REVIEWER'S REPORT

of a thesis submitted for awarding the scientific degree „Doctor of Sciences"
in professional field 4.1 Physical Sciences (Condensed matter physics),
according to the procedure pursued in
Faculty of Physics of Sofia University "St. Kliment Ohridski"

The report is prepared by Prof. D.Sc. **Stoyan Christov Russev from Faculty of Physics of Sofia University "St. Kliment Ohridski",** in his capacity as a member of the scientific jury according to Order No. RD 38-464/27.07.2022 of the Rector of Sofia University.

Title of the Thesis: "Surface photovoltage spectroscopy of semiconductor optoelectronic materials and nanostructures"

Author of the Thesis: Assoc. Prof. Dr. Veselin Todorov Donchev

I. General description of the submitted documents

1. Data for the submitted documents

The candidate Assoc. Ph.D. Veselin Todorov Donchev has submitted a dissertation in English and an Author's Abstract (in Bulgarian and English), as well as the mandatory tables for the Faculty of Physics from the Regulations on the Terms and Procedures for Acquiring Scientific Degrees and occupying academic positions at SU "St. Kliment Ohridski". A curriculum vitae, copies of diplomas for completed higher education and candidate of sciences, a declaration of authorship, a reference from the Scopus database for citations and copies of the publications included in the presented dissertation are also presented.

I have no remarks or comments on the documents submitted by the candidate for the defence - they fully correspond to the requirements of the law (ЗРАСРБ, ППЗРАСРБ) and the Regulations for the terms and conditions for acquiring scientific degrees and occupying academic positions at SU "St. Kliment Ohridski" (ПУРПНСЗАДСУ).

2. Applicant data

After graduating from the 9th French language high school, Sofia Veselin Donchev continued her studies at the Faculty of Physics of the SU "St. Kliment Ohridski", where he graduated as a physicist in 1985. In 1991, he defended his dissertation on the topic "Investigation of electrical and optical properties of point defects in gallium arsenide" at the Faculty of Physics of SU "St. Kliment Ohridski" and continues as a physicist in the Department of Solid State Physics and Microelectronics. Since 1993 he has been a senior assistant, 1997-2004 - chief assistant and since 2004 - associate professor in the Department of Condensed Matter Physics. In the period 2010-2013, he was an administrator at the European Commission, Brussels (Administration of scientific projects under 7 RP in the field of nanoelectronics and microsystems). From 2013 until now, he has been the second term Head of the Department of Physics of Condensed Matter and Microelectronics, Faculty of Physics, SU "St. Kliment Ohridski".

3. General characteristics of the candidate's scientific achievements

Assoc. Prof. Donchev's scientific interests are in the field of electronic and optical properties of semiconductor materials and structures and photoelectric and optical methods for their research. The dissertation reflects his results from his works in the field of semiconductor optoelectronic materials and nanostructures and in particular - development and improvement of the method of surface photovoltaic spectroscopy and its use for the study of these materials and nanostructures.

The candidate's total publication activity includes 2 book chapters, 47 scientific journal articles, 38 scientific journal conference papers, 44 conference proceedings papers and 3 teaching aids. 82 of these publications are reflected in the Scopus database, with currently a total of 390 citations (not including self-citations of the author and his co-authors) and an h index of 9.

Of these publications, 24 works are included in the dissertation, 15 of which are in journals with an impact factor, 6 are conference reports published in journals with an impact rank and 3 publications in other scientific journals, and 176 citations are presented (without self-citations of all authors), such as the review article F2 (included in the dissertation) was cited 109 times.

The scientometric data of the candidate's scientific achievements (according to the evidence presented by him), required by ПУРПНСЗАДСУ and Additional requirements of the Faculty of Physics of SU "St. Kliment Ohridski" are summarized in the table below.

Group of indicators	**Indicator**	**Requirements for "Doctor of Sciences" according to ПУРПНСЗАДСУ-Faculty of Physics**	**According to the submitted documents**
А	1	50 points	50 points
Б	2	100 points	The presented dissertation
В	3, 4	-	335 points
Г	5..10	A minimum of 100 points from indicators from 5 to 10	400 points
Д	11	Minimum 100 citations (ie minimum 200 points)	352 points
Е	12..20		Guidance of 1 successfully defended PhD student - 50 points.
Additional requirements of the Faculty of Physics of SU "St. Kliment Ohridski"		Number of Group I Publications in the last 3 years	3 publications
		Group I publications in groups of indicators B and D included in the dissertation - minimum 14 publications	15 Group I publications
		Number of publications in groups of indicators C and D with significant contribution of the candidate - minimum 9	14 publications with significant contribution of the candidate
		Golden publications	3 publications
		h index – minimum 6	h index - 9

