OPINION

on a dissertation for the acquisition of the educational and scientific degree "doctor" in the professional field 4.1 "Physical Sciences", scientific specialty: "Electrical, optical and magnetic properties of condensed matter", under the defense procedure at the Institute of Optical Materials and Technologies "Acad. Yordan Malinovski" - BAS

Topic of the dissertation: "Obtaining nano-sized layers of 2d materials for applications in optoelectronics"

Author of the dissertation: Nikolay Diyanov Minev

Scientific supervisor: Prof. Dr. of Science Vera Marinova

Prepared the opinion: Prof. Dr. of Science Evgeniya Petrova Valcheva, Sofia University "St. Kliment Ohridski", Faculty of Physics, according to Order No. RD-15-311 / 15.04.2026

The presented dissertation work includes 160 pages, 55 figures, 7 tables and 271 cited specialized literary sources. It contains an introduction, relevance, purpose and structure of the dissertation, five chapters, conclusion and main contributions of the dissertation. Also included are a list of author's publications used in the dissertation, participation in international conferences, national forums and seminars, a list of noted citations. Additionally, participation in projects on the topic of the dissertation, a list of tables and figures, a list of main symbols and abbreviations are presented.

The aim of the dissertation is to establish the optimal conditions for the synthesis of transition (noble) metal dichalcogenides (TMDCs) and to investigate their properties and optoelectronic applications.

The first three chapters are overviews, presenting basic properties and applications of 2D materials, such as graphene, transition metal dichalcogenides, and transition noble metal dichalcogenides. Basic methods for the preparation and synthesis of transition metal dichalcogenides and basic characterization methods in modern condensed matter physics are comprehensively presented.

From the experimental part, the fourth chapter presents the main results of the technological process for the deposition of nanoscale PtSe2 and PtTe2 layers by Thermally Assisted Conversion (TAC), PtSe2 with liquid precursors and PtSe2 and PdSe2 by CVD method. The synthesis of 3D single crystals of PdSe2, obtained by the high-temperature solution method, is also included. The influence of technological parameters (temperature, pressure, gas flow rate, type of precursors) on the synthesis of TMDCs layers is studied to achieve controllable growth of single-layer and multilayer structures with high spatial homogeneity over a large area. The resulting layers were thoroughly and correctly characterized by Raman spectroscopy, XPS, XRD, AFM, TEM and ellipsometry. As a result, recipes for successful synthesis of TMDCs with noble metals were developed, with the resulting layers having nanoscale thicknesses that are stoichiometric and with precise thickness control.

Chapter five is dedicated to the study of optoelectronic applications and more precisely three applications are developed: applications of transparent, conductive PtSe2 nanolayers as light switches based on polymer-dispersed liquid crystals (PDLC); application of PdSe2 in a field-effect transistor and application of PtSe2 as antibacterial coatings against Escherichia coli. Here, it is shown for the first time that 7nm thick PtSe2 layers work effectively as light switches in the near infrared region (1064 nm). The application of PdSe2 as an active element in field effect transistors (FET) has been demonstrated and good electrical conductivity, light sensitivity and high air resistance have been demonstrated. High antibacterial activity of PtSe2 layers against Escherichia coli has been proven. It has been found that upon UV irradiation, the viability of the bacteria decreases to 1.2%, which is due to the photocatalytic generation of reactive oxygen species (ROS). Thus, the main goals of the dissertation have been achieved, namely the development of technological methods for the synthesis and characterization of new 2D materials from the group of transition metal dichalcogenides (TMDCs) - specifically platinum diselenide (PtSe2), platinum ditelluride (PtTe2) and palladium diselenide (PdSe2) - and demonstration of their applications in optoelectronics and biotechnology.

The main contributions of the dissertation can be defined as:

1. The methods of thermally assisted conversion (TAC) and chemical vapor deposition (CVD) at low pressure have been successfully optimized for obtaining nanoscale layers with controlled thickness on various substrates at lower temperatures and atmospheric pressure.

2. A relationship between the synthesis conditions and the physical characteristics of the materials (structural, morphological and optical) has been established.

3. The potential of PtSe2 as a transparent conductive material in liquid crystal devices (PDLC) has been demonstrated, offering competitive characteristics compared to standard ITO, especially in the infrared region. 4. A strong antibacterial effect of PtSe2 layers activated by light has been established, which opens the way to the creation of new types of self-disinfecting surfaces and sensors.

The dissertation is based on four publications, two of which are in quartile Q1, one in quartile Q2 and one in conference proceedings, thus satisfying the requirements of the law. All four publications are co-authored, with the dissertation candidate being the first author in two and second in two publications, which I consider to be indicative of his leading participation. This is also evidenced by the large number of citations, 11 to date. The number of participations in international conferences – 18 and in national forums and seminars – 4 is also significant.

The dissertation candidate has a thorough knowledge of the issues, both the theoretical statements and the experiment and the requirements of the practical applications. The list of literary sources is extensive. The presented material is analytically precise and the conclusions and generalizations are clearly stated. The scientific and applied results represent an original contribution and meet the requirements of the Law on the State of the Republic of Bulgaria, the Regulations for its implementation and the Regulations on the conditions and procedure for acquiring scientific degrees and for occupying academic positions at the Institute of Optical Materials and Technology-BAS.

The abstract presents the results obtained in the dissertation work correctly and accurately.

In conclusion, I would like to note that the dissertation candidate possesses in-depth knowledge and skills in the scientific specialty "Electrical, optical and magnetic properties of condensed matter" and shows the qualities of a scientific researcher. A significant amount of scientific research work has been carried out in the presented dissertation work. Therefore, I would like to recommend to the esteemed jury to award Nikolay Minev the educational and scientific degree "doctor" in the professional field 4.1.Physical Sciences.

Sofia, 2.06.2026

Prepared the opinion:

Prof. Dr. of Science Evgeniya Valcheva