

ENGINEERING SCIENCES

INNOVATING CARBON MATERIALS OPEN NEW POSSIBILITIES FOR INCREASING PERFORMANCE OF Li-ion BATTERIES

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ABSTRACT

The purpose of research and development, the results of which are presented in this publication is the modification of carbon materials for use in anode and cathode materials Li batteries with non-aqueous electrolytes. Innovative carbon materials will provide increased energy and safety of lithium current sources, while at the same time reducing the cost of lithium current sources.

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Introduction. The market of lithium-ion batteries until 2020 will grow to 50 billion dollars. The chemistry of electrodes and electrolyte materials is one of the key branches of battery technology. The cost of active electrode materials, separators and electrolytes is a large part of the material costs of lithium-ion cells: The cost of materials is about 83% of the total cost of producing lithium batteries

With the growing concern for energy, safety and the cost of lithium batteries, the importance and popularity of innovative carbon materials for lithium battery electrodes is growing.

For use in lithium batteries as electrode materials, carbon / graphite materials must meet the following requirements: high electronic conductivity; structural characteristics that provide high rate of electrochemical reactions; inhibitor properties relative to electrochemical and chemical reactions of decomposition of non-aqueous electrolyte components.

Li-ion batteries carbon materials are used for two types of electrodes: anodes and cathodes. In the anodes of Li-ion batteries the carbon / graphite is an active electrode material that is directly involved in the electrochemical process. When charging the current source, lithium cations Li^{+} are introduced into the structure of graphite - the process of intercalation is underway. When the current source is discharged, the process of de-intercalation of lithium cations takes place. The structure of the carbon material determines the efficiency of the electrochemical reactions of intercalation / de-intercalation. In the cathodes of lithium current sources, carbon material is introduced into the composition of the cathode mass as an additional component to ensure the electronic conductivity of the cathode mass.

The electronic conductivity of carbon / graphite materials is important factor for increasing the efficiency of the electrochemical processes on the anode and cathode of Li-ion batteries.

Our article relates to carbon materials for using in anode of Li-ion batteries. We developed technologies of carbon modification for further making use of them in as anodes of rechargeable lithium-ion batteries. Method of modification of carbon material for electrodes of lithium-ionic current sources is based of heat treatment of graphite intercalated mass using the reactor with special design [1].

Results of investigation the following properties of the modified innovating carbon / graphite are presented below: 1) electronic conductivity of powdered materials using non-contacted electromagnetic method; 2) density of the powdered materials; 3) structure of powdered materials using scanning electron microscope; 4) electrochemical properties of anode based on the initial carbon materials and anode based on the modified carbon materials.

Research results.

Non-contact electromagnetic testing the conductivity of powdered materials.

Enerize Corporation developed method and equipment for non-destructive non-contact testing and determination of physical chemical properties, for example conductivity, of powdered materials including electrode materials, cement, and different products in chemical industry. [2, 3] Below presented photos of this equipment. Equipment includes unique inductive transducer design that generates a uniform electromagnetic field. Combined system includes inductive system and capacitance system.

Using electromagnetic capacitance method allows to recognize changes of conductivity and density of powdered materials that used for fabrication the electrodes of the Li-ion batteries. This allows to comparing the properties of the innovating graphite materials, optimize the parameters of modification and compare the properties of innovating graphite and graphite from the market.

Below presented photo of this equipment.



Fig. 1. Device for Electromagnetic Evaluation of the Electrical Conductivity of Powdered Materials for Lithium Batteries

Sample Measurement Parameters:

Conductivity range: 0.1 S/m – 1000 S/m

Measurement time: less than 20 s

Accuracy: $\pm 5\%$

Sensor size: 15mm diameter, and can be changed

Example of using: measuring and comparison the conductivity of various electrode materials: Graphite for anode Li-ion batteries; graphite as conductive additive for cathode mass; LiMn_2O_4 LiCoO_2 LiFePO_4

Below presented results of the testing the conductivity and density the powders of three types of the carbon materials: 1. Modified carbon CNK; 2. acetylene soot (black); 3. Graphite for Li-battery from market, BG-34.

Modified carbon / graphite, CNK has been fabricated using the method of modification that developed by the co- authors of the presented article [1].

