Fabrication of Micro-electrode for Lithium Ion Battery by Electrophoretic Deposition Process

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Introduction

Micro-ordered batteries have been paid much attention as micro-technology applications. In order to use them in practical devices, new architecture for preparation of electrodes should be needed. One of possible electrode structure for micro-batteries is a patterned electrode. In our laboratory, we have prepared a micro-battery via micro-injection processes of sols for electrode materials on a glass substrate with micro-patterned gold current collectors.[1] The prepared micro-battery operated reversibly at 2.5 V. However, the sols used in this technique should be dilute, which makes it difficult to obtain thick electrodes for high discharge capacity. In addition, supporting materials such as conducting materials and binders can not be used owing to the calcination of sols at high temperatures.

Electrophoretic deposition (EPD) is one of transfer processes to fabricate uniform coatings on a substrate without heat treatment. In this process, thickness and density of the coating are easily controlled. Furthermore, the coating composed of some materials can be formed simultaneously. Here, an integrated array $Li_4Ti_5O_{12}$ (LT) electrode was fabricated by EPD method and its electrochemical evaluation was carried out.

Experimental

LT used as an active material was prepared by solid state reaction method. CH_3COOLi and TiO_2 were ball-milled, and calcined at 500 °C for 3 h and then 800 °C for 20 h. The sample was characterized by XRD, Raman spectroscopy, and scanning electron microscopy (SEM). A suspension for EPD was prepared by ultrasonic dispersion of LT, Ketjen Black (KB), polyethylene oxide (PEO, Mw = 100000), and iodine in acetonitrile. The weight ratios of LT, KB, PEO, and iodine were set to be 40: 1: 1: 3. We deposited electrode materials on a conventional flat electrode or a comb-type electrode array by using the EPD configuration shown in Fig. 1. EPD was performed at 0 °C with stirring by magnetic stirrer at 100 rpm.

The prepared electrode was assembled in an electrochemical cell with Li metal anode to evaluate its electrochemical performance. 1 mol dm^{-3} $LiPF_6$ in a 1:1 mixture in vol. of ethylene carbonate (EC) and diethyl carbonate (DEC) was used as an electrolyte. The cell was charged at various rates and discharged at 0.1 C rate.

Result and Discussion

Figure 2 shows charge and discharge curves of Li/$LiPF_6$ (EC: DEC = 1:1 in vol.)/(LT composite electrode prepared on a flat Cu electrode) cell. The electrode prepared by EPD worked as the cathode and exhibited discharge capacity of 142 mA h g^{-1} at 0.1 C. Figure 3 shows the SEM image of composite electrodes fabricated on a comb-type electrode array by EPD. The electrode materials were successfully deposited on the lines selected in the electrode array (every other line). The deposit thickness was estimated to be 4.2 μm from SEM observation. Figure 4 shows the cyclic voltammogram of Li/gel electrolyte (PMMA including $LiClO_4$(EC:DEC = 1:1 in vol.))/(LT composite electrodes prepared on a electrode array) cell. The redox peaks was observed reversibly at 1.55 V. The discharge capacity was estimated to be 1.37 μA h. This value is greatly higher than that obtained in our previous work (360 nA h by injection process), suggesting that EPD method is favorable to increase energy densities of micro-lithium batteries.

References

[1] K. Dokko, J. Sugaya, H. Nakano, T. Yasukawa, T. Matsue, and K. Kanamura, *Electrochem. Comm.*, **9**, 857-862 (2007).

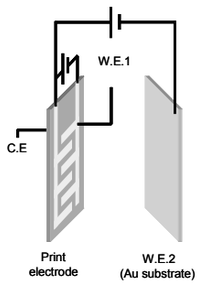

Fig. 1 Schematic of the electrode configuration used in EPD.

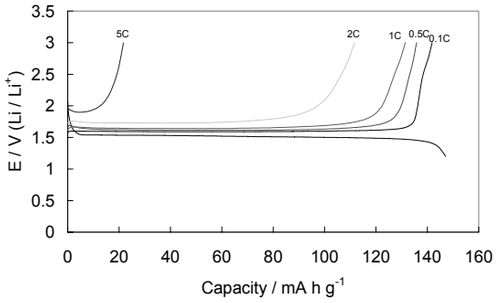

Fig. 2 Charge-discharge curves of Li/$LiPF_6$ (EC: DEC = 1.1 in vol.)/$Li_4Ti_5O_{12}$ on Cu flat electrode cell fabricated by EPD.

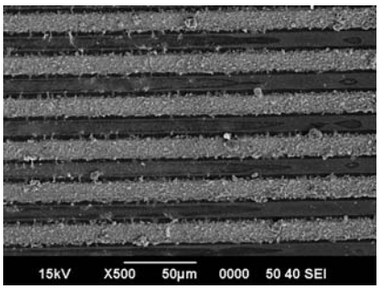

Fig. 3 SEM image of composite electrodes fabricated on a comb-type electrode array by EPD.

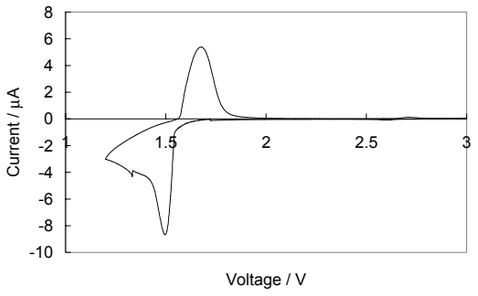

Fig. 4 Cyclic voltammogram of Li/PMMA-gel/ $Li_4Ti_5O_{12}$ on an electrode array cell fabricated by EPD.