REVIEW
of the official reviewer for the thesis work
of Tulegenova Malika Askarovna on the topic "Anticorrosion protective coatings based on graphene nanostructures", provided for the degree of Doctor of Philosophy (PhD) in the specialty "6D071000 - Materials Science and Technology of New Materials".

№	Criteria	Compliance with the criteria (one of the options must be marked)	Justification of the position of the official reviewer
1.	The topic of the thesis (as of the date of its approval) corresponds to the directions of development of science and/or state programs	1.1 Compliance with priority directions of science development or state programs:	Thesis work of Tulegenova Malika Askarovna corresponds to the priority directions of science development and state programs in the field of materials science.
		1) The thesis was carried out within the framework of a project or target program funded from the state budget (specify the name and number of the project or program) 2) The thesis was carried out within the framework of another state program (specify the name of the program) 3) The thesis corresponds to the priority direction of science development, approved by the Higher Scientific and Technical Commission under the Government of the Republic of Kazakhstan (specify the direction)	The thesis was carried out within the grant financing for 2018-2020 - № AP05130413 «Development of technology for creating protective coatings based on functionalized graphene nanostructures and researching their properties».
2.	Importance for science	The work **makes** a significant contribution to science, and its importance is **well disclosed**	Thesis work makes a significant contribution to science, as the results obtained are new and of interest in the physics of nanomaterials and materials science. The importance of the thesis work is well disclosed by the author and lies in the demonstration of the effectiveness of anticorrosion protective coatings based on graphene nanostructures.
3.	Principle of independence	Level of independence: 1) High; 2) Medium; 3) Low;	A significant amount of the thesis work was carried out by the author independently. A lot of work with literature sources has been done,

		4) There is no independence	which is reflected in the literature review. Computer models and theoretical calculations were carried out using the DFT method in Dmol3 module of the Materials Studio program. Also the author independently conducted experimental studies of anticorrosion protective coatings based on graphene nanostructures, including obtaining, processing and analyzing the results.
4.	Principle of internal unity	4.1 Justification of the relevance of the thesis: 1) Justified; 2) Partially justified; 3) Not justified	The relevance of the thesis work is sufficiently justified. The thesis work is devoted to the theoretical and experimental studies of the anticorrosion protective coatings based on graphene nanostructures. The relevance of the work is well disclosed in the introduction and is mainly related to the use of coatings, which should demonstrate reliable protection of metal surfaces (copper and nickel) from corrosion under the influence of external factors. Also calculations of computer simulation can predict and evaluate the anticorrosion protective properties of graphene nanostructures at the nanoscale. Consequently, the relevance of the thesis work is beyond doubt.
		4.2 The content of the thesis reflects the topic of the thesis: 1) Reflects; 2) Partially reflects; 3) Does not reflect	The thesis consists of an introduction, three sections, a conclusion and a list of references, which in their content reflect the research topic "Anticorrosion protective coatings based on graphene

			nanostructures".
		4.3 The purpose and the tasks correspond to the topic of the thesis: 1) correspond; 2) partially correspond; 3) do not correspond	The purpose and the tasks of the research correspond to the topic of the thesis. The purpose is set in such a way as to give an understanding of the main directions in which the author reveals the topic of the thesis, and the tasks, in turn, give an understanding of the main stages of the research work.
		4.4 All sections and provisions of the thesis are logically interconnected: 1) completely interconnected; 2) the interconnection is partial; 3) there is no interconnection	All sections of the thesis, the main provisions for the defense, the results and the conclusion are consistent with each other and correspond to the topic of the thesis. The presented thesis work is a completed work.
		4.5 New solutions (principles, methods) proposed by the author are reasoned and evaluated in comparison with known solutions: 1) there is a critical analysis; 2) the analysis is partial; 3) the analysis does not represent the one's own opinions, but quotes from other authors	New solutions (principles, methods) proposed by the author, consisting in the development of technology for obtaining and research the effectiveness of anticorrosion protective coatings based on graphene nanostructures, are reasoned and evaluated in comparison with known solutions. There is a critical analysis.
5.	Principle of scientific novelty	5.1 Are the scientific results and provisions new? 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	The scientific results and the main provisions for the defense are completely new. In particular, with the direct participation of the author, was developed a specialized electrostatic energy analyzer for Auger electron spectroscopy, allowing to analyze ultrathin layers of anticorrosion protective coatings based on graphene nanostructures.
		5.2 Are the conclusions of the thesis new? 1) completely new;	The conclusions of the thesis are completely new. Conclusions are made

		2) partially new (25-75% are new); 3) not new (less than 25% are new)	based on the results of a detailed analysis of the experimental data. Conclusions are presented at the end of each section, and the final summarizing conclusions are indicated in the conclusion.
		5.3 Technical, technological, economic or management decisions are new and reasonable: 1) completely new; 2) partially new (25-75% are new); 3) not new (less than 25% are new)	Technical, technological, economic or management decisions are new and reasonable. In the theoretical study of anticorrosion coatings, a new solution was the use of computer simulation and quantum-mechanical numerical calculations by the DFT method, which allows us to obtain sufficiently accurate information about the properties of the studied complex nanosystems and predict their behavior under various external factors. An important technical and technological solution is the creation of the Conical Face-Field Electrostatic Energy Analyzer, which due to its simple and convenient design allows to analyze the graphene nanostructures directly in the growth chamber.
6.	Validity of the main conclusions	All the main conclusions are **based** on scientifically sound evidence or well grounded (for qualitative research and areas of study in the arts and humanities)	Based on the thesis materials 11 publications were made, including 3 articles published in journals recommended by the Committee for Control of Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 3 articles was published in the journals, which included in Scopus database, 1 article in international journal and 4 abstracts published at national and international conferences. The author's publications

