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# Cyclic voltammogram of single-walled carbon nanotubes having a small diameter distribution

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## Introduction

Since single-walled carbon nanotubes (SWCNTs) have high electrical conductivity, high specific surface area, high charge transport capability, and tunable porosity, SWCNTs are expected to be used as electrode materials for Li ion batteries and electric double layer capacitors (EDLC). However, the ion adsorption mechanism in SWCNTs, which is crucial for optimizing their performance, has not yet been clearly understood. In order to elucidate it, we should perform electrochemical measurements of the well-defined SWCNT sample.

## Experimental

*Structural analysis of SWCNTs*

Synchrotron XRD measurements were performed, using beam line BL-18C. The experiments were carried out using monochromatized X-ray (0.614 Å). Diffraction patterns were collected using a two-dimensional imaging plate (IP) detector at 160 mm behind the sample position. The X-ray wavelength and the distance from the sample to the IP were determined on the basis of the X-ray diffraction peaks of $CeO_2$ powder sample by double cassette method. In order to eliminate preferred orientation effect, quartz capillary sample tube was oscillated during the measurement.

*Electrochemical measurements*

Cyclic voltammetry (CV) measurements were carried out using a potentiostat/galvanostat controlled by a computerized system. A specially designed cell with a conventional three-electrode configuration was used. In this cell, SWCNT working electrode, $Ag/Ag^+$ reference electrode, and carbon fiber counter electrode were used with 1 M triethylmethylammonium tetrafluroborate in propylene carbonate as electrolyte.

## Results & Discussion

As shown in Fig. 1, the XRD pattern which can be indexed by 2-dimensional hexagonal lattice corresponding to the SWCNT bundle structure ($a$ = 1.79 nm, $R$ = 0.74 nm) was observed. The intense diffraction peaks indicate that the SWCNT sample used in the present study is well crystallized and its diameter distribution is quite small. Fig. 2 shows the observed CV curves of the SWCNT sample. Unlike the CV curves, what we call "butterfly" shape, previously observed by other researchers, the CV curve observed in the present study has big "humps" on both sides of the rest potential. The observed CV shape looks like dumbbell. It was found by the comparison between the electronic density of states (DOS) of SWCNTs and the dumbbell CV shape that the drastic increase of current in "dumbbell" can be explained by the van Hove singularity in the DOS of the semiconducting SWCNTs in the sample.

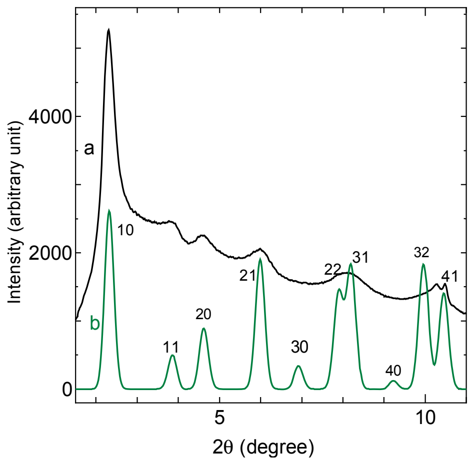


**Fig. 1** (a) Observed and (b) simulated XRD patterns of the SWCNT sample.

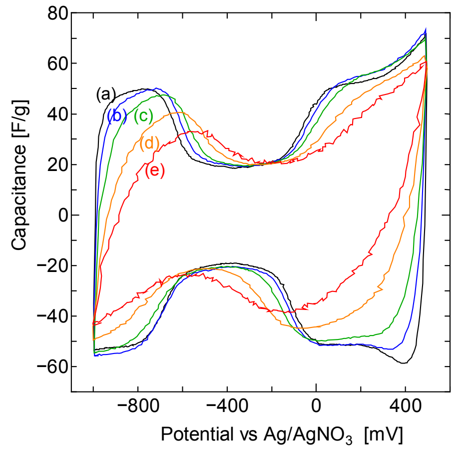


**Fig. 2** Cyclic Voltammograms of the SWCNT sample at sweep rate of (a) 5, (b) 10, (c) 20, (d) 50, (e) 100 mV/s.

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