Graphene oxide – a new electrode nanomaterial for chemical current sources

Kornilov Denis Yurievich

Abstract

Scientific and technical progress in the field of nanotechnology has contributed to the creation of new functional nanomaterials with unique physical and chemical properties, which gave a rapid impetus to the development of electronic technology. Over the past few years, a lot of attention in many research laboratories has been focused on the research of graphene materials. It should be clarified that according to the ISO/TS 80004-13 dictionary of the international organization for standardization, graphene materials include:

Graphene – single layer of carbon atoms with each atoms bound to three neighbours in a honeycomb structure;

Bilayer graphene – two-dimensional material consisting of two well-defined stacked graphene layers;

Trilayer graphene – two-dimensional material consisting of three well-defined stacked graphene layers;

Few-layer graphene two-dimensional material consisting of three to ten well-defined stacked graphene layers;

Graphene oxide (GO) – chemically modified graphene prepared by oxidation and exfoliation of graphite, causing extensive oxidative modification of the basal plane;

Reduced graphene oxide (RGO) – reduced oxygen content form of graphene oxide/ This can be produced by chemical, thermal, microwave, photo-chemical, photo-thermal or microbial/bacterial methods or by exfoliating reduced graphite oxide.

But, in the group of graphene materials, graphene oxide is considered as an intermediate in the production of reduced graphene oxide (a material very close in properties to ideal graphene), since the combination of properties of graphene oxide is not as unique as that of graphene. However, graphene oxide is characterized by hydrophilicity, high chemical activity, proton conductivity, and the possibility of changing in stoichiometric composition, the number and type of oxygen-containing functional groups during synthesis or subsequent reduction using various reducing agents or reduction conditions, which allows to vary GO properties and generally consider graphene oxide as an independent nanomaterial with a wide range of applications, this, in turn, indicates the relevance of developing nanostructured functional materials. For example, the use of various levels of reduction of GO allows creating multipolar electrodes of lithium-ion batteries and supercapacitors, various oxygen-containing functional groups contained on the surface of graphene oxide can be a substrate for the formation of transition metal nanoparticles and the creation of photocatalysts or chemical and biological sensors based on such a composite, graphene oxide membranes are capable of selective separation of gases and metal ions.

The relevance of the work determined by the comprehensive research of the properties of nanostructured functional materials based on graphene oxide. The performed research fills in the gaps about several practically important properties of graphene oxide, as well as determines the conditions for obtaining nanostructured functional materials based on graphene oxide and their application. The dissertation developed physical and chemical principles for creating nanostructured functional materials (films, microspheres, aerogels) based on graphene oxide, conducted comprehensive studies of their structure and properties, and analyzed the possibility of using the obtained materials to modify existing and create new electrode-active components of chemical source of electric energy. The possibility of using graphene oxide as the main current-forming component of the cathode of primary lithium chemical source of electric energy is proposed and demonstrated. Presented process of electrochemical reduction of graphene oxide in a lithium electrolyte.

The purpose of the dissertation is to develop physical and chemical principles for creating functional nanostructured materials based on graphene oxide, to establish the features of their structure and properties, to determine the possibility of their use for modifying existing and creating new electrode-active components of chemical source of electric energy. Establishing the process of electrochemical reduction of graphene oxide by studying the reaction products formed in this process.

Main tasks were:

1. Analysis of the possibility of changing the content of oxygen-containing functional groups in graphene oxide by changing the synthesis conditions;

2. Study of the process of chemical and thermal recovery of graphene oxide thin films;

3. Development of a method for obtaining films with specified characteristics from graphene oxide dispersion;

4. Development of a technique for obtaining microspheres from graphene oxide dispersion;

5. Development of a method for obtaining aerogel with specified characteristics from graphene oxide dispersion;

6. Investigation of electrochemical characteristics of the obtained functional nanostructured materials;

7. Investigation of structural and chemical changes in graphene oxide during electrochemical reduction;

8. Investigation of the possible mechanism of the process of electrochemical reduction of graphene oxide in a lithium electrolyte.

Scientific novelty:

1. For the first time presented a method for producing thin films based on reduced graphene oxide by directed heat treatment of the surface of the water dispersion of graphene oxide with a stream of heated air;

2. Established the possibility of regulating the surface area, structure and composition of aerogels based on graphene oxide by changing the synthesis conditions has been;

3. Presented the distinction electrochemical properties of graphene oxide depending on the forms (films, powders, and aerogels);

4. In contrast to traditional metal-containing electrode materials used in lithium power sources was first proposed and demonstrated the use of graphene oxide as electrode-active material for primary lithium battery cathode;

5. Presented the change of structure, surface morphology and composition of the graphene oxide during the electrochemical reduction;

6. The proposed process of the electrochemical reduction of graphene oxide in a lithium electrolyte.

The practical significance of the work

This work is aimed at solving the problems of developing new functional nanomaterials with specified properties based on graphene oxide and creates a foundation for technical and technological solutions for the use of graphene oxide. The obtained information about the properties of functional materials based on graphene oxide will be in demand in laboratory and technological processes when designing and predicting the characteristics of chemical chemical source of electric energy.

The developed method for producing thin films based on reduced graphene oxide by directed heat treatment of the surface of the water dispersion of graphene oxide with a stream of heated air opens new opportunities for obtaining carbon coatings with specified properties.

The developed method for obtaining porous electrodes based on graphene oxide opens the possibility of creating promising high-energy chemical source of electric energy.

The practical feasibility of creating a galvanic cell based on graphene oxide with a specific energy exceeding 700 mAh/g opens wide opportunities for Autonomous electronic devices.

Defense Provisions

1. Technological features of obtaining functional nanostructured materials (films, microspheres, aerogels) based on graphene oxide;

2. Results of research of physical and chemical properties of nanostructured materials (coatings, films, microspheres, aerogels) based on graphene oxide;

3. Electrochemical characteristics of functional materials based on graphene oxide in lithium chemical current sources;

4. Results of complex experimental studies of the influence of synthesis modes and parameters on the main characteristics of functional nanostructured materials based on graphene oxide, which determine the design criteria for power supplies;

5. The process of electrochemical reduction of graphene oxide in a lithium electrolyte.