

## Electrochemical behavior of Sb anode synthesized by electrodeposition for Na-ion batteries

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### Introduction

It is expected that the price of lithium keep rising since the reservoir of lithium in natural resources are significantly limited for the rapid growth of Li-ion battery market. Hence, Na-ion batteries are considered as an alternative to Li-ion batteries for large-scale applications due to the low-cost and abundance of sodium resources. While a variety of cathodes materials for Na-ion batteries have been reported<sup>[1]</sup>, the availability of anode materials is much rare. Among the candidates, Sb is a very attractive anode material for Na-ion battery due to high theoretical capacity (660 mAh/g) and relatively low cost.<sup>[2]</sup>

Commonly, Sb-based electrodes are prepared by a solid-state method (slurry process) such as high-energy ball milling: Qian *et al.* and Wu *et al.* reported Sb/C and SiC/Sb/C composite, respectively.<sup>[2, 3]</sup> Compared with such a conventional slurry process, a synthesis of the electrode by the electrodeposition has several advantages: simple, binder and conductive agent-free process, high purity and an intrinsically electrical contact with current collector.<sup>[4]</sup> In all the past studies, however, Sb electrode synthesized by electrodeposition has not yet been reported for Na-ion batteries. Therefore, in this study, the Sb anodes were prepared by the electrodeposition from diverse electrolytic baths and the effects of the crystal structure on the electrochemical properties of Sb anode were investigated by ex-situ analyses.

### Experimental

Sb electrodes were prepared by the electrodeposition at a constant current density in a potassium antimony tartrate bath, antimony chloride bath and antimony oxide bath, respectively. Electrodeposition of Sb was performed on Cu foil at room temperature, with the solution being stirred magnetically at ~ 240 rpm. The Sb electrode was dried in vacuum for 6 h after rinsing with distilled water to prevent the oxidation.

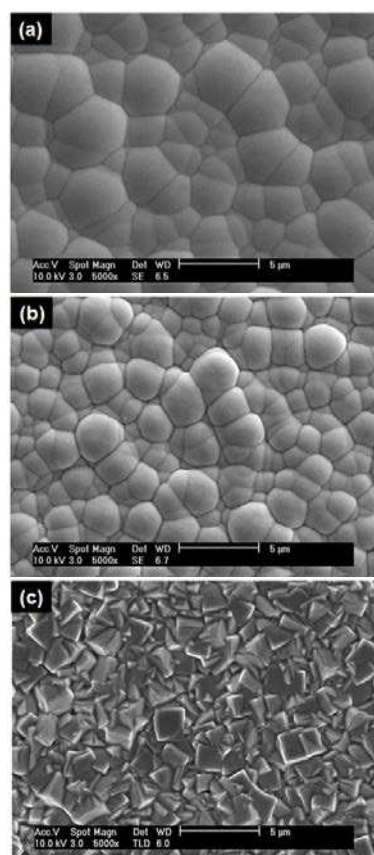
The electrochemical behavior of the Sb electrodes was investigated using two-electrode Swagelok-type cell with electrode area of 1 cm<sup>2</sup> assembled in an Ar-filled glove box. The cell consists of the Sb electrodes as a working electrode, a pure Na as a counter electrode and 1 M NaClO<sub>4</sub> dissolved in a mixture of propylene carbonate and 0.5 vol. % of fluoroethylene carbonate as an electrolyte. The electrochemical test was conducted at a current density of 60 mA/g in the potential range of 0.01 ~ 1.5 V vs. Na<sup>+</sup>/Na at 25 °C.

### Results and discussion

Figure 1 shows the effects of the electrolytic bath on the surface morphology of Sb electrodeposit. As shown figure 1, Sb deposit in antimony oxide bath exhibits cubic-like shape with high crystallinity. In contrast, Sb deposit formed in potassium antimony tartrate bath was

composed of granular particles and those in antimony chloride bath also consisted of more small granular particles than former deposits.

Sb electrode using potassium antimony tartrate bath shows improved cycling performance rather than those formed in the other electrolytic baths. The specific capacity of Sb electrode electrodeposited in potassium antimony tartrate bath was maintained at 382.9 mAh/g after 50 cycles that corresponds to 66.0 % of the initial capacity (552.9 mAh/g). However, Sb electrodes using other two electrolytic baths exhibit rapid capacity fading during initial cycles (under 15 % of initial capacities after 25 cycles).



**Figure 1.** SEM images of Sb deposited in (a) Potassium antimony tartrate bath, (b) Antimony chloride bath, and (c) Antimony oxide bath.

### References

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