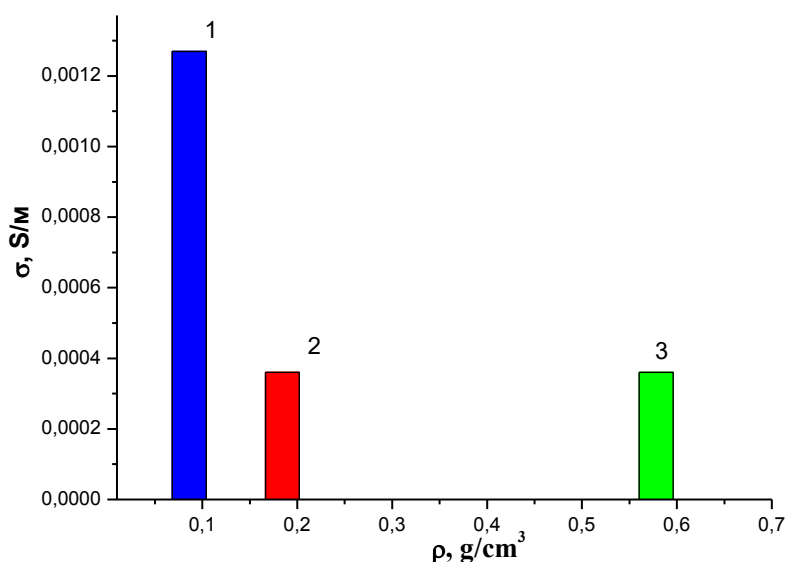


Fig.2. Comparison conductivity and density different types of carbon powders

1. Modified carbon, CNK; 2. Acetylene soot (black); 3. Graphite BG-34. Superior Graphite Co.

Results presented on the Fig.2 illustrate that the conductivity of the innovating carbon / graphite that has been fabricated using the developed of the method of modification has high level of the conductivity as compare with other carbon materials that are using in Li-ion battery industry.

Modified carbon / graphite has a low level of the density. This is a positive important factor because due to low level of density, this electron conductive powder can be evenly distributed over the volume of the electrode material.

Illustration the structure of modified carbon / graphite using the scanning electron microscopy.

ESM of the plates from the different samples of modified graphite. Initial graphite is a side material from metallurgical process.

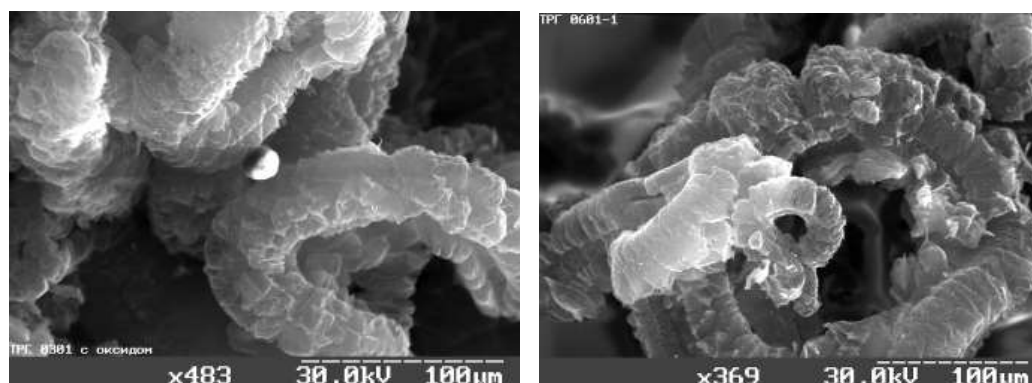


Fig. 3. Scanning electron microscopy the samples of modified graphite

Parameters of graphite modification allow control of the graphite plane structure and electrochemical properties of anode.

Comparison electrochemical properties anodes based on the modified and non-modified graphite in non-aqueous electrolytes.

