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## Porous V<sub>2</sub>O<sub>5</sub>/Carbon Nano-composites Electrodes for Rechargeable Power Sources with Large Capacity and High Power

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### Abstract

Nanoporous composite electrodes for rechargeable power sources were successfully fabricated by coating porous carbon with thin V<sub>2</sub>O<sub>5</sub> gel layers. Their electrochemical properties were demonstrated, which took after both lithium ion batteries and electrochemical double layer capacitors. The nanoporous V<sub>2</sub>O<sub>5</sub>/carbon composites exhibited large capacity of more than 100 mAh (g-composite)<sup>-1</sup> and good rate capability of 80% at 5.0 A (g-composite)<sup>-1</sup>. The good performance is explained by electric double layer capacitance of large surface area and high rate lithium insertion to thin V<sub>2</sub>O<sub>5</sub> gel layers.

### Introduction

Rechargeable power sources with both large capacity and high power are strongly demanded for their potential application to power sources for electric vehicles (EVs). Electric double layer capacitors (EDLCs) and lithium ion batteries (LIBs) are the most promising candidates. EDLCs exhibit good rate capability but low capacity. On the other hand, capacity of LIBs are relatively high but their power density is not enough for EVs. In this study, composite electrodes based on concepts of both EDLCs and LIBs were synthesized.<sup>1)</sup> We prepared V<sub>2</sub>O<sub>5</sub>/carbon nanoporous composites that utilize capacitance of both double layer and pseudo capacitance of lithium insertion into V<sub>2</sub>O<sub>5</sub>. The structure and the electrochemical properties of the composite electrodes are reported.

### Experimental

Ordered porous carbons that are employed as frameworks of composite electrodes were synthesized by using colloidal crystals of SiO<sub>2</sub> (particle size: 110 nm) as templates. The detailed procedure was reported elsewhere.<sup>2)</sup> The porous carbons were dispersed in a V<sub>2</sub>O<sub>5</sub> sol that were prepared by dissolving vanadium powder in hydrogen peroxide.<sup>3)</sup>

After stirring, carbons were collected by filtration and dried. This coating process was repeated several times.  $V_2O_5$ -coated carbon thus obtained is hereafter abbreviated as  $V_2O_5[n]/C$ , where  $n$  is the number of the coating process. Surface areas and porous structure of  $V_2O_5[n]/C$  were investigated by  $N_2$  ad-/desorption isotherms and TEM, respectively. Electrochemical properties of  $V_2O_5[n]/C$  were investigated by cyclic voltammetry and galvanostatic charging/discharging in 1 M  $LiClO_4$  (PC + DME).

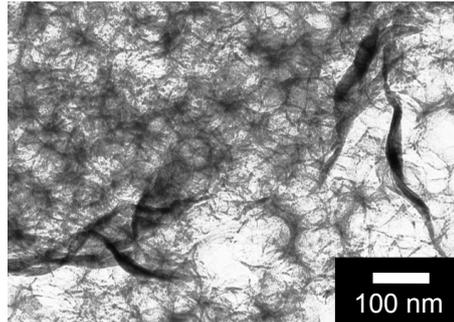


Fig. 1. TEM image of porous  $V_2O_5[9]/C$ .

### Results and Discussions

TEM images revealed the porous carbons had ordered spherical pores with a diameter of 110 nm, and was coated with  $V_2O_5$  for  $V_2O_5[n]/C$  (Fig. 1). The amounts of loaded  $V_2O_5$  increased almost linearly with repeating the coating process, and about 34 wt-% of  $V_2O_5$  was loaded after 11th cycle. In cyclic voltammograms (Fig. 2), for pristine carbon, almost rectangular voltammograms were obtained due to charging/discharging of double layer capacitance, which was calculated to be about  $80 \text{ F g}^{-1}$ .

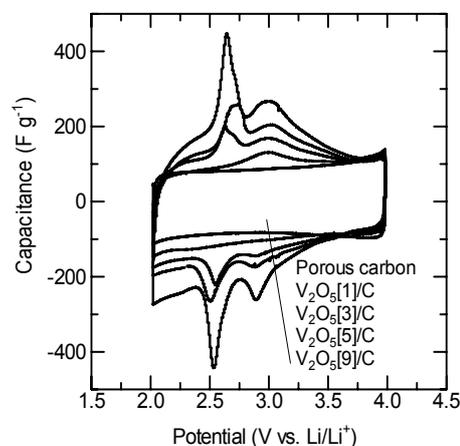


Fig. 2. Cyclic voltammograms of porous carbon and  $V_2O_5[n]/C$  nanoporoues composites.

Coating  $V_2O_5$  layers on carbons resulted in appearance of two pairs of red-ox peaks at 2.6 V and 2.9 V, indicating lithium insertion to and extraction from amorphous  $V_2O_5$ .  $V_2O_5[n]/C$  exhibited large capacity of  $50 - 100 \text{ mAh (g-composite)}^{-1}$  between 2.0 – 4.0 V vs.  $Li/Li^+$ , and 80% of capacity was retained at a high charge rate of  $5.0 \text{ A g}^{-1}$ . In summary, large capacity and high rate capability of  $V_2O_5$ /carbon nanoporous composites were successfully demonstrated.

### References

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