Amorphous Titanium/Vanadium Oxide Composite As a High-rate Negative Electrode Material for Lithium-ion Batteries

Jeong Beom Lee, Oh B. Chae, Ji Heon Ryu and Seung M. Oh

a Department of Chemical and Biological Engineering, Seoul National University, 1 Gwanak-ro, Gwanak-gu, Seoul 151-744, South Korea
b Graduate School of Knowledge-based Technology and Energy, Korea Polytechnic University, Gyeonggi, 429-793, South Korea
† Correspond to seungoh@snu.ac.kr

Lithium-ion batteries (LIBs) have been used in various applications ranging from portable electronic devices to electric vehicles (xEVs). However, in order for LIBs to be used in wider applications, they should meet the technical requirements; large specific capacity, high power density, high safety and long cycle life. Especially, for the high-power applications, the conventional negative electrode such as graphite is not viable because of the limited rate property and safety problems incurred by lithium plating.

Amorphous metal oxides have been proposed as a promising negative electrode due to their high specific capacity and rate capability. These advantageous properties are resulted from a high population of structural defects in these amorphous materials, which serve as the storage sites and diffusion pathways for Li$^+$ ions.

In this work, an amorphous TiO$_2$/V$_2$O$_5$ composite has been prepared and its electrochemical properties as a negative electrode have been assessed. The composite was synthesized using a simple sol-gel route. A Ti and V containing precursor solution was dropped into an urea solution to obtain a precipitate of high porosity. Primary particles whose size is less than 100 nm are flocculated to form secondary particles. This composite with small primary particles and high surface area shows promising electrochemical properties such as specific capacity, cycle retention and rate performances. Its specific capacity is over 250 mA h g$^{-1}$ when it is charged/discharged in current density of 100 mA g$^{-1}$ (0.8-3.0 V vs. Li/Li$^+$). When the current density is increased for 10 times, the specific capacity is larger than that of lithium titanate (Li$_4$Ti$_5$O$_{12}$).

The high capacity and rate property can be rationalized as follows. First, the Ti/V oxide composite triggers a high degree of amorphization. Second, the composite with low crystallinity has an open structure that offers more lithium storage sites and lithium transport channels. Third, the nano-sized primary particles shorten the lithium diffusion to give high-rate performance. However, this electrode still shows an appreciable irreversible capacity in the first cycle, which seems to be caused by side reactions on the surface and lithium trapping in amorphous matrix.

Figure 1. X-ray diffraction pattern of amorphous titanium/vanadium oxide.

Figure 2. Voltage profiles of amorphous titanium/vanadium oxide

References