As can be seen from the presented data, all minimum national requirements, as well as those of Sofia University and the additional requirements of the Faculty of Physics, are met, and for most indicators, significantly exceeded. This allows me to state that the scientific publications included in the dissertation work meet the minimum national requirements (according to Art. 2b, paras. 2 and 3 of the RSARB) and the additional requirements of SU "St. Kliment Ohridski" to acquire the academic degree "Doctor of Physical Sciences" in professional direction 4.1 Physical Sciences (Physics of Condensed Matter).

The scientific publications included in the dissertation work do not repeat those from previous procedures for acquiring the scientific title "doctor" and the academic position "associate professor" of the candidate.

For me, there is no doubt that the scientific publications included in the dissertation work are the personal work of the author and his co-authors - no plagiarism has been proven in the submitted dissertation work and Author's abstract.

4. Characteristics and assessment of the candidate's teaching activity

The teaching activity of the candidate is related to lectures and leading exercises in bachelor's and master's degrees of study in the Faculty of Physics. He lectures on Mechanics, Molecular Physics (since 2004) and Optoelectronic Devices (since 2020) for undergraduates, Nanostructured Materials and Devices for Information Technologies and Physical Foundations of Optoelectronics in the Master's program "Microelectronics and Information Technologies (since 2004). He is the head of the Laboratory of Electricity and Magnetism, Faculty of Physics of SU "St. Cl. Ohridski". He was the scientific supervisor of 6 and consultant of 4 graduate students, consultant of 2 doctoral students and scientific supervisor of 1 defended and 1 current doctoral student.

5. Analysis of the applicant's scientific and scientific-applied achievements contained in the materials for participation in the competition

The scientific achievements presented in the dissertation are in three interrelated directions - design, construction and improvement of an experimental setup for Surface Photovoltaic Spectroscopy (SPS); development of new approaches for extracting information from surface photovoltage spectra (SPV spectra); application of the developed equipment and methodology for the study of various materials and nanostructures for optoelectronics and photovoltaics.

The dissertation is presented in English and includes an introduction, four chapters, main results and contributions, a list of publications included in the dissertation work and a bibliographic reference to literary sources. The abstract (presented in Bulgarian and English) faithfully and accurately reflects the main points in the dissertation.

The first chapter is an overview and in it the method of surface photovoltaic spectroscopy (SPS) is considered, as well as basic information about the semiconductor nanostructures and materials, the subject of research by the author.

Chapter 2 describes the experimental details of the SPS apparatus developed and used by the author and, in particular, the mode of operation with chopped light using a MIS (metalinsulator-semiconductor) structure capable of operating in a wide spectral range (450-1800 nm). During the construction and improvement of the experimental setup, special attention was paid to reducing and compensating the influence of parasitic capacitances. For this purpose, a comprehensive theoretical analysis was made and based on it, in my opinion, the optimal schematic solution for the connection between the sample and the standard equipment (synchronous amplifier) was used. This is particularly important for the purpose set by the author – measuring not only the standardly used in the SPS method amplitude, but also the phase spectra. Here are also the contributions of the author, reflected in this chapter - a fundamental clarification of the question of what additional information the phase brings, namely:

- The phase of the SPV signal is related to the bending direction of the energy zones and this information is local – ie. from the point of signal generation.
- The SPV phase is also related to the free carrier generation rate. The joint influence of these two factors - the initial bending of the zones and the generation rate - was analyzed.
- For more than one SPV generation process (e.g. in multilayer structures), a vector model of the SPV signal is proposed, which facilitates the combined analysis of the amplitude and phase spectra.
- For the practical use of phase spectra, a well-defined zero value of the SPV phase is important, and the author proposed and used in the experiments a procedure for its determination.
- The relationship between phase shift and optical absorption coefficient and photon flux density is discussed. As the author himself notes, this qualitative discussion, although very useful for the interpretation of the results, needs to be supplemented in future work with a quantitative description and/or numerical simulations of the SPV signal generation processes.

The next two chapters of the dissertation present original results of the author's research on various materials and nanostructures using the SPS technique. These results are interesting not only for themselves, but also as an illustration of the use of the SPS method and the ways proposed in chapter 2 of using the signal phase as an additional information channel.

