

Opponent Review of Doctoral Dissertation

Applicant: Ing. Laila Znbill

Title of Dissertation: Low Energy Solid State Converters for Energy Harvesting

Opponent: prof. Ing. Miroslav Husák, CSc.

Opponent's Department: Czech Technical University in Prague, Faculty of Electrical Engineering, Dpt. of Microelectronics

In accordance with the Study and Examination Rules of BUT, in his/her review the opponent will mainly comment on:

- a) the topicality of the dissertation,*
- b) whether the dissertation achieved its given objective,*
- c) the problem-solving procedure and the results of the dissertation along with the concrete contribution of the doctoral student,*
- d) the significance for practical application or the progress in the field,*
- e) formal and language qualities of the dissertation,*
- f) whether the dissertation fulfils the conditions of Section 47 (4) of the Act,*
- g) whether the student proved his/her creative abilities in the given research field and whether the work does or does not comply with the standard requirements placed on the dissertations in the given field. The review is not valid without this conclusion.*

It is necessary to add a concise commentary to each of the points below.

Ad a) Topicality of the dissertation

The topic of the dissertation is topical.

Comment:

The development of new energy sources of small powers using physical phenomena is a current research topic.

Organic semiconductors play a major role in research and development. Semiconductors are easy to prepare, they have a low cost, they can be used in many applications.

The presented work deals with the research of thermoelectric cells from organic semiconductors and low-energy converters for the processing of the obtained energy. Attention is also paid to the applications of solar cells.

The main topic of the presented dissertation is research into the use of organic semiconductors for low-energy converters of the Energy harvesting type. The photovoltaic cell and the thermoelectric cell are the basic elements to be solved. Optimized arrangement of active layers of organic thermoelectric generator working with thermoelectric pair formed by PEDOT: PSS and Ni materials. The development of these structures has brought new scientific knowledge.

Attention is also focused on a new circuit solution of a very low voltage converter with a planar transformer. The solution is suitable for integration in the form of a hybrid integrated circuit. The implementation of a functional sample and the measurement of its parameters can be evaluated positively.

Current research issues are solved in the work, the chosen topic has a dissertable character and fully corresponds to the field of "Microelectronics and Technology". The chosen topic fully corresponds to modern trends in the field of doctoral studies and contributes to the further development of energy harvesting technology based on the principle of energy harvesting. The dissertation contains new and original scientific results.

Ad b) Objective of the dissertation

The objective of the dissertation was achieved.

Comment:

The main objectives of the work are defined in Chapter 2 (p. 42) in 4 points. However, only 2 points are scientific:

- Research and design of a low voltage low energy DC/DC converter to process the output from Energy harvesting transducers.
- *Research and design of a thermoelectric converter using simple technologies and available materials.*

Defined targets of the type "Compile overview concerning preparation of EH photovoltaic structures..." (objective 1) or "Compile overview concerning preparation of EH thermoelectric cells..." (objective 2) do not belong to the objectives. These activities are necessary for the solution of each work, the activities can be considered as a basic standard starting work necessary for the solution of scientific results.

The dissertation is divided into 4 chapters. The core of the work is given in Chapter 3, where scientific activities are described and the achieved results are evaluated in partial conclusions.

Ad c) Problem-solving procedure and the results of the dissertation and the concrete contribution of the doctoral student

The problem-solving procedure and the results of the dissertation are above average.

Comment:

Problem-solving procedure

Ing. Zanbill dealt with the topic of the dissertation for a long time, systematically and in great detail. Known methods of scientific work were used for the solution (analysis of the current state, design of the solution, technological implementation and experimental verification of functional samples). The instrumentation and technological equipment of the BUT laboratories, was used to solve the work. The methods of work were supported by the study of literature. The thesis contains a list of literature with 172 titles. The list of used literature also includes the doctoral student's own publications.

The results of the dissertation and the concrete contribution of the doctoral student

The benefits of the dissertation are listed in Chapter 3. The main partial benefits of the work can be defined:

- Verification of the possibility of applying layers of organic semiconductors (PEDOT) by screen printing
- Implementation of thermoelectric cells in the form of a multilayer structure, including electrical contacts on an insulating pad
- The design of a low voltage low energy DC/DC converter to process the output from the Energy harvesting converters. The bipolar as well as unipolar transistors were under tests, unipolar transistors in the bulk-driven configuration were used for the first time.

The main scientific benefit is the verification of the possibility of realizing cells from organic semiconductors (specifically PEDOT) using printing techniques with subsequent effective processing of very low voltages and powers.

The author designed and implemented a multilayer thermoelectric cell structure made of organic semiconductor (PEDOT) using the printing technique (the technique is designed for industrial protection due to innovation).

The doctoral student verified the electrical properties and service life of the implemented structures. The material for thermoelectric cells was prepared at the Faculty of Chemistry. The proposed DC / DC low power converters use a significantly different circuit structure than converters for higher outputs.