			demonstrate the good validity of the main conclusions.
7.	The main provisions for the defense	It is necessary to answer the following questions for each provision separately: 7.1 Is the provision proven? 1) proven; 2) rather proven; 3) rather not proven; 4) not proven 7.2 Is it trivial? 1) yes; 2) no 7.3 Is it new? 1) yes; 2) no 7.4 Level for application: 1) narrow; 2) medium; 3) wide 7.5 Is it proven in the article? 1) yes; 2) no	The main provisions for the defense of the thesis: 1. Ideal graphene, graphenes with structural defects in the form of vacancy, divacancy and a small gap in the sheet (0.25 nm) have a high efficiency of protective effect against oxygen penetration due to the formation of a potential barrier when the oxygen molecule interacts with the surface of the graphene layer. 7.1 proven 7.2 no 7.3 yes 7.4 wide 7.5 yes 2. In the graphene sheet with sufficiently large gaps (0.45 nm) the maintenance of high efficiency of protective effect against oxygen penetration is achieved by its functionalization with impurity gallium atoms due to the formation of a strong Ga-C covalent bond (2.6 eV) and high oxygen adsorption energy of gallium (1.8 eV). 7.1 proven 7.2 no 7.3 yes 7.4 medium 7.5 yes 3. Anticorrosion graphene coatings obtained by chemical vapor deposition demonstrate reliable protection of copper and nickel surfaces from thermal

			corrosion, which is associated with the high quality of the coatings (D/G ratio ≈ 0.08). 7.1 proven 7.2 no 7.3 yes 7.4 wide 7.5 yes 4. Auger spectrometer, designed and implemented using the Conical Face-Field Electrostatic Energy Analyzer (R_E ≈ 0.71 % for γ = - 0.04 and R_E ≈ 0.60 % for γ=0), allows to control both small and large areas of anticorrosion graphene coatings, as well as their structures in situ. 7.1 proven 7.2 no 7.3 yes 7.4 wide 7.5 yes
8.	Principle of reliability Reliability of sources and information provided	8.1 Choice of methodology –is justified or methodology is described in sufficient detail: 1) yes; 2) no	The choice of methodology is justified by the modern generally accepted scientific theories of solid state physics and spectroscopy. The general methodological basis of the thesis is a comprehensive approach, including analysis and generalization of fundamental research.
		8.2 The results of the thesis work were obtained using modern methods of scientific research and methods of processing and interpreting data using computer technologies: 1) yes; 2) no	All the results of the thesis work were obtained using modern methods of scientific research and experimental data processing. Technology of obtaining graphene nanostructures by chemical vapor deposition, obtaining graphene nanostructures by the diffusion method

			under vacuum conditions, obtaining graphene oxide films were carried out on the basis of experimental facilities.
		8.3 Theoretical conclusions, models, identified relationships and regularities have been proved and confirmed by experimental research (for areas of training in the pedagogical sciences the results have been proved on the basis of a pedagogical experiment): 1) yes; 2) no	The experimental results obtained in the course of the work are in good agreement with the theoretical conclusions made on the basis of computer simulation and quantum-mechanical calculations of the effectiveness of the protective action of coatings based on graphene nanostructures against oxygen penetration.
		8.4 Important statements are **confirmed** by references to relevant and reliable scientific literature	Important statements are confirmed by references to relevant and reliable scientific literature.
		8.5 Used literature sources are **sufficient** for a literature review	The list of references includes 232 references to scientific sources, including 11 publications of the author. Therefore, it is safe to say that used literature sources are sufficient for a literature review.
9	Principle of practical value	9.1 The thesis has a theoretical value: 1) yes; 2) no	Thesis has a theoretical value. The results of the work can be used in the field of materials science and physics of nanomaterials in the study of ultrathin anticorrosion coatings.
		9.2 The thesis is of practical importance and there is a high probability of applying the results obtained in practice: 1) yes; 2) no	Thesis is of practical importance and there is a high probability of applying the results obtained in practice, as the problem of corrosion is a significant problem, especially in industrialized countries.
		9.3 Are the suggestions for practice new? 1) completely new; 2) partially new (25-75% are new);	The methods for obtaining and studying ultrathin anticorrosion coatings proposed in the thesis work are completely new

		3) not new (less than 25% are new)	and can contribute to the advancement of research in this direction.
10.	Quality of writing and design	The quality of academic writing is: 1) high; 2) average; 3) below average; 4) low.	The thesis is written in a very high quality, accessible and competent language, using professional terminology in the field of materials science.

Conclusion on the possibility of awarding the degree of Doctor of Philosophy (PhD)

Thesis work performed on the topic: "Anticorrosion protective coatings based on graphene nanostructures" is a completed research work, which, due to its scientific novelty and practical significance meets all the requirements of the rules of awarding the degree of Doctor of Philosophy (PhD) of the Committee for Quality Assurance in the Field of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan, and its author Tulegenova Malika Askarovna deserves to be awarded the degree of Doctor of Philosophy (PhD) in the specialty "6D071000 - Materials Science and Technology of New Materials".

Official reviewer:

Vice-rector for Global Partnership and Lifelong Learning
JSC International University of Information Technologies
PhD, associate professor

(sign)

Daineko Yevgeniya

Подпись указанного лица удостоверяю