Improvement of the electrochemical performance of electrochemical capacitors using nano carbon materials / Study on carbon fibers and its composites

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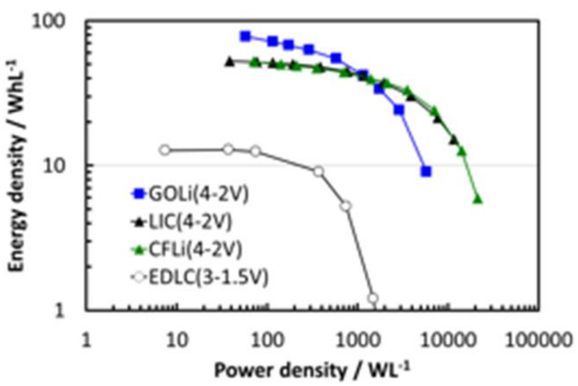
Research Outline

Electrochemical capacitor using GIC

Compared to rechargeable batteries such as Li-ion batteries, electric double layer capacitors (EDLCs) are garnering attention as storage devices due to their superior high-speed charge/discharge capabilities and long cycle life. However, a challenge lies in their low energy density. To address this issue, hybrid capacitors (HCs) combining EDLC-type electrode and battery-type electrode with high energy density have been developed. In a HC, one electrode stores electric energy through a non-Faradaic process, while the other electrode stores energy through a Faradaic process.

In our previous studies, we demonstrated the ability to regenerate used Li primary batteries into novel electrochemical capacitors (ECs). The positive electrode of Li primary batteries employs a covalent-type graphite intercalation compounds (GICs), which undergoes electrochemical reduction during the firstly-discharge process. The electrochemically reduced GICs exhibit conductivity, enabling it to behave as an EDLC-type electrode. These novel HCs derived from Li primary batteries possess remarkably high energy densities. Particularly, the GO/Li capacitor utilizing graphite-oxide (GO) showed a very high energy density of 80 Wh/L. however, at high power densities, the energy density significantly decreases, indicating challenges related to high internal resistance.

Currently, we address the reduction of the internal resistance and further improvement of the electrochemical properties of these ECs.



Carbon fiber and its composite

Carbon fiber-reinforced plastics (CFRPs) are utilized in a multitude of fields, including aerospace, automotive, sports and leisure goods, due to their exceptional specific strength, specific modulus, and chemical stability, among other qualities. In particular, the incorporation of CFRP in automotive components is anticipated to increase in the future, driven by anticipated benefits such as enhanced fuel efficiency through vehicle weight reduction and reduced greenhouse gas emissions.

Currently, carbon fibers are primarily manufactured from either polyacrylonitrile (PAN) or pitch-based precursors. Prior to the high-temperature carbonization process, which is typically conducted at temperatures between 200–300 °C, a stabilization process is essential. This stabilization process requires significant time and energy, contributing to the high cost of carbon fibers. Consequently, current research is focused on developing novel carbon fibers with low cost and high mechanical properties by reconstructing raw materials and exploring novel manufacturing approaches. Furthermore, carbon fiber-reinforced plastics (CFRP) are utilized in aircraft components and wind turbine blades, among other applications. As the anticipated usage of CFRPs is expected to increase in the future, there is a growing concern about the disposal of CFRP waste as it reaches the end of its service life. While the majority of CFRP waste is currently disposed of in landfills, landfill disposal is already prohibited in EU. Additionally, carbon fibers are expensive to produce and require high energy consumption, which highlights the necessity for CFRP waste recycling in order to achieve a sustainable society. Currently, the focus is on recovering recycled carbon fibers from CFRP waste, with various recycling technologies proposed, including pyrolysis, chemical dissolution, and physical methods. The pyrolysis method is anticipated to be a promising approach in terms of the processing volume of CFRP waste. However, the recycled carbon fibers recovered through the pyrolysis method exhibit a notable reduction in tensile strength. Consequently, efforts are being made to address this issue by subjecting the recycled carbon fibers to a simple and mild surface treatment with the objective of restoring strength and improving adhesion to the matrix resin.