Performance and Safety Evaluation of Li_2FeSiO_4/SiO Battery

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Introduction

It is expected that Li_2FeSiO_4 should be a safe and cheap cathode material made of abundant materials. There are few reports about full cells using Li_2FeSiO_4 cathode. We have reported a full cell of Li_2FeSiO_4/C.[1] In order to demonstrate the safety of Li_2FeSiO_4 cathode, we matched the cathode with an SiO anode, which we have developed with 1500mAhg^{-1} capacity and excellent cyclability.[2] We made 1 Ah class coffee-bag type Li_2FeSiO_4/SiO battery and tested the battery for a nail penetration test and an over-charge test in order to evaluate the safety of the battery.

Experimental

Preparation of Li_2FeSiO_4[3] and SiO anode[2] was previously reported. Cathode materials, Li_2FeSiO_4-carbon composite, acetylene black (AB), and PVdF were mixed in a ratio of 90:2:8 and coated on aluminum sheet. Anode materials, SiO, AB, and polyimide binder (PI) were mixed in a ratio of 80:2:18, coated on nickel plated steel sheet then dried in vacuum at 250 °C. The anode was contacting lithium foil in electrolyte liquid in order to be lithiated. [2] The electrodes were rolled with a separator sheet to a battery, which was packed into a aluminum laminate sheet with electrolyte liquid of 1M $LiPF_6$ / ethylene carbonate / diethylcarbonate + vinylene carbonate (1/1 v/v + 1wt%). A battery of 800 mAh capacity was made and charged/discharged in the voltage range of 1.2-4.2V at 30 °C.

A battery of 1 Ah capacity was charged and tested in a nail penetration test. The battery was penetrated by a nail of which temperature at nail head was measured using a thermocouple set inside the nail. Another battery of 1 Ah capacity was charged and examined in over-charge test. The battery was over-charged at 5A (5C) for 10 min then 10A (10C) until the charging voltage was reached to 32 V.

Result and Discussion

The Li_2FeSiO_4/SiO battery showed a capacity of 600 mAh at 0.2C (160mA) and 400 mAh at 1C (800mA), respectively. The charge and discharge curves of the Li_2FeSiO_4/SiO battery were shown in Fig. 1 at 1 C-rate from 2nd to 1000th cycles. The average voltage of the battery was 2.0 V. The curves after 100th cycle showed little change with the one of 1000th cycle. The capacity of the battery was 400 mAh at 1 C-rate and showed excellent capacity retention ratio (1045th/10th) 89.1% (Fig. 2).

The result of nail penetration test of charged 1 Ah Li_2FeSiO_4/SiO battery was shown in Fig. 3. After a nail penetration slight temperature increase and decrease of battery voltage with time was observed. At the time when the nail pulled-off, relatively large short-circuit occurred but there was no ignition or explosion.

The result of an over-charging test of charged 1 Ah Li_2FeSiO_4/SiO battery was shown in Fig. 4. Although the battery showed no change during 5A (5 C-rate) over-charge for 10 minute, after a couple of minutes under 10 A charge, the voltage and the surface temperature of the battery abruptly increased and then blew smoke without frame. The temperature maximum was 290 °C and the charging voltage reached to 32 V, which was preset cut-off voltage.

As shown above, the Li_2FeSiO_4/SiO battery demonstrated excellent durability of more than 1000 cycles and safety in nail-penetration and over-charged tests.

Reference

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2. T. Miyuki, Y. Okuyama, T. Sakamoto, T. Kojima, and T. Sakai, *Electrochemistry*, **80**, 401 (2012).(JPN)
3. T. Kojima, A. Kojima, T. Miyuki, Y. Okuyama, and T. Sakai, *J. Electrochem. Soc.*, **158**, A1340 (2011).

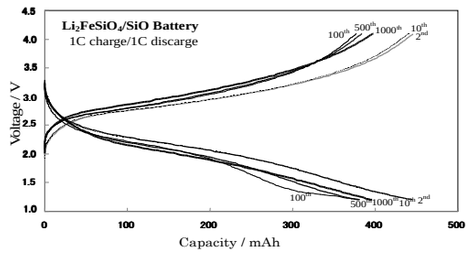

Fig.1 Charge and discharge curves of Li_2FeSiO_4 /SiO battery with the 1 C-rate (800mA) in the voltage range of 1.2–4.1 V at 30 °C.

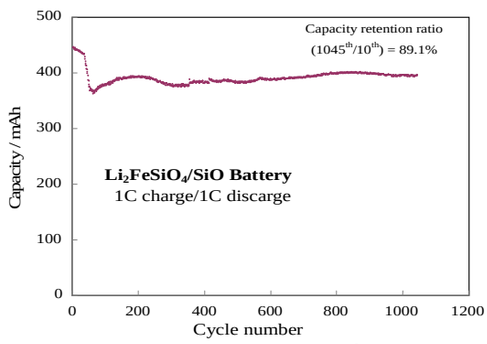

Fig. 2 Discharge capacity until 1045th cycle of Li_2FeSiO_4 /SiO battery with the 1 C-rate (800mA) in the voltage range of 1.2–4.1 V at 30 °C.

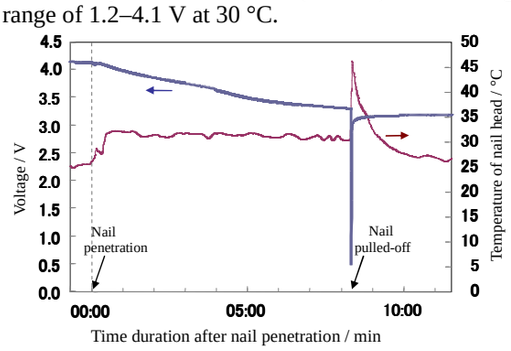

Fig.3 The relationship between temperature, voltage of a full-charged 1 Ah Li_2FeSiO_4/SiO battery and elapsed time after a nail penetrated the battery.

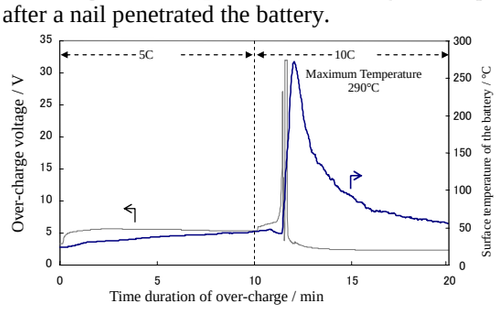

Fig.4 The relationship between temperature, voltage of a full-charged 1 Ah Li_2FeSiO_4/SiO battery and charging time of 5A or 10A.