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By P. Meystre

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38 **Plasma Physics and Controlled Nuclear Fusion**
By K. Miyamoto

39 **Plasma-Material Interaction in Controlled Fusion**
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Vols. 1–26 of the former Springer Series on Atoms and Plasmas are listed at the end of the book

D. Naujoks

Plasma-Material Interaction in Controlled Fusion

With 54 Figures and 11 Tables

Springer

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to Natalie

Preface

Nuclear fusion has the potential to provide a major part of mankind's energy needs for many millennia. On the way to controlled thermonuclear fusion on our planet, the principal goals—from the physical point of view—are firstly to obtain a sufficiently stable plasma, secondly, to heat this plasma to ignition temperature, and finally, to avoid excessive interaction of the hot plasma with the solid wall of the containing vessel. With respect to the foreseen use of a fusion reactor as an energy-producing device, an ideal plasma confinement is unattainable nor is it desired. The generated energy together with the helium particles (fusion "ash") must be removed from the central region and conducted to the energy exchanging facilities (blanket), as well as to the gas exhausting and purifying systems—at the rate they are produced. The so-called first wall, the border between the hot plasma with sun-like parameters (and beyond) and the "cool earth", should be able to withstand the high energy and particle fluxes with little or no maintenance.

During the last few decades a large number of dedicated experimental results as well as theoretical and simulation studies have been performed—thanks to the effort of scientists from many countries participating in this truly international project of controlled fusion. Several aspects of plasma–surface interaction have been reviewed in various publications [1–5] as well as in proceedings of conferences such as the series of *Plasma Surface Interaction* and *Fusion Reactor Materials* conferences. A comprehensive "Data Compendium" related to atomic processes taking place in plasma–surface interactions and material questions is given in special supplements issued by the journal *Nuclear Fusion* [6–9].

I tried to provide an in-depth look at the multi-faceted aspects of plasma–surface interaction in controlled fusion, to give a comprehensive analysis of the main processes and the main parameters ruling them, together with an assessment of the most critical questions and open points that demand further investigation. I hope this can assist the reader by performing their own estimations and assessments of relevant physical processes and problems. For further

studies, references to selected papers are given. A comprehensive review of the enormous experimental work done in this field is out of the scope of this book, but can be found in the references given above. A more detailed quantitative analysis can be acquired by applying simulation techniques, which are presented shortly, used together with special data compilations.

Since the involved processes are identical, the book might also be of interest in the fast-paced field of surface modification by means of plasma technology. Whether thin layers are deposited on materials in order to improve the surface characteristics or whether plasma ions are implanted into the depth using biased targets, the underlying physics is the same as in fusion experiments.

I would like to thank Prof. V. N. Afanas'ev for conducting my initial steps into scientific work in the field of particle interaction with solids, who has encouraged me to combine experimental, theoretical, and simulation studies wherever it seems possible. He suffered, but dealt gracefully with my poor Russian during my stay in Moscow.

I am much obliged to Dr. R. Behrisch, who has introduced me to the world of plasma–surface interaction. He allowed me to benefit from his wide experience and pushed me to make things clear and simple without unessential elaborating—not always with success I am afraid. I have also learned from him to *fight* for each discharge against the persistent fear of the operators of how a rather small surface probe would harm the device by exposing it into the plasma. I am thankful to Prof. G. Fussmann, who surprised me with analytical descriptions of effects, which I thought were studied only by computer simulation, and who showed me, in detail, that the complexity of particle–surface interaction is quite negligible compared to the situation in another topic—in plasma physics. The suggestions and corrections made by both of them are very appreciated and helped to improve the manuscript significantly.

Thanks to all colleagues I worked with in the inspiring and challenging atmosphere of the international fusion community.

I am grateful to Dr. Ascheron for his encouragement and support to publish this book with Springer, and in particular, to Ms. Blanck for her excellent technical assistance. Many thanks to Ms. Dewitz for most of the drawings and illustrations.

Greifswald, May 2006 *Dirk Naujoks*

Contents

Part III Operation Limits and Criteria