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**To Whom It May Concern**

**REVIEW**  
**of the foreign scientific consultant Doctor of physical-chemistry**  
**Professor G.W. Beall**

**for the thesis of Kuanyshbekov Tilek Kuanyshbekuly**

**“Researching the properties of functionalized few-layer graphene nanostructures” submitted for the degree of Doctor of Philosophy (PhD) in the specialty**  
**6D071000 – Material science and technology of new materials**

Graphene, functionalized graphene, in particular graphene oxide (GO) and other carbon materials are of great interest for the scientific community due to such unique properties as: high level of thermal and electrical conductivity, strength and excellent adsorption characteristics. One of the main directions in the study of graphene is GO which has another name such 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.

The most attractive property of FFLGN is the change in its electrical and optical characteristics, which is realized by removing functional oxygen-containing groups using thermal reduction of FFLGN films and membranes in air and hydrogen atmosphere at optimum temperature conditions. Also, thermal reduction contributes to the production of graphene and graphene-like materials in a large-scale quantity, which is still an actual problem and to this day researchers are trying to achieve a large-scale and more affordable production technology.

Thesis work of Kuanyshbekov T.K. on the topic "Researching the properties of functionalized few-layer graphene nanostructures" is devoted to the synthesis and computer simulation of FFLGN, production of FFLGN films and membranes and investigation of their physicochemical properties after thermal reduction at various temperatures.

Kuanyshbekov T.K. passed a scientific internship in the period from April 13 to June 30, 2018, under my leadership at Texas State University, San Marcos, Texas, USA. During the scientific internship, Kuanyshbekov T.K. performed experimental work on the topic of the thesis. In the process of performing the experimental part, he did the following types of work: thermal reduction of the FFLGN membrane in a hydrogen atmosphere at temperatures: 150 ° C, 300 ° C, 500 ° C, 900 ° C; study of the influence of temperature on the structure and composition of the membrane FFLGN. After thermal reduction, the samples were investigated in the following instruments: Thermogravimetric analysis (TGA Q50), X-ray diffraction (XRD), Raman spectroscopy. It was found that heat treatment of the FFLGN membrane affects the change in intensities and the ratio of the Raman spectroscopy bands, as well as the decrease in the interplanar distance  $d$  from 1.1 to 0.3 nm, the thickness decreases from about 22 to 14  $\mu\text{m}$ , which is explained by a decrease in the average size of the  $\text{sp}^2$  domains in the structure and removal of oxygen-containing functional groups. 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.

Kuanyshbekov T.K. successfully completed the tasks, and also distinguishes himself with such personal qualities as: high level of activity, responsibility for the assigned work, and hard work. The research performed by the author is a well-structured, complete, holistic work. According to the obtained results, I can highlight the main scientific and practical significance, that the synthesized FFLGN membrane and its thermally reduced samples have a well developed layered structure, which was investigated by an electron microscope that is promising materials as gas sensors, in particular, humidity sensors.

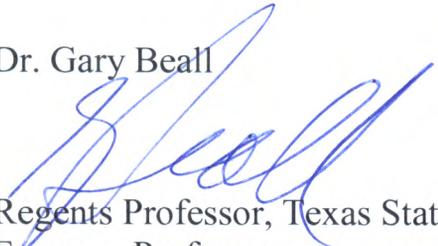
Thesis Kuanyshbekov T.K. contains a significant amount of experimental material based on a comprehensive approach to solving research problems. The results of the research work have been reviewed and discussed many times with a positive assessment from national and international conferences. The main results are published in 9 publications.

As a scientific co-advisor of Kuanyshbekov Tilek Kuanyshbekuly, considering the above, I consider that in terms of the results obtained in the

thesis, the personal qualities of the applicant, the dissertation by Kuanyshbekov Tilek Kuanyshbekuly "Researching the properties of functionalized few-layer graphene nanostructures" meets the qualification requirements of an international standard for a Ph.D. and I strongly endorse it for the presentation to the Dissertation Council of your University and Kuanyshbekov T.K. deserves awarding of the Ph.D. degree in the specialty 6D071000 - "Materials Science and Technology of New Materials".

Sincerely yours,  
A foreign scientific advisor  
Doctor of physical-chemistry  
Professor

Dr. Gary Beall



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