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

HABILITATION THESIS REVIEWER'S REPORT

Masaryk University	
Applicant	Mgr. Jaroslav Hnilica, Ph.D.
Habilitation thesis	Diagnostics of High Power Impulse Magnetron Sputtering Discharge
Reviewer	doc. Ing. Tomáš Kozák, Ph.D.
Reviewer's home unit, institution	University of West Bohemia, Department of Physics, Plzeň, Czech Republic

The habilitation thesis is focused on optical diagnostics of high-power impulse magnetron sputtering (HiPIMS) discharges. It is a compilation of eight scientific articles published in high-quality international journals accompanied by additional text explaining the context of the research, highlighting the role of the applicant, and discussing the most important results. The thesis is split into two equally sized parts devoted to two main topics, namely the spokes and the dynamics of sputtered particles in HiPIMS discharges.

Both topics are highly actual and are studied simultaneously at renowned laboratories all over the world. The thesis proves that the applicant mastered using state-of-the-art instruments, original designs of experiments and complex data analysis to understand the physical processes in HiPIMS discharges. For example, I would like to highlight:

- the analysis of spoke structure and dynamics at a broad range of discharge conditions,
- the use of strip probes to detect spokes by current probes and correlate to OES images,
- the development of a theoretical model of spokes,
- adoption of the EBF method to determine the atom and ion densities and its independent verification, and
- detailed LIF mapping of atom and ion densities, including the regions very close to the sputtered target.

The obtained results are highly original and competitive on the international level and have led to significant advances in the understanding of HiPIMS discharges. This is supported by the fact that the articles of the applicant are highly cited and his contributions at international scientific conferences (some of which I was able to attend in person) were strongly appreciated by the HiPIMS plasma community.

The thesis also shows that the applicant has established many fruitful collaborations with leading scientists in the field and, therefore, confirms his recognition by the community as an expert on plasma diagnostics and the physics of HiPIMS discharges.

The thesis fulfils all requirements expected of a habilitation thesis and I can recommend the thesis for defence.

Reviewer's questions for the habilitation thesis defence (number of questions up to the reviewer)

1. Regarding the semi-empirical classification of spoke shapes, can you elucidate more the difference between diffusive and round spokes? Under what conditions do they occur? From a minimalistic point of view, would it be possible to consider the diffusive spoke a special case of the round spoke when the spoke mode number is low? Are there any fundamental differences in the underlying physics (like the difference between triangular and round spokes)?

2. On page 27, you write regarding the EBF method: "The OES measurement is simple and enables us to implement the EBF method into any sputtering experiments". However, I assume there are some limits on the minimum measurable density of plasma species, for which substantial reabsorption occurs. Can you quantify the detection limits of the method?

3. How do you explain that in Figure 2.2, the Ti^+ density increases more slowly and reaches a lower peak value in the second pulse of m-HiPIMS than in the first pulse? It might be surprising considering the target current is not so much lower in the second pulse and Ar is likely rarefied from the previous pulse.

4. On page 34, you write that despite some effort, you were not able to measure any signal from Ar ions. Could you describe in more detail, what are the challenges associated with measuring Ar ions, and what methodology would be most appropriate for the task?

Conclusion

The habilitation thesis entitled "Diagnostics of High Power Impulse Magnetron Sputtering Discharge" by Jaroslav Hnilica **fulfils** the requirements expected of a habilitation thesis in the field of Physics of Plasma.

Date: 30. 10. 2023 Signature: