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Annex No. 10 to the MU Directive on Habilitation Procedures and Professor Appointment Procedures

# HABILITATION THESIS REVIEWER'S REPORT

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| **Masaryk University** | |
| **Applicant** | Mgr. Jan Čech, PhD. |
| **Habilitation thesis** | Development of non-thermal plasma sources for fast plasma treatment of materials: Diagnostics and applications |
| **Reviewer** | doc. RNDr. Karol Hensel, PhD |
| **Reviewer's home unit, institution** | Faculty ot Matematics, Physics and Informatics, Comenius University, Bratislava, Slovakia |

The habilitation thesis deals with the development, diagnostics and applications of two technologically interesting and promising types of plasma discharges developed for fast and efficient processing of various materials. Specifically, diffuse coplanar surface barrier discharges (*DCSBD*) used for surface modification of temperature-sensitive materials and *CaviPlasma* technology used for fast treatment of liquids. The author has devoted two decades of his scientific work to the study of the above discharges. As he states in the thesis, at the time when he started studying the discharges, despite their evident application potential, the mechanisms of the discharges were not investigated in sufficient detail, which prevented further development and optimization of these technologies. This unfavorable situation motivated his interest in the diagnostics of these discharges and application-oriented basic research.

The author has devoted himself to various non-invasive diagnostic techniques of optical and spectral methods. He specialized mainly in spatially, temporally, spectrally and phase-resolved optical emission spectroscopy and visualization of discharges. He correlated the results of these measurements with oscilloscope measurements of the electrical characteristics of discharges. He developed codes for processing large data sets and their analysis, as well as numerical models to support the interpretation of the results. In the case of discharge in a liquid, he identified the generated reactive particles and described the spatially and temporally resolved dynamics of radicals. In addition to diagnosing discharges, he also investigated their application potential for treating the surfaces of materials such as glass, foils or textiles (*DCSBD*), or for decontamination of water from drugs, hormones, pesticides and suppression of the growth of microorganisms (*CaviPlasma*).

The work is designed as a commentary to 15 scientific articles that form the appendix to the work. They provide a comprehensive overview of the author's involvement in the research and development of the *DCSBD* and *CaviPlasma* systems, their diagnostics and applications. The commentary has a total of about 50 pages, first half of which is dedicated to *DCSCD* and the other half to *CaviPlasma*. The author begins both parts with a historical introduction and a review of the literature devoted to barrier discharges (volumetric, surface, including coplanar) or discharges in contact with water (above water, in water, in bubbles, including cavitation) and their physical properties. He clearly explains motivation of his work, a description of his own results, new knowledge gained from them, and their scientific contribution. He also devotes sufficient space to the results of discharge applications and comments on their further optimization and use in the future. Both parts of the work are

concluded with a chapter in which he evaluates how the results of his work contributed to the expansion of scientific knowledge of discharges and also evaluates the societal contribution of both technologies.

The structure of the work and the quality of the text are, in my opinion, at a very high level. The work has a simple and clear system of organization and the reader can navigate through it very easily. The individual parts describing the results are very logically connected to each other and are generally very easy to read. The pictorial part (figures) is also very appropriately chosen and optimally complements the accompanying text to the results, so that it can be easily and, above all, correctly understood by the reader. At the same time, it also demonstrates the portfolio of diagnostic or computational techniques that the author had to master to produce these figures. Overall, the text makes it sufficiently clear what are generally known facts and what the originality of the author's research and results lies in, and what their added value is. The author himself explicitly states this several times in the text. This allows the reader to appreciate the quality of his results and clearly see and understand their scientific contribution.

The author's contribution to the development of *DCSBD* technology is undeniable. By spatially mapping the rotational temperature, he helped optimize the geometry of the electrodes. He explained the influence of geometry and overvoltage on the probability of repeated generation of a microdischarge along the same discharge path, or rather on the dynamics of microdischarges in the multifilamentary regime. He described the influence of residual heat on the memory effect of the discharge and the relaxation of the charge before the breakdown. He also contributed to several applications of *DCSBD*, especially in hydrogen atmosphere, for the reduction of surface layers of metal oxides or the functionalization of nanoparticles.

Similarly, the author's contribution to the *CaviPlasma* technology is clearly visible. First of all, the fact that he co-invented this internationally patented technology combining hydrodynamic cavitation with an electric discharge. As part of the physical study of the discharge, he discovered and described its two different operating modes, spark and glow discharge, depending on the electrode configuration. Also, the influence of power and water conductivity on the energy efficiency and the rate of production of reactive particles in water. As part of the discharge applications, he participated in experiments in the purification of water contaminated with cyanobacteria, up to the development of a prototype of a commercial water purifier.

My primary task was to evaluate the quality of the habilitation thesis and its contribution to the expansion of scientific knowledge, which I did. However, I would also like to comment on the scientific papers, to which the text of the work refers, and also on the person of Mgr. Jan Čech, PhD (*JČ*). In total, the appendix of the thesis contain 15 scientific journal papers. JČ appears 8 times as the first author. In 6 papers, he had at least a 50% share in the preparation of the manuscript; in 6 papers, he participated in at least 30% of the experimental work, which included not only the implementation of the measurements themselves, but also the design and development of the experimental apparatus, methodology, diagnostic techniques and data analysis. In addition, at least 4 papers were created under his leadership as a supervisor. These numbers clearly demonstrate *JČ*'s versatility and his ability to design, implement and manage an experiment, process data, discuss and publish them in a high-quality manner. I would like to appreciate the overall quality of the papers that form the appendix of the thesis, especially those in prestigious journals such as the physical *Plasma Sources Science and Technology* (IoP), *Physics of Plasma* (AIP) but also the multidisciplinary *Journal of Physical Chemistry Letters* (AChS).

I have known many of *JČ*'s works from the past and I have always perceived them as very systematic, detailed and graphically attractive. His oral or poster presentations at conferences were similar. They were methodical, formally perfectly edited with clean and clear texts/keywords and images/videos. This handwriting of *JČ* is also evident from the processing of the habilitation thesis, which is more or less perfect not only in terms of content but also in terms of form. To summarize, overall, I have not had such a good feeling while reading a habilitation or other final/progress thesis as here for a long time. I thoroughly enjoyed reading it here. The work is, in a word, excellent.

**Reviewer's questions for the habilitation thesis defence**

1) Is it possible to somehow set up or modify the *Caviplasma* system to generate other reactive species (e.g. nitrogen-containing, RNS)? This could be very interesting for agricultural applications, since nitrates (NO3-) are the primary form of nitrogen and an essential nutrient for plant growth. In other words, is it possible to adjust ROS/RNS ratio in plasma-generated water would be possible.
2) Are you considering or have you already carried out tests in the *Caviplasma* system using (photo)catalysts (e.g. in powder form) to possibly increase the production of certain radicals/oxidants or support Fenton-based processes?

**Conclusion**

The habilitation thesis entitled Development of non-thermal plasma sources for fast plasma treatment of materials: Diagnostics and applications by Mgr. Jan Čech, PhD. **fulfils** requirements expected of a habilitation thesis in the field of Physics.

Date: 13.11.2025 Signature: