From the Editor

This section of the journal publishes a material about the defense of the first doctoral dissertation in our country on graphene topics. Scientific consultant of the work - Doctor of Chemical Sciences, Full Member of the Russian Academy of Natural Sciences, Professor Gubin Sergei Pavlovich, Chief Researcher of the N.S. Kurnakov Institute of General and Inorganic Chemistry of the Russian Academy of Sciences, scientific head of "AkKo Lab" LLC.

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Graphene oxide - a new electrode nanomaterial for chemical current sources

Denis Yu. Kornilov

"AkKo Lab" LLC, http://www.akkolab.ru/

Moscow 107143, Russian Federation

E-mail: kornilovdenis@rambler.ru

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Abstract: **The material of the defense of the dissertation for the degree of Doctor in Engineering Sciences is presented. The relevance of the search for new electroactive nanomaterials for current sources of portable electronic equipment in conditions of its high energy consumption with its miniaturization and increase in performance is noted, the object of research is characterized – graphene oxide as a cathode material for lithium chemical current sources, the formulation of research tasks is formulated, the physicochemical methods of analysis.**

Keywords: **chemical current sources, cathode materials graphene oxide**

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15 of December 2020, at the Dissertation Council 05.07 of the D.I. Mendeleev Russian University of Chemical Technology, Denis Kornilov defended his dissertation work on the theme "Graphene oxide – a new electrode nanomaterial for chemical current sources" for the degree of Doctor in Engineering Sciences. In the report of the doctoral candidate was outlined: the relevance of the search for new electroactive nanomaterials for current sources of portable electronic equipment in the conditions of its high energy consumption with its miniaturization and increased speed was noted, the object of research – graphene oxide as a cathode material for lithium chemical current sources (in contrast to transition metal oxides – cathode materials of widespread use), formulated the research tasks, the physical and chemical methods of analysis are listed. The object of research was a wide range of functional materials based on graphene oxide with different stoichiometry, size and shape:

- Graphene oxide films obtained from the dispersion of graphene oxide by the spin-coating method;
- Graphene oxide films obtained from the dispersion of graphene oxide by the dip-coating method;
- Films of reduced graphene oxide obtained from by directed heating of the surface of the graphene oxide dispersion;

- Spheres made of reduced graphene oxide obtained by drip injection of heated oil into the graphene oxide dispersion;
- Aerogels based on graphene oxide obtained by freeze-drying of highly concentrated dispersion of graphene oxide.

Here it is necessary to clarify that in accordance with the ISO/TS 80004-13 dictionary of the International Organization for Standardization [1], graphene materials include:

- Graphene is a monolayer of carbon atoms;
- Double-layer graphene is a material consisting of two layers of carbon;
- Three-layer graphene is a material consisting of three layers of carbon atoms;
- Few-layers graphene is a material containing from 3 to 10 layers of carbon atoms;
- Turbostratic double-layer graphene – double-layer graphene whose layers are in an arbitrary azimuthal orientation relative to each other;
- Graphene oxide (GO) is a chemically modified graphene produced by the oxidation and exfoliation of graphite;
- Reduced graphene oxide (RGO) is a form of graphene oxide after chemical, thermal, microwave, photochemical, photothermal, or microbial/bacterial recovery.

This classification is consistent with publications [2-4] which indicated the presence of practically confirmed unique properties in graphene materials consisting of no more than 10 layers of carbon atoms.

For example, single-layer graphene has a large surface area, which is 2640 m^2/g [5], high electrical conductivity, high mobility of current carriers ($2 \cdot 10^5$ $cm^2/(V \cdot s)$) [6].

Graphene can withstand currents exceeding 10^7 A/cm^2 [7].

Graphene is a strong material with Young's modulus of 1TPa [8], it can undergo 20% deformation without breaking the crystal lattice [9].

The thermal conductivity of a graphene monolayer is 5000 W/(m·°C) [10], which is 10 times higher than the values of copper.

The optical transmission coefficient in graphene reaches 97.7% [11].

Also, the advantages of graphene materials include the possibility of obtaining them in various ways, while various methods and technological techniques for the synthesis of graphene materials allow them to be obtained in various forms, which can be attributed to another advantage of this material. Changes in the properties of the objects of study from the conditions of production, heat treatment conditions, and the reducing agents used were established and analyzed.

The obtained results served as the basis for the study of the possibility of using graphene oxide in secondary chemical current sources (lithium-ion batteries) as an additive in cathode materials, namely, coatings of reduced graphene oxide on the surface of microparticles of the cathode material of the composition $LiNi_{0.33}Mn_{0.33}Co_{0.33}O_2$ flows; corrosion inhibitor of the current collector, namely, a coating of graphene oxide on the surface of an aluminum current collector; an anode material in the form of hollow spheres of reduced graphene oxide; cathode materials in the form of films, powders and aerogels of graphene oxide. At the same time, the results of electrochemical studies of graphene oxide allowed us to establish high values of the electrochemical potential and high values of the irreversible energy intensity depending on the surface area of the objects of study, which indicated the direction of further research, namely, to establish the influence of the degree of oxidation and surface area on the energy-intensive characteristics of graphene oxide aerogels.

Also, complex physicochemical research methods were used to analyze graphene oxide-based aerogels as they were discharged. As a result, it was found that during the electrochemical reduction of graphene oxide, particles of about 20 nm in size are formed on its surface, the number of which increases when the discharge reaches 2.0 V, and when the voltage reaches 1.5 V, a sufficiently dense layer of particles is observed, which, when the voltage reaches 1 V, takes the form of a solid massive coating. The results allowed us to determine the products formed during the discharge on the surface of graphene oxide, which in turn served as the basis for establishing current-forming processes. Based on the obtained data, the theoretical capacity of graphene oxide reaching 3292 C was calculated, which exceeds the values of the discharge capacity of known cathode materials used in the production of primary chemical current sources by 1.5-3 times.

Thus, the presented chain of consecutive interrelated studies of graphene oxide allowed us to establish the practical possibility of its direct application as a high-energy cathode material of primary lithium chemical current sources since practical results were obtained at the level of 721 mAh/g. Based on the practical results, the model of the prototype of the electrochemical cell of the lithium|graphene oxide system is calculated, the specific (weight) energy intensity of which exceeds the values of the specific (weight) energy intensity of the galvanic cells produced by industry by 25-400%, which in turn is of important socio-economic and economic importance since high-energy-intensive primary chemical current sources open up wide opportunities for autonomous electronic devices.

The results obtained in the dissertation work create a foundation for technical and technological solutions for the using of graphene oxide, and information about the electrochemical properties of functional materials based on graphene oxide will be in demand in the laboratory and technological processes when designing and predicting the characteristics of innovative chemical current sources, the introduction of which will make a significant contribution to scientific and technical development.

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