Title	リチウムイオン二次電池用負極活物質・バインダーの最適化によるSi系負極の性能向上
Author(s)	高森, 紀行
Citation	
Issue Date	2024-03
Type	Thesis or Dissertation
Text version	ETD
URL	http://hdl.handle.net/10119/19079
Rights	
Description	supervisor: 松見紀佳, 先端科学技術研究科, 博士

The Performance Enhancement of Silicon-based Lithium-ion Batteries
by Optimization of Active Material and binders

1. Introduction

Lithium-ion batteries(LIB) has been used widely as portable devices and electric vehicles. However, the commercial LIB is facing the limitations of energy density due to its anode materials. Silicon has been gathered interest owing to its high theoretical capacity (3600 $mAhg^{-1}$), which is higher as ten times than that of graphite (372 $mAhg^{-1}$). Nevertheless, Si has a huge volume change after charge-discharge process. This phenomenon resulted in cracking Si particles, continuous growth of solid electrolyte interfaces, and capacity decay as battery. Therefore, the optimization and exploring the anode materials are under proceeding to overcome above problems.

In this research, we prepared new anode active materials and binder to enhance the performance of Si-based anode. The battery evaluations and various characterizations has applied to unveil the mechanism of performance improvement.

2. Nitrogen doped C/SiC (N-doped C/SiC)

According to the group of Prof. M. Thackeray, the zinc-blend structure materials exhibited high structural stability during charge-discharge process[1]. Motivated by this report, we synthesized β-silicon carbide(β-SiC) which has zinc-blend structure. This β-SiC has been combined with Nitrogen-doped carbon to improve the electrical conductivity. The Nitrogen doped Carbon/β-Silicon carbide composite (N-doped C/SiC) based cell exhibited 1200 mAg^{-1} for 400 cycles due to its improved resistance and stabilized structure.

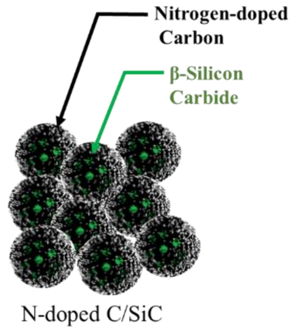

Fig. 1 The of structure of N-doped C/SiC

3. Silicon@Carbon@Acetylene Black Glass (Si@C@ABG)

Micro size silicon has a high potential for increasing volumetric capacity[2]. However, its application for battery is plagued by inadequate cycling stability and low Li^+ diffusion. Thus, we coated Micro Si particles by carbon and acetylene black glass (Si@C@ABG). Acetylene black glass contains silicon oxycarbide which has high endurance. Due to the improved the structural strength and its conductivity, Si@C@ABG based anode displayed excellent capacity and rate performance in both of half-cell and full cell conditions.

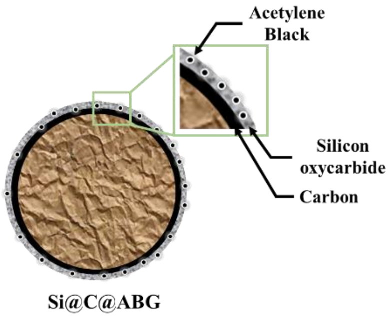

Fig. 2 The of structure of Si@C@ABG

4. Poly(vinylphosphoric acid) binder (PVPA)

The binder materials play a considerable role in to maintain the structure of the electrode. The optimization of these binders is necessary for encouraging the energy density of LIBs. The lowest unoccupied molecular orbital (LUMO) have a influence on electrochemical behavior for anode materials[3]. Based on this report, Poly(vinylphosphoric acid) (PVPA) binder was applied as binder to Micro-Silicon oxide/graphite composite anode. PVPA-based anode half cell exhibited 650 $mAhg^{-1}$ for 200 cycles, which is higher than the case of other commercial binder based cells.

Reference

1) J.-T. Vaughey, J. O'hara, M.-M. Thackeray, *Electrochem. Solid-State Lett.,* **3** (2000) 13.
2) G. Zhu, D. Chao, W. Xu, M. Wu, and H. Zhang, *ACS Nano* **15** (2021) 15567-15593.
3) S.-G. Patnaik, R. Vedarajan, N. Matsumi, BIAN based functional diimine polymer binder for high performance Li ion batteries, *J. Mater. Chem. A*, **5** (2017) 17909.

Keywords
Lithium-ion battery, Anode active material, Anode binder, Silicon, Siliconoxy carbide, Poly(vinylphosphoric acid)