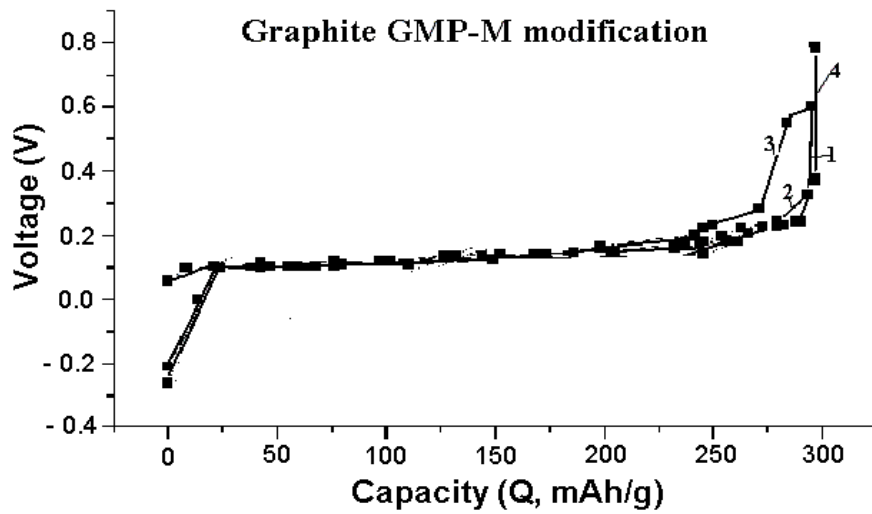


Fig. 4. Discharge characteristics of the anode based on the modified graphite

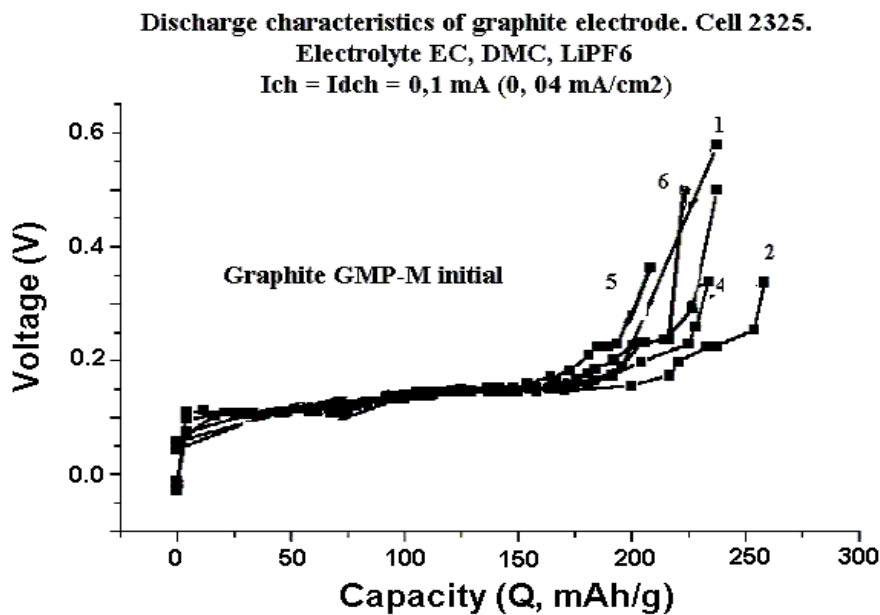


Fig. 5. Discharge characteristics of the anode based on the unmodified graphite

Coin cell 2325. Electrolyte: EC, DMC, LiPF₆

Discharge current: 0.1 mA or 0, 04 mA/cm² Charge current: 0.1 mA or 0, 04 mA/cm²

Presented results confirm that the discharge capacity of the anode based on the modified graphite is higher than the discharge capacity of the anode based on the unmodified graphite. Also, during cycling the parameters of anode based on the modified graphite are stable, while the parameters of anode based on the unmodified graphite are not stable.

It means that the Li-ion batteries with anode based on the modified graphite will have a high level energy, and effective parameters during battery cycling

Conclusions.

1. The developed method of modification carbon material results in providing high energy and power characteristics of anode of Li - ion batteries.

2. Anode based on modified graphite CNS has a high electronic conductivity, low density, and high energy during discharge, stability parameters during cycling. and allows to produce flexible lithium batteries with high energy.

3. Using as a source material for modification of natural Ukrainian graphite, or metallurgical wastes ensures low cost of the developed innovative carbon material for lithium current sources.

4. In following article we will be presenting results of development technology of fabricating anode based on the modified carbon.

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