

Application of alginate-binder to carbon anodes and their electrochemical performance

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Carbon electrodes have widely been used as anode for commercial lithium-ion batteries (LiBs). Electrochemical performance of the carbon electrodes is strongly affected by their components, such as conductive material and binder. In particular, a choice of binder is very critical in optimizing performance of the carbon electrodes. Recently, it has been reported that graphite electrode characteristics in a PC electrolyte without additives was improved by using of poly(acrylic acid) (PAA) as binder¹. The mechanism of the improvement involves the formation of more uniform and thinner SEI layer by coating the PAA binder on the surface of the graphite. Komaba et- al. have also reported that electrochemical reversibility of lithium intercalation in PC and ionic liquid electrolytes was improved by using polymer with oxygen-containing functionalities such as poly(methacrylic acid) (PMA) and poly(vinyl alcohol) (PVA) as binder for graphite electrodes². Their mechanism would be similar to that of the PAA case. Thus a choice of the binder should have a significant influence on the property of the electrode/electrolyte interface.

In this work, we have investigated suitability of alginate-salt binders for conventional graphite anode materials in LiBs. Alginate is natural polymer, which is categorized as polysaccharide derived from brown seaweeds. In our previous study, we reported on an alginate-based gel electrolyte for use in an electric double layer capacitor (EDLC) based on activated carbon electrodes. The EDLC cell with the alginate gel electrolyte exhibited excellent cycle performance with higher discharge capacity than that of a conventional EDLC cell. We believe that such performances should originate from high affinity of the alginate matrix toward the carbon electrode materials. Various carbon anodes containing alginate binder with different cation species were also fabricated and evaluated by several electrochemical measurements.

The carbon anode was prepared by mixing 91 wt.% carbon material, 3 wt.% conductive agent (carbon black), and 6 wt.% alginate-salt (typically Na cation-type) binder dispersed in pure water. The resulting slurry was cast onto Cu foil and dried at 80°C for 12 h under a vacuum condition. The obtained electrodes were punched to be a disk shape with a diameter of 12 mm for the LiB cell test. For comparison, the carbon anode with SBR binder was also prepared. The electrolytes used were 1 mol dm⁻³ LiPF₆ in EC:DMC (1:1 by volume) as organic electrolyte and 0.32 mol dm⁻³ lithium bis(trifluoromethanesulfonyl)imide (LiTFSI) in 1-ethyl-3-methylimidazolium bis(fluorosulfonyl)imide (EMImFSI) as ionic liquid electrolyte (IL). The electrochemical measurements were carried out on coin-type cells CR2032 which were assembled with the carbon anode / separator / Li foil in an argon-filled glove box.

Figure 1 shows cyclic voltammograms of the alginate binder-based cells with the organic and IL electrolytes. Each cell indicates reversible redox current response derived from lithium insertion / de-insertion. In addition,

it is observed that the cell with the IL electrolyte exhibits much better redox current response than the corresponding cell with the organic electrolyte.

Figure 2 shows rate performance of the cells with the organic and IL electrolytes. We found that the cell with the alginate-salt binder exhibits a good rate performance thanks to its high affinity for carbon materials. The origins of such natural-polymer effect and the influence of different cation-type on LiB performance are also investigated by several electrochemical measurements.

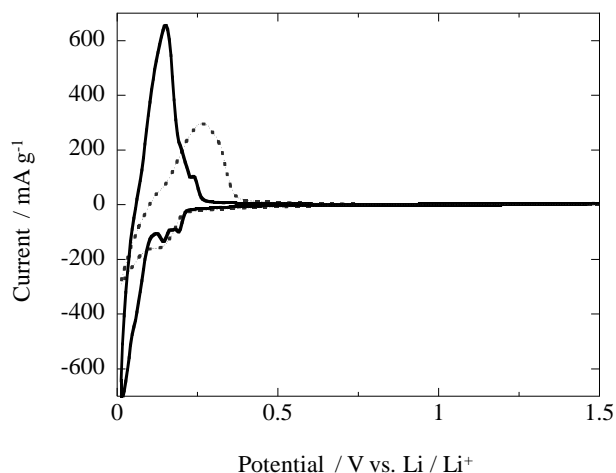


Figure 1. Cyclic voltammograms of cells using alginate-Na binder with (···) 1.0 M LiPF₆/EC+DMC and (—) 0.32 mol dm⁻³ LiTFSI / EMImFSI

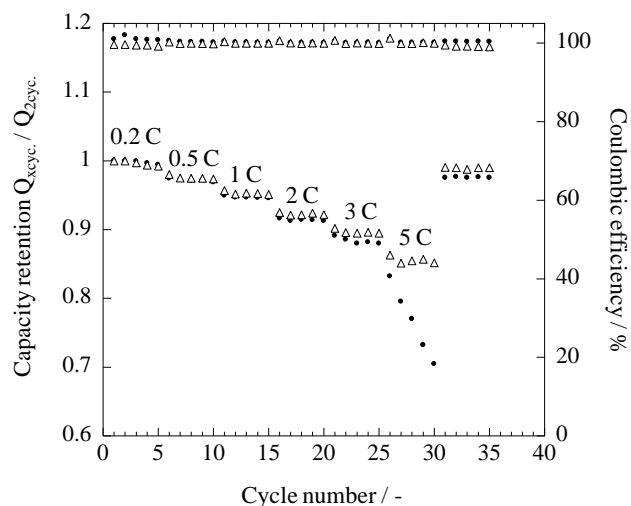


Figure 2. Rate performance of (●) SBR binder and (△) alginate-Na binder-based cells with IL electrolyte.

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