

Preface

This textbook is a general introduction to the electron kinetics and plasma spectroscopy in the context of electrical gas discharges. It was designed to be read by advanced undergraduate and graduate students that have followed before an introductory course on plasma physics, of the type of Francis F. Chen's book (*Introduction to Plasma Physics and Controlled Fusion*), and that want to pursue their studies by acquiring basic knowledge in electron kinetics and plasma spectroscopy. Both topics are presented assuming that no significant previous knowledge exists. The exposition is based on other textbooks and some journal references, but in this latter case, the choice of the references reflects only a pedagogical option of the authors. The journal references listed in the book do not intend to cover a given topic in a very exhaustive and updated way because, in authors' opinion, this is not relevant to whom that intends to establish a first contact with the area. The aim of this book is therefore to supply the students with a comprehensive tool in which the basic concepts and formulae are totally derived and to which they can easily return whenever they need. The book is divided in two parts.

The structure of the first part is as follows. Chapter 1 presents the fundamentals of electrical gas discharges. It describes in general trends as a gas discharge works from a microscopic point of view using in certain passages a qualitative description only. Chapter 2 is devoted to the transport Boltzmann equation, in a first stage remembering the conditions of application to a gas of neutral molecules and in a second stage with its further application to a gas of electrons in the case of electron-molecule collisions. Chapter 3 presents the analysis and the solutions of the electron Boltzmann equation in velocity space for the case of an applied direct-current electric field. Chapter 4 presents an extension of the previous chapter to the case of a time-varying electric field, both for the case of high-frequency fields, where no time modulation exists in the so-called electron energy distribution function, and for the case of radio-frequency fields, where large time modulation may exist. Chapter 5 treats the Boltzmann analysis in the space of positions by considering the electron transport and the electron diffusion. Since the diffusion constitutes a loss term for electrons, other source or sink terms need to be included as well for consistency, such as electron ionization and electron attachment. Finally, Chap. 6

treats different aspects associated with the presence of space-charge electric fields in the medium. This firstly includes the concept of ambipolar diffusion, but other aspects are analysed as well, such as the transition from ambipolar to free diffusion as the space-charge density decreases, either in a discharge or at the beginning of a post-discharge, the ambipolar diffusion with an external magnetic field, the Boltzmann equation in a glow discharge, in which a radial space-charge electric field exists, and some Boltzmann treatments such as the local-field approximation that cannot be used anymore.

The second part of the textbook is composed of five chapters with the aim of introducing the students to equilibria in plasmas, spectroscopy diagnostics of electrical discharges and finally an overview of current applications of these plasmas. Chapter 7 presents and discusses basic concepts of the most relevant collisional-radiative models usually found in low-temperature plasmas. The corona model is introduced followed by a description of the excitation-saturation balance and the partial local Saha equilibrium. The possibilities of optical emission spectroscopy and its limitations and the interpretation of spectra are shown in Chap. 8. Some notions of line radiation and reminders of atomic and molecular physics are given without being exhaustive about the subject. In subsequent sections, the authors present the notions of spontaneous emission, absorption and stimulated emission and a brief discussion of molecular bands. Applications of optical emission spectroscopy to infer some plasma parameters, such as electron density and gas and vibrational temperatures, are shown. Some experimental techniques such as actinometry and titration for determination of species concentrations are presented. In Chap. 9, the bases of the incoherent absorption are presented and discussed. A case study of metastable kinetics in the argon positive column is proposed with the aid of classical absorption spectroscopy. Chapter 10 is devoted to introducing the principles of laser spectroscopy followed by an explanation of many gas lasers, solid-state lasers and liquid lasers. Experiments with absorption of one photon are presented together with absolute density measurements. Multiphoton laser-induced fluorescence is studied, and the bases of multiphoton absorption are addressed. The purpose of Chap. 11 is not to be exhaustive but to present some important industrial and technological applications of discharge plasmas. The fields where low-temperature plasmas are being employed today are vast and rapidly growing and cannot be described in a single textbook chapter. Much will be left out; however, a special emphasis is given in new breakthrough applications of plasmas in health science, production of biofuels and agriculture.

The sequence of the chapters in the book was thought having in mind that either advanced undergraduate or graduate students should be introduced to the field of kinetics and spectroscopy of low-temperature plasmas in a pedagogical and self-contained format. The authors suggest to the instructors of a two-semester course, for advanced undergraduate students, the exclusion of the following sections and subsections in Part I: Sects. 3.4, 3.5 and 3.6 in Chap. 3, Sects. 4.2 and 4.3 in Chap. 4, Sect. 5.3 in Chap. 5 and Sects. 6.2.3 and 6.2.4 in Chap. 6. In Part II, the sections from 8.4 to 8.7 may be removed from Chap. 8, as well as the Sects. 10.2

to 10.4 in Chap. 10. In case of graduate students, all the contents are advised and may be covered in a two-semester course.

This textbook relies on the experience of more than 20 years of Jorge Loureiro in teaching the plasma kinetics of low-temperature plasmas in Instituto Superior Técnico (IST), Universidade de Lisboa, Portugal, and of Jayr Amorim in teaching the different techniques and diagnostics of plasma spectroscopy at Instituto Tecnológico de Aeronáutica (ITA), São José dos Campos, Brazil. The authors would like hence to thank both institutions for all the support received along the teaching of these matters, as well as for the encouragement received from many colleagues and the contributions from students to improve this book. One of the authors (J. Loureiro) would also like to thank the support received from Instituto de Plasmas e Fusão Nuclear, which is the centre where his research has been realized at IST.

Lisboa, Portugal
São José dos Campos, Brazil
June 2016

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Kinetics and Spectroscopy of Low Temperature Plasmas

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2016, XIII, 450 p. 145 illus., 142 illus. in color.,

Hardcover

ISBN: 978-3-319-09252-2