

## Analysis of SEI Composition on Porous Carbon by Ultrasoft X-rays

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Lithium-ion batteries (LIBs) are widely used for energy storage; however, further enhancement of energy density is necessary to meet future demands. Graphite, the standard anode material, is already close to its theoretical capacity. To overcome this limitation, we investigate porous carbon anodes, which can store more lithium through the formation of a solid-solid electric double layer (SS-EDL) at the interface between the solid electrolyte interphase (SEI) and the electrode. While this mechanism offers high capacity, the structure of the SEI and its role in degradation remain unclear [1]. This study uses soft X-ray absorption spectroscopy (XAFS) to analyze the internal composition of porous carbon electrodes and gain insight into SEI formation and lithium storage behavior.

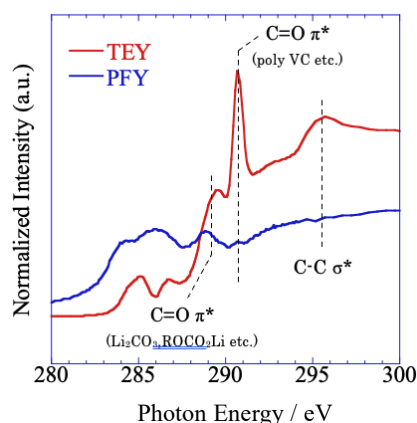
Porous carbon with a particle size of 2  $\mu\text{m}$  and pore size of 10 nm was used as the active material. Electrodes were prepared by mixing the porous carbon with acetylene black, CMC, SBR, and water to form a slurry, which was coated onto etched aluminum foil. After drying and punching, the electrodes were assembled into two-electrode cells with lithium metal and 1 M LiTFSI in vinylene carbonate as the electrolyte. Charge-discharge tests were conducted at 300 mA/g (0.5–3 V). After cycling, electrodes were washed with dimethyl carbonate and measured by carbon K-edge XANES at BL-11 of the SR Center, Ritsumeikan University, using both TEY (surface-sensitive) and PFY (bulk-sensitive) modes.

Fig. 1 shows the carbon K-edge XANES spectra of the electrode after the first cycle. Peaks at  $\sim 289.1$  eV and  $\sim 290.6$  eV correspond to C=O bonds in SEI components [2,3]. The TEY spectrum revealed strong signals from poly(vinylene carbonate) (poly VC), indicating its dominance at the surface. In contrast, the PFY spectrum showed relatively weaker poly VC signals, suggesting compositional variation between the surface and interior of the porous carbon particles. These results imply that organic SEI components (poly VC,  $-(\text{C}-\text{C})_n-$ ) are localized at the surface, while inorganic components ( $\text{Li}_2\text{CO}_3$ ,  $\text{ROCO}_2\text{Li}$ ) dominate the interior.

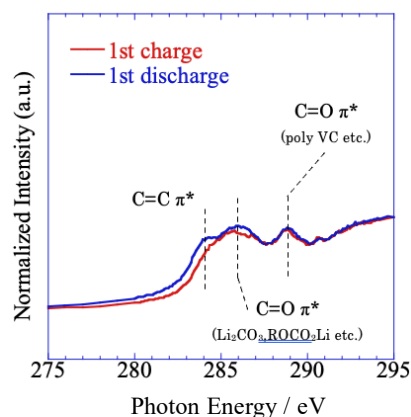
Fig. 2 presents PFY-mode XANES spectra after the first charge and discharge. The peak near 283.8 eV, assigned to C=C bonds in the porous carbon [4], decreases after charging. This suggests that Faradaic reactions between lithium ions and the carbon framework occur, potentially causing irreversible damage to the pore structure. Such degradation may

contribute to capacity fading over repeated cycles.

Future work will investigate the influence of SEI composition—both surface and bulk—on electrochemical performance, as well as explore porous carbon materials with tailored structures to enhance cycling stability.



**Fig. 1** Observed C K-edge XANES spectra in TEY and PFY modes.



**Fig. 2** Observed C K-edge XANES Spectra with 1st-cycled electrode.

### References

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