Investigation on the electrochemical performances of Li$_4$Mn$_5$O$_{12}$ for battery applications

N. H. Zainol$^{1,2}$ · Z. Osman$^{1,2}$ · N. Kamarulzaman$^3$ · R. Rusdi$^3$

Received: 14 July 2016 / Revised: 9 September 2016 / Accepted: 4 October 2016
© Springer-Verlag Berlin Heidelberg 2016

Abstract In this study, well-crystallized Li$_4$Mn$_5$O$_{12}$ powder was synthesized by a self-propagating combustion method using citric acid as a reducing agent. Various conditions were studied in order to find the optimal conditions for the synthesis of pure Li$_4$Mn$_5$O$_{12}$. The precursor obtained was then annealed at different temperatures for 24 h in a furnace. X-ray diffraction results showed that Li$_4$Mn$_5$O$_{12}$ crystallite is stable at relatively low temperature of 400 °C but decompose to spinel LiMn$_2$O$_4$ and monoclinic Li$_2$MnO$_3$ at temperatures higher than 500 °C. The prepared samples were also characterized by FESEM and charge-discharge tests. The result showed that the specific capacity of 70.7 mAh/g was obtained within potential range of 4.2 to 2.5 V at constant current of 1.0 mA. The electrochemical performances of Li$_4$Mn$_5$O$_{12}$ material was further discussed in this paper.

Keywords Cathode material · Li$_4$Mn$_5$O$_{12}$ · Li-ion battery · XRD · FESEM

Introduction

Batteries are currently being developed to power an increasingly diverse range of applications, and extensive research has been directed toward the development and optimization of the lithium-ion batteries (LIBs). This is due to their high energy and power densities considerable interest for portable electronic devices and also hybrid vehicles. Therefore, it is important to choose the high-performance electrode materials which largely determine the potential window, energy density, rate capability, and cycling stability of a battery [1].

Among the spinel-type lithium manganese oxides (LMO), LiMn$_2$O$_4$ has been considered as one of the most promising cathode for rechargeable LIBs due to its low cost, abundance, fast charge-discharge reactions, high coulombic efficiency, and non-toxicity [2–4]. However, LiMn$_2$O$_4$ suffers from large polarization at high charge-discharge rates and a fast capacity fading at elevated temperature [5, 6]. Many researchers prove that it is due to Jahn-Teller distortion [7] of the lattice which causes electrochemical grinding and manganese dissolving into electrolyte [8] resulting in phase transformations and cathode and anode passivation. Hence, these problems are the main obstacle to its commercialization for LIBs. To overcome these limitations, various strategies such as doping techniques [9–11] and surface modifications [12, 13] have been attempted in order to increase the battery performance.

Li$_4$Mn$_5$O$_{12}$, the end number of lithium-rich Li-Mn-Os, is a stoichiometric spinel with cubic symmetry and cationic arrangement of LiMn$_2$O$_4$ [14]. It has good electrochemical stability as compared to single spinel manganese phase. The Mn oxidation state in LiMn$_2$O$_4$ is +3.5; however, in the case of Li$_4$Mn$_5$O$_{12}$, manganese is in the +4 oxidation state. Li$_4$Mn$_5$O$_{12}$ compounds are generally referred to as low temperature spinel since it is highly oxidized at low temperature.