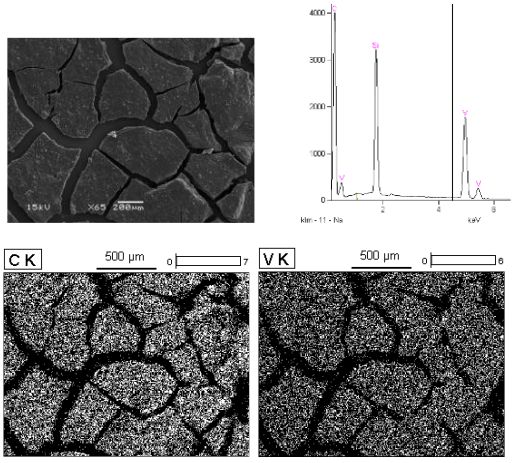

Figure 1. Scanning electron microscopy and energy dispersive X-ray spectroscopy analysis of vanadium carbide on Vulcan XC72 (VC_{XC72}).

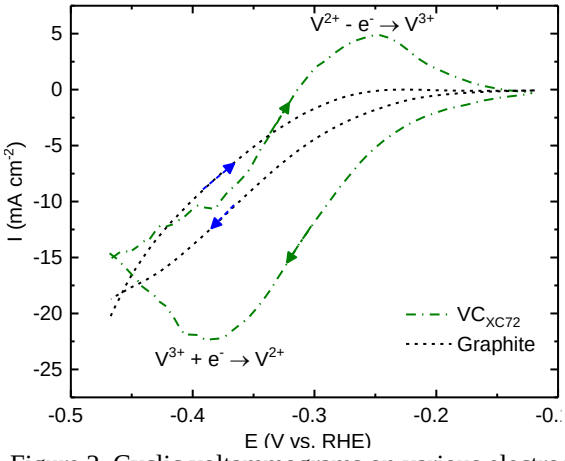

Figure 2. Cyclic voltammograms on various electrodes at 5mV s^{-1} in N_2 saturated 3 M H_2SO_4 + 1 M V^{3+}/V^{2+} at 25ºC.

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