The synthesis of hard carbon anode material for sodium-ion batteries via hydrothermal carbonization.

Grigorii Lakenko[1], Zoya Bobyleva [2], Oleg Drozhzhin [2] and Evgeny Antipov [2,3]

[1] Faculty of Material Science, Lomonosov Moscow State University, Leninskie gory GSP-1, 119991 Moscow, Russia

[2] Department of Chemistry, Lomonosov Moscow State University, Leninskie gory GSP-1, 119991 Moscow, Russia

[3]Skoltech Center for Energy Science and Technology, Skolkovo Institute of Science and Technology, Nobel str.3, 143026, Moscow, Russia

The need for energy storage systems is growing every year, sodium-ion batteries (SIBs) can be used as such sources, which are a promising alternative to lithium-ion batteries (LIBs). The key problem in the commercialization of the technology is the search for electrode materials with satisfactory electrochemical characteristics. Graphite, an anode material in lithium-ion batteries, is not suitable for SIBs, since sodium ions do not intercalate into the interlayer space of graphite. For SIBs anodes, non-graphitizable hard carbon materials are used, the structure of which contains disordered graphene-like layers.

Hydrothermal carbonization followed by high-temperature annealing can be used for the synthesis of hard carbon anode materials. It allows to obtain hard carbon with small particle size (~ 1μm) and low specific surface area (~1 m2), which should have a positive effect on the electrochemical characteristics of the material. Also, one of the features is the possibility of varying the synthesis parameters over a wide range. But the influence of the parameters of hydrothermal synthesis on the electrochemical characteristics of hard carbon remains an open question. The aim of this work is to develop synthetic approaches based on hydrothermal carbonization to obtain hard carbon with improved electrochemical characteristics.

Glucose was chosen as the carbon source. To achieve this goal, we investigated how the parameters of hydrothermal carbonization can affect the properties of hard carbon. For this, the concentration of glucose solution, temperature, and duration of hydrothermal carbonization were varied. The second stage of synthesis was high-temperature annealing in an inert atmosphere at 1300°C. The obtained samples were analyzed using various methods: FTIR spectroscopy, elemental CHNOS analysis, low temperature nitrogen adsorption, scanning electron spectroscopy, and galvanostatic cycling.

Hard carbon obtained by hydrothermal carbonization demonstrates high ICE up to 91% and good reversible capacity ~300 mAh/g. SIB's prototypes based on hard carbon and $Na_3V_2(PO_4)_2O_2F$ and $Na_3V_2(PO_4)_3$ cathode materials demonstrate good electrochemical characteristics: an ICE of about 80% and a discharge capacity of about 100 mAh/g, as well as good cycling stability (capacity retention of 90% for 100 cycles).

It was shown, that the morphology of hard carbon, namely, the particle size, on which the specific surface area depends, has a significant effect on ICE. A high concentrationa of glucose and low pH allows to obtain material with desired particle size and reduced the surface area. A temperature of 200°C and a duration of 3 hours is sufficient for hydrothermal carbonization to occur, and a further increase in these values does not lead to an improvement in the properties of the material. The obtained samples of hard carbon have suitable characteristics for successful application in sodium-ion batteries.

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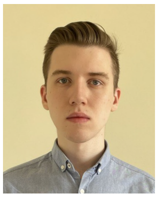

Griogrii Lakienko is second year master student at Faculty of Materials Science of Lomonosov Moscow State University. He received his bachelor's degree from the same faculty. The main area of research is the development of carbon-based anode materials for metall-ion batteries.

Presentating author: Grigorii Lakienko, e-mail: bojk25@gmail.com tel: +79373125494