Performance Improvement of a Vacuum Deposited Si Film for Li Insertion/Extraction

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Introduction

In an attempt to enhance the anode capacity of Li-ion batteries we examined a vacuum deposited Si film on a Ni foil [1]. This method is simpler as compared with an elegant method proposed by Yonezu and his coworkers, where Si film is sputtered on a specially roughened Cu substrate [2]. In our method, however, an issue was found that the Li extraction capacity was decreased with the increase of the film thickness.

In this study we examined to find a condition where a high capacity can be kept even with thicker Si film.

Experimental

Metallic Si was evaporated on a Ni foil by heating a Si wafer in a tungsten boat at the melting point of silicon in a vacuum chamber. The film thickness was monitored by a quartz crystal microbalance mounted near the Ni foil. The thickness range of the evaporated film examined was 100 to 2000 Å.

A 1 x 1 cm square sheet of the Ni foil covered with an evaporated silicon film was immersed in an electrolyte solution of EC/DMC (1:1 v/v) or PC (containing 1 M $LiClO_4$) and the cyclic voltammetry and a constant current charge discharge tests were examined in an argon flowing glove box at an ambient temperature.

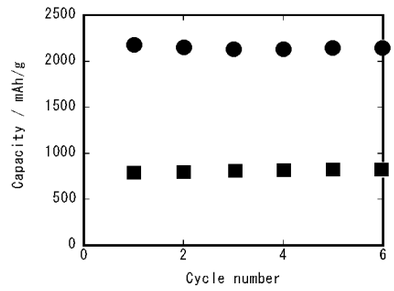
Results and Discussion

The Li extraction capacity from the vacuum-deposited Si film was found dependent on the deposited film thickness as shown in Fig. 1. The capacity was quite much depressed for the film thicker than 1000 Å. This implies that the film structure changes during the deposition process, which could be ascertained from the difference in electronic conductivity between the two films. Thicker film was less conductive. This suggests that increasing the electronic conductivity of the deposited film may enhance the capacity. We tried to enhance the film conductivity by making a multi-layered film where a thin Cu film was sandwiched between the two Si films (see inserted model of the cross section in Fig. 2).

The cycleability of the multiplayer film where a Cu layer was sandwiched by two Si layer was improved remarkably as compared with that of a single Si layer film, which is shown in Fig. 2. The conductivity of the multiplayer film was higher than that of the single one. Similar results were obtained with a Ag film as well.

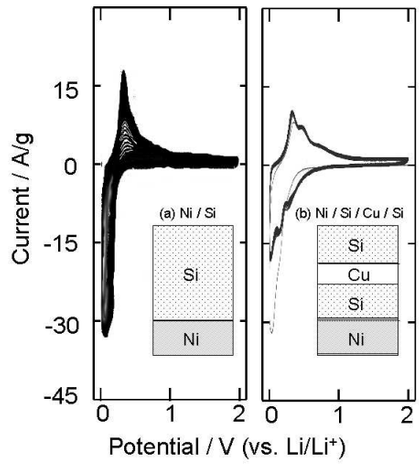
As shown in Fig. 3, the constant current charge/ discharge cycle test for the multi-layer film having total Si thickness of 1500 Å gave good cycleability. The initial charge loss was depressed remarkably for the conductive film.

Fig. 1 Cycling results of Li extraction from an evaporated



Si film. Film thickness: ● 770 Å; ■ 1500 Å

Fig. 2 CVs of two types of deposited Si layer obtained in



PC containing 1 M $LiClO_4$. (a) 1500 Å thick Si single layer; (b) 100 Å thick Cu layer is sandwiched by two 750 Å thick Si layers

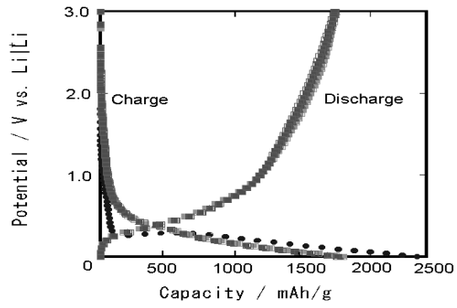


Fig. 3 Charge/discharge curves (1C rate) of a multi-layer film (Si/Cu/Si) vacuum deposited on a Ni foil. Total thickness of Si is 1500 Å

◆: 1st cycle, ■: 2nd cycle, ▲: 3rd cycle, ■: 4th cycle, □: 5th cycle.

References

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[2] H. Ikeda, I. Yonezu, et al, Presented at the 42nd Battery Symposium in Japan, Nov. 21, in Yokohama, Japan (2001); K. Sayama, et al, Presented at the 11th International Meeting on Li Batteries, Monterey, CA, USA, June 23-28, 2002, Abs. No.:52.