The stated benefits obtained correspond to the set goals. The new findings were verified by measuring on suitable samples produced. In addition to electrical properties, the long-term stability of structure samples was also investigated.

The work brings new original knowledge, the work is adequate in terms of information contained.

Ad d) Significance for practical application or progress in the field

The significance for practical application or progress in the field is average.

Comment:

The work brings an average level in new knowledge in the field of basic research, but also in the field of application for direct application in practice. The achieved knowledge will be applied in the design and implementation of specialized low-power harvesters. The dissertation provided suggestions for further theoretical work in the field of energy collection from organic sensors / cells.

Ad e) Formal and language qualities of the dissertation

Formal and language qualities of the dissertation are average.

Comment:

The work is very extensive, 136 pages of basic text (including a list of used literature) and 51 pages of appendices. Several references to own publications are given in the bibliography. But I miss the complete list of the doctoral student's own publications (as stated in the short brochure).

I evaluate positively the summary of the achieved results at the end of chapters 3.1, 3.2, 3.3.

The issue of harvesters is described in detail at the beginning of the dissertation. However, the organization of the information is on average comprehensible and clear. The introductory chapter is an interesting and detailed introduction to the issue. The core of the work is contained in an extensive chapter 3. The summary of the achieved results at the end of each subchapter is considered very positive. The professional level of the work is good and brings new and original knowledge.

I have some comments on the formal arrangement of the dissertation, some pictures could have been more concise, figures and calculations could have been given in a broader sense. I would expect a more detailed discussion at the end of the work, because a number of important and usable results were presented in the work.

Formal shortcomings:

- A number of formal errors, such as typos, are in the work, such as the title of the work, etc.
- Why is the physical dimension $v \Omega$ written bold, other physical dimensions are written in a standard font, e.g. Tab. 3, Tab. 4, Tab. 5, the text is also stated in bold font, etc.
- The number and physical dimension are written with / without a space, ego page 53 in the equation stated 1Ω , page 64 stated 5Ω .

- Different symbols for the supply voltage are used in the figures, e.g. the abbreviation V_{in} (Fig. 21), U_1 (Fig. 22) or $V+$ (Fig. 23), $+V_c$ (Fig. 28) etc.
- The equations are not numbered.
- Decimal points instead of dots, e.g. Tab. 6., Tab. 11, Tab. 12, text p. 70 etc.
- Standard and italic font in one table (Tab. 9).
- The list of abbreviations and symbols is missing.
- Different graphic quality of own images, e.g. Fig. 32 less legible (gray color used instead of black).
- Fig. 42, Fig. 43: The output quantities and physical dimensions on the x, y axis is missing.
- References to literature are not in ascending order.

Ad f) The dissertation fulfils the conditions of Section 47 (4) of the Act

The dissertation fulfils the conditions of Section 47 (4)*) Act No. 111/1998 Sb. Higher Education Act: YES

*(*4) Studies are duly finished with a doctoral state exam and dissertation defence, which prove the ability and readiness to work independently in the field of research or development, or in theoretical and creative arts. The dissertation must comprise original and published results or results accepted for publication.*

Ad g) Creative abilities of the student in the given research field. Compliance with the standard requirements placed on the dissertations in the given field.

The doctoral student did prove her creative abilities in the given research field and the work does comply with the standard requirements placed on the dissertations in the given field.

Comment:

The doctoral student has been dealing with this issue for several years and has achieved some success. This information can be evaluated from the submitted materials and the results of the work.

The doctoral student demonstrated creative abilities in the given area of research, she continued the previous research of the workplace, she chose suitable methods of solving the work, including her own theoretical approach. She demonstrated mastery of the principles of independent research work, as well as teamwork. The core of the work has been sufficiently published.

I can state that she is a worker with a corresponding scientific erudition. I obtained this information by summarizing all available facts and knowledge about the professional activities and abilities of the doctoral student.

Overall evaluation:

I evaluate the achieved results as corresponding to the set goals of the dissertation. The doctoral student demonstrated the ability of independent scientific work and orientation in the given professional field. The text of the dissertation is written clearly, the graphic design is at a good level. The core of the dissertation was sufficiently published. Theoretical and experimental results were obtained. The goals of the work were fulfilled. The dissertation corresponds in terms of generally accepted requirements for the dissertation.

I recommend the thesis for the defense of the academic title of Ph.D.

Opponent's questions:

- What other technologies can be used to implement energy generators (for Energy harvesting systems) using organic materials?
- Is it possible to further improve the results and ideas presented in the work and how?
- Practical application of dissertation results in the near future, where and when?
- The work has several scientific conclusions. What scientific conclusion can be assessed as the most important?

I recommend do not recommend the dissertation for the defence.



Date: 26.07.2021

Signature: 