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Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Julijana Cvjetinovic

PhD Program: Physics

Title of Thesis: Optical and mechanical properties of diatom algae and related materials

Supervisor: Professor Dmitry Gorin
Co-supervisor: Professor Alexander Korsunsky

Name of the Reviewer: Dr. Ilya Turchin

I confirm the absence of any conflict of interest	**Date: 19-09-2023**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

The PhD thesis under review presents a comprehensive investigation of diatom algae on three different levels, with a particular emphasis on the mechanical and optical properties of diatom algae and monitoring of diatom growth using optoacoustic and fluorescence visualization techniques. Furthermore, the thesis explores the potential application of gold-coated diatomite as a surface-enhanced Raman scattering (SERS) platform.

The results obtained in the reviewed PhD thesis on the optical and mechanical properties of diatom algae and related materials hold significant scientific value. The research findings not only contribute to the current state of the art in the field but also align with the international level of research. The candidate has 19 publications in total, and some of the publications are in high-ranked journals. Among them Scientific Reports, Photoacoustics, and Physical Chemistry Chemical Physics, where the candidate is the first author. Publications and presentations at the conferences further validate the importance of obtained results and recognition within the scientific community.

Abstract and Introduction:

The abstract and introduction sections of the thesis provide a clear and concise overview of the research area, highlighting the significance of studying the optical and mechanical properties of diatom algae and related materials. The objectives, research questions, and hypotheses are well presented, setting the stage for the subsequent sections. The introduction successfully engages the reader and provides a solid foundation for understanding the context and importance of the research. The thesis demonstrates a commendable level of novelty by combining the study of both mechanical and optical properties of diatom algae using different approaches, probing vibrational eigenmodes in diatom frustules via combined in silico computational study and atomic force microscopy experimentation, employing novel techniques for monitoring the growth of diatoms during long term cultivation utilizing optoacoustic and fluorescence visualization techniques. This interdisciplinary approach adds new dimensions to the understanding and characterization of diatom algae. Moreover, the exploration of gold-coated diatomite as a SERS platform fabricated using a combination of freezing induced loading and layer-by-layer assembly methods represents a novel application of diatom algae in the field of surface-enhanced spectroscopy. The literature review section showcases a thorough and well-organized examination of prior research on the topic. The candidate demonstrates a comprehensive understanding of the existing literature, addressing key concepts, theories, and findings within the field. The inclusion of recent studies and the critical analysis of their limitations and knowledge gaps further enhances the relevance and value of the literature review.

Materials and Methods:

The thesis encompasses an extensive materials and methods section that provides a comprehensive description of the experimental procedures conducted. The utilization of different methods is appropriately justified and demonstrates the author's ability to utilize advanced techniques, such as fluorescence and photoacoustic imaging, optical spectroscopy, Raman spectroscopy, different approaches in AFM, surface modification, algae cultivation, and many others. The detailed methodology facilitates reproducibility and enables the scientific community to further expand on the findings presented in the thesis.

Results and Discussion:

The results and discussion section is divided into five parts, providing a structured and systematic presentation of the findings. Each part is logically organized and accompanied by comprehensive data analysis, supporting the claims made throughout the thesis. The discussion critically evaluates the results in relation to the research objectives and hypotheses, facilitating a deeper understanding of the implications and potential applications of the findings.

Conclusions:

The conclusions drawn from the research work are well-supported by the experimental results and data analysis. The thesis provides a connection between the mechanical and optical properties of diatom algae and offers insights into their potential applications. The conclusions provide a valuable contribution to the scientific understanding of diatom algae and lay the foundation for future investigations in this field.

Questions and comments:

- The thesis acknowledges the potential application of diatom algae as Micro-Electro-Mechanical Systems (MEMS) devices. While the exploration of this application is promising, further investigation and validation are required to determine the practical feasibility and scalability of implementing diatom algae as MEMS devices.

- Page 68: “A couple of meters below the surface, almost half of the light intensity is in the UV region (below 400 nm), compared to about 3% at the surface level, which means that diatoms live in a light environment dominated by UV and blue light, and supports the idea that the frustule may play a role in UV light protection.” It seems that the calculation of the portion of light in the UV region (<400 nm) below water surface is not correct, because absorption in water is higher in this region compared to the region of 400-500 nm even for distilled water. Moreover, Figure 76 confirms that in the deep sea layers (>100 m) the maximum of spectral intensity is within the range of 450-500 nm.

- In connection with the above question. If the maximum of spectral intensity in deep sea layers is in the range of 450-500 nm, why is the electromagnetic field was simulated at 420 nm wavelength for Coscinodiscus oculus-iridis?

- On page 125 fluorescence imaging and spectroscopy of different types of chlorophyll (a,b,c) and carotenoid is described, but it is difficult to understand the spectral features from the text with many references. A graph with absorption spectra of all components would be beneficial.

- The graph in Fig.75 (Page 210) demonstrate absorption spectra of cleaned frustules. How did absorption and scattering effects were separated in the measurements? It was mentioned above that the dielectric permittivity of silica has a small imaginary part that suppose that absorption is lower in comparison with scattering.

Minor comments:

- Figure 6. Pictures enumerated as 1,2,3,..on the Figure, while on the Figure caption they are enumerated as a,b,c,..

- Page 66: “For both phototrophic organisms as well as autotrophic organisms, light plays an important role in their growth, behavior, and development.” – it seems that “autotrophic” is an odd word here.

- It seems that D is missing in Eq 3 (Page 180)

- Page 65. It is difficults to understand the following sentence: “Perhaps, the reduction (by means of magnesiothermic reaction 45) of silica to ultimately obtain silicon frustule would allow to eliminate the natural variability of hydrosilica material and through this to exclude the contribution of this factor in mechanical response interpretation”.

In conclusion, the reviewed thesis offers valuable contributions to the understanding of the mechanical and optical properties of diatom algae, while also exploring the potential of gold-coated diatomite as a SERS platform. The research provides novel insights and employs advanced techniques, resulting in a well-documented investigation. The conclusions are well-supported, and the potential applications are acknowledged. Nonetheless, considering the limitations and further scope for exploration would enrich

the research outcomes and open avenues for future studies in this field.
Provisional Recommendation
☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*
☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*
☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*