3D-Interconnected, Microporous $Na_3V_2(PO_4)_3$@C Cathode with a Superior Cycling Stability for Na-Ion Batteries

Pravin N. Didwal, Rakesh Verma, Chan-Jin Park
Department of Materials Science and Engineering, Chonnam National University, 77, Yongbongro, Bukgu, Gwangju 61186, *Korea*

E-mail: parkcj@jnu.ac.kr

With the recent spread of renewable energy systems, there have been continuous needs for large scale energy storage based on batteries to support the renewable energy systems. Currently, Li-ion batteries (LIBs) have been used as main power sources for portable devices and electric vehicles. However, the LIBs have a limitation for the large-scale energy storage system due to the limitation of Li resources and the resultant rise of the price of raw materials. Therefore, it is necessary to search economic alternative battery systems. In this regard, sodium-ion batteries (SIBs) has an economic merit due to more abundance and cheaper price of Na resources compared with Li. Recently, NASICON-type $Na_3V_2(PO_4)_3$ has attracted much attention as a potential cathode material as well as an anode material for SIBs. The 3D framework of $Na_3V_2(PO_4)_3$ supplies the large interstitial space in its structure, which enables facile diffusion of Na-ions. However, it can suffer from the distorted VO_6 octahedral units in the NASICON structure, which can degrade its intrinsic electronic conductivity. In an aspect of cathode, the K-ion diffusion kinetics in cathode may be improved by increasing porosity of electrode and coating the active materials with appropriate amount of carbon.

In the present work, 3D-interconnected, microporous $Na_3V_2(PO_4)_3$ and $Na_3V_2(PO_4)_3$@C composites were synthesized by a simple citric acid assisted sol–gel method, in which citric acid and glucose were used as reducing agent and carbon source, respectively. The crystal structure, morphology and carbon content of $Na_3V_2(PO_4)_3$@C were analyzed by XRD, FE-SEM, TGA and TEM. Furthermore, electrochemical characteristics of the $Na_3V_2(PO_4)_3$@C electrodes was investigated through cyclic voltammetry, electrochemical impedance measurements and cyclic charge-discharge tests.

The well synthesized 3D-interconnected, microporous $Na_3V_2(PO_4)_3$@C composites with suitable amount of the amorphous carbon offered good conductivity as well as stable structure. It exhibited a high capacity (117 mAh g^{-1} at 1 C), a superior rate capability (82.5 mAh g^{-1} at a rate of 20 C), long cyclic stability (87% capacity retention even after 1000 cycle at 20 C) and excellent rate capability. In particular, the long cyclability and superior rate capability of the electrode can be attributed to the improved electrical and ionic conductivity of the electrode by forming the 3D-interconnected, microporous network structure and uniform carbon coating.