Chapter 3 is devoted to SPS studies of nanostructures for optoelectronic applications. The first group of structures are AlAs/GaAs superlattices with embedded GaAs quantum wells obtained by molecular beam epitaxy. One of the first SPS studies of such structures is presented, measuring the amplitude and phase SPV spectra and comparing them with photoluminescence spectra and numerical calculations. The energies of exciton transitions determined by SPS are in very good agreement with the values obtained from photoluminescence and numerical calculations, which also allow the degree of interfacial blurring to be estimated. The obtained original results are reported in articles F2, F4 − F6 and O1 (here and below - according to the numbering from the list of articles included in the dissertation presented by the author).

Quantum line and quantum dot structures in quantum wells have been widely studied for their application in optoelectronics for light emitters and detectors. An important issue for light emitters is the control of the emitted wavelength (e.g., the optimal ranges for telecommunications). The thesis presents original results [F3, R1 and R2] from SPS studies of interdiffuse InAs/InGaAlAs quantum-dot structures in quantum wells for light emitters. It is shown that tuning the emission wavelength to the optimum value for 1.55 μm telecommunication fibers can be achieved by blurring the interfaces obtained by two different techniques - rapid thermal annealing and nitrogen ion bombardment. Other structures investigated with SPS are InAs quantum dots in quantum wells for infrared photodetectors [F9]. Here, the vector model has been successfully used to explain the features in the SPS spectra and to extract information about various superimposed SPV signals. Finally, this chapter presents the results [F7−F8] of SPS studies of multilayer structures with InP/GaAs type-II quantum dots, interesting with the spatial separation of the two types of current carriers.

Chapter 4 is devoted to SPS studies of two groups of materials for photovoltaics - silicon nanowires prepared by metal-assisted chemical etching and GaAs-based dilute nitrides. Silicon nanowires are interesting for coatings of c-Si solar cells in order to reduce reflection, but they have a drawback - a high rate of carrier recombination due to the large surface/volume ratio. The use of the SPS technique to evaluate the effectiveness of a chemical treatment to reduce recombination centers on nanowires has been successfully demonstrated here [F10]. Diluted GaAs-based nitrides are interesting for photovoltaics with the possibility of providing tunable band gaps in multijunction solar cells. The studies here [F11-F15, R3-R6] again demonstrate the capabilities of the SPS technique and are among the first to apply it to the study of InGaAsSbN and GaAsSbN structures obtained by liquid phase epitaxy. Important new information about the properties of these structures has been obtained.

The candidate's scientific and scientific-applied contributions can be defined as the development and improvement of an experimental method and the enrichment of existing knowledge with the possibility of applying these scientific achievements in practice. As can be seen from the scientometric indicators discussed above, the candidate's results are widely reflected in the works of other authors.

Of the 24 works included in the dissertation, Assoc. Prof. Donchev is the first author in 12 of them, in all the others - the second author, and in 5 of them the first author is his doctoral student. I believe that the personal contribution of Prof. Donchev in the obtained results and his leading participation in obtaining them are indisputable.

6. Critical notes and recommendations

I have no critical notes and recommendations.

7. Personal impressions of the candidate

Assoc. Prof. Donchev and I know each other as colleagues in the Faculty of Physics from two closely related scientific departments, united in 2019 into one department, of which he is currently the head. My impressions are excellent - he is an erudite colleague with a high sense of responsibility in both scientific, teaching and administrative work. He knows how to work, organize and lead work in a team.

8. Conclusion

After having familiarized myself with the presented dissertation work, Author's abstract and the other materials, and based on the analysis of their significance and the scientific and scientific-applied contributions contained in them, **I confirm** that the scientific achievements meet the requirements of the law (ЗРАСРБ) and Regulations for its application and the relevant Regulations of Sofia University "St. Kliment Ohridski" for **the acquisition of the scientific degree "Doctor of Physical Sciences"**. In particular, the candidate satisfies the minimum national requirements in the professional direction and no plagiarism has been found in the dissertation work, abstract and scientific works submitted for the competition.

I give my positive assessment of the dissertation work.

II. GENERAL CONCLUSION

Based on the above, I recommend the scientific jury to award Assoc. Prof. Dr. Veselin Todorov Donchev the scientific degree "Doctor of Science" in professional field .4.1. Physical Sciences (Condensed matter physics).

Stoyan Rusev — Digitally signed by Stoyan Rusev Date: 2022.09.17 14:43:33 +03'00'

16.09.2022 Reviewer's report prepared by: ....

(Prof. D.Sc.. Stoyan Russev)