Sodium Titanium Sulfide Na_2TiS_3 as Electrode Material for All-Solid-State Sodium Secondary Batteries

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Rechargeable batteries with high energy density, safety, and long life are desired for various applications such as electric-vehicles and smart grids. All-solid-state sodium secondary batteries are expected as next generation rechargeable batteries. Sodium is an abundant and low-cost resource compared to lithium. In addition, all-solid-state batteries with inorganic solid electrolytes reduce the risks of leakage and combustion of electrolytes.

The development of active materials with high capacity and reversibility is important. We have focused on the potential of the metal sulfides as electrode active materials. It is well known that alkali metals can be reversibly inserted to and extracted from the interlayer of transition metal sulfides such as TiS_2 [1]. Afterward, TiS_2 has been adopted as active material for sodium-ion-batteries with liquid electrolytes [2]. We reported that all-solid-state sodium batteries using TiS_2 positive electrode materials and Na_3PS_4 glass-ceramic electrolyte successfully operated at room temperature [3]. In addition, replacement of TiS_2 by metal polysulfide electrode such as amorphous-TiS_3 improved the capacity of the cells due to the anion redox [4]. However, the batteries using these electrodes need negative electrode materials containing sodium. In this study, we have developed Na_2TiS_3 as sodium-containing positive electrode materials.

Electrode materials with the composition of Na_2TiS_3 were prepared by solid phase reaction of Na_2S and TiS_2. Two kind of phase were precipitated by changing the cooling rate. Na_2TiS_3 prepared with rapid cooling exhibited a higher electric conductivity than Na_2TiS_3 prepared with slow cooling. The all-solid-state sodium batteries constructed using rapidly-cooled Na_2TiS_3, Na_3PS_4 glass-ceramic, and $Na_{15}Sn_4$ operated from charging process at room temperature and showed a high reversible capacity of 300 mAh g^{-1} (-Na_2TiS_3) for 5 cycles. The newly developed Na_2TiS_3 is a promising active material with high capacity and cycle capability for all-solid-state sodium secondary batteries.

References

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