REVIEW
of the scientific adviser Doctor of physical-mathematical science
Professor A.M. Ilyin

for the thesis of Kuanyshbekov Tilek Kuanyshbekuly

"Researching the properties of functionalized few-layer graphene nanostructures" submitted for the degree of Doctor of Philosophy (Ph.D.)
in the specialty
6D071000 – Material science and technology of new materials

Currently, due to its unique mechanical, electrical and optical characteristics, graphene, functionalized graphene, and its related structures continue to show interest in various fields of science and technology. One of the important directions in the study of graphene is the study of its functionalization, for example, graphene oxide, which can be referred to as functionalized few-layer graphene (FFLGN). Graphene oxide (FFLGN) is an oxide form of graphene, which is an atomic-thin sheet-like material dispersed in water, which has numerous oxygen-containing groups, where oxygen is introduced into graphene by chemical oxidation. When graphene is functionalized with strong acids such as H_2SO_4, HNO_3, $KMnO_4$, bulk graphite will have hydroxyl and epoxy groups on their main plane, as well as carbonyl and carboxyl groups at the edges, with the result that functionalized graphene becomes a semiconductor, as a result, unlike graphene, its field of practical application will expand significantly. In this regard, functionalized graphene is an actual material and has a wide range of applications in semiconductor electronics for creating biosensors, supercapacitors, various gas sensors, humidity sensors, organic electrodes, LEDs, etc.

Thesis work of Kuanyshbekov T.K. is devoted to the synthesis and computer simulation of FFLGN, obtaining of FFLGN films and membranes and investigation of their physicochemical properties after thermal reduction at various temperatures. Kuanyshbekov T.K. assimilated the methods of computer simulation and quantum-mechanical calculations, has worked out technology for producing FFLGN using the modified Hammers method, FFLGN films, and membranes (obtained using the vacuum filtration method). FFLGN films were thermally reduced in air at temperatures: 80 °C, 120 °C, 160 °C, 200 °C, 240 °C, 280 °C, and their optical and electrical properties were investigated, and the influence of temperature on the structure and composition of the FFLGN membrane after thermal reduction in a hydrogen atmosphere at next temperatures: 150 °C, 300 °C, 500 °C, 900 °C were studied. The TGA of FFLGN was performed and the optimal modes of heat treatment of films and membranes of FFLGN were determined at which the functional oxygen-containing groups were removed, as a result of which the optical and electrical characteristics changed. A humidity sensor based on an FFLGN membrane was created, and its electrophysical characteristics were studied.

The research performed by the Kuanyshbekov T.K. is a well-structured, complete, holistic work. The results of the study of the properties of FFLGN have the following scientific and practical significance: the process of functionalization of graphene by the oxidation with such strong oxidizing agents as H_2SO_4, HNO_3, $KMnO_4$ leads to the production of graphene in large volumes; the possibility of changing the electrical and optical properties of FFLGN films by removing functional oxygen-containing groups at various temperatures of thermal reduction in air and hydrogen atmosphere are shown, also reduced FFLGN thin films potentially can be used in optoelectronics, electronics, nanoelectronics, etc .; In addition, another important scientific and practical significance in the study FFLGN is thermally reduced FFLGN membranes, which have a developed layered structure, that allows them to be considered as promising materials in the manufacture of electronic devices, electrical sources, in particular, lithium-ion batteries, and they can also be used in gas sensors, biosensors, and humidity sensors;

Research results by Kuanyshbekov T.K. quite fully reflected in 9 scientific publications, 3 of which were published in the proceedings of international conferences, 4 articles in national journals of the Committee's list for publishing the main results of dissertations for the PhD degree and 2 articles in scientific journals with impact factor, which is included in the Web of Science and Scopus databases.

Kuanyshbekov T.K. in the course of work on his thesis, he showed himself to be an active, hardworking, responsible, qualified specialist in his field, able to independently conduct research using various experimental methods, participated in the calculation of the density functional theory (DFT) to create computer models of FFLGN. He passed a scientific internship in the period from April 13 to June 30, 2018, under leadership Dr. G.W. Beall at Texas State University, San Marcos, Texas, USA. In the period of scientific internship, Kuanyshbekov T.K. performed experimental work on the topic of the thesis and the results of the researching the properties of FFLGN were obtained during an internship.

Considering the above, I consider that in terms of the results obtained in the thesis, the personal qualities of the applicant, the thesis of Kuanyshbekov Tilek Kuanyshbekuly " Researching the properties of functionalized few-layer graphene nanostructures" meets the qualification requirements for dissertations for the Ph.D. degree, and Kuanyshbekov T.K. deserves awarding of the Ph.D. degree in the specialty 6D071000 - "Materials Science and Technology of New Materials".

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Doctor of physical-mathematical science
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