Electrophoretic Deposition of Tri-rutile Electrode Materials for the Lithium-ion and Sodium-ion Rechargeable Cells

Abstract

Rechargeable batteries have gained attention due to the limited availability of fossil fuels. Lithium-ion batteries (LIB) represent one of the widely used energy storage devices, for powering portable electronics, electric transportation, and power grids. However, with lithium's high cost and limited and asymmetric geographical distribution, sodium-ion batteries (SIBs) have become popular due to their low cost, abundant sodium resources, and similar electrochemistry to lithium.

In this work, three tri-rutile metal oxides are synthesized, i.e., nickel antimony oxide ($NiSb_2O_6$; NSO), cobalt antimony oxide ($CoSb_2O_6$; CSO), and zinc antimony oxide ($ZnSb_2O_6$; ZSO), which are tested as anodes for alkali-ion batteries. Compared to commercial graphite anodes, these tri-rutile materials offer a higher theoretical capacity and high lithium insertion potential. The tri-rutile material has a structure with two dissimilar cations occupying the octahedral sites. NSO, CSO, and ZSO are prepared by a simple co-precipitation method. The corresponding electrodes of nickel antimony oxide-carbon black (NSO-CB), cobalt antimony oxide-carbon black (CSO-CB), and zinc antimony oxide-carbon black (ZSO-CB) are fabricated by the electrophoretic deposition (EPD) method. Deposition parameters of 3 minutes and 100 V are suitable for electrode fabrication. The detailed reaction mechanism of NSO material reveals the structural breakdown of NSO into NiO and Sb_2O_5. The electrochemical performance of the NSO-CB electrodes (half-cell) demonstrates the high reversible capacity of 574 $mAhg^{-1}$ after 100 cycles at 500 mAg^{-1} and a good rate capability of 370 $mAhg^{-1}$ at 5000 mAg^{-1}. The full-cell of $Li(Ni_{0.8}Co_{0.1}Mn_{0.1})O_2$//NSO-CB delivers a high energy density of 251.87 $Whkg^{-1}$. When NSO-CB electrodes are tested for SIBs, they exhibit a specific capacity of 255 $mAhg^{-1}$ after 50 cycles at 100 mAg^{-1}. The CSO-CB electrode

demonstrates a high reversible capacity of 796 $mAhg^{-1}$ after 550 cycles at 500 mAg^{-1} along with an excellent rate capability of 510 $mAhg^{-1}$ at 4000 mAg^{-1} for LIBs. The full-cell of $Li(Ni_{0.8}Co_{0.1}Mn_{0.1})O_2$//CSO-CB delivers a high energy density of 241.08 $Whkg^{-1}$. When tested as an anode for LIB, ZSO-CB exhibits a high specific capacity of 464 $mAhg^{-1}$ after 400 cycles at 500 mAg^{-1} and a good rate capability of 370 $mAhg^{-1}$ at 4000 mAg^{-1} for LIBs. Therefore, NSO, CSO, and ZSO can be potential anode materials for lithium-ion and sodium-ion batteries.

Keywords: Anode; Nickel antimony oxide; Cobalt antimony oxide; Zinc antimony oxide; Tri-rutile material; Electrophoretic deposition; Lithium-ion battery; Sodium-ion battery;