ELECTRON KINETICS IN THE TERNARY MIXTURES Ar-O₂-N₂ AND He-O₂-N₂

PAULO A. SÁ^{1,2}, KINGA KUTASI³ and VASCO GUERRA¹

¹Instituto de Plasmas e Fusão Nuclear – Laboratório Associado, Instituto Superior Técnico, Univ. Técnica de Lisboa, 1049-001 Lisboa, Portugal E-mail: vguerra@ist.utl.pt
²Departamento de Engenharia Física, Faculdade de Engenharia da Universidade do Porto, 4200-465 Porto, Portugal E-mail: paulosa@fe.up.pt
³Research Institute for Solid State Physics and Optics of the Hungarian Academy of Sciences, POB 49, H-1525 Budapest, Hungary E-mail: kutasi@mail.kfki.hu

Abstract. The electron kinetics of the ternary mixtures $Ar-O_2-N_2$ and $He-O_2-N_2$ is investigated. Special attention is paid to the changes in the ionization coefficient as a function of the mixture composition and the reduced electric field.

Gas discharges involving the ternary mixture $Ar-O_2-N_2$ look very promising in some very recent applications, such as plasma sterilization (Kylián and Rossi 2009) and treatment of sugarcane bagasse for biofuel production (Amorim et al. 2009). The latter application requires additional investigation on the ternary mixture He-O₂-N₂, which provides different pathways for gas heating and cooling.

Full self-consistent kinetic models have been developed previously for lowpressure gas discharges in helium (Alves and Ferreira 1991, Alves et al. 1992), Ar-O₂ (Guerra et al. 2010, Kutasi et al. 2010) and N₂-O₂ (Guerra and Loureiro 1997, Guerra and Loureiro 1999).

The first step in the study of the new applications involving ternary mixtures is the investigation of their electron kinetics, even if the processing takes place in the afterglow. As a matter of fact, electrons gain energy from the applied field and subsequently release it in different collision processes, such as excitation, dissociation and ionization of the gas. The coupling of the different kinetics determines the concentrations of the different heavy-particles in the discharge, defining the initial conditions to the afterglow. Herein we focus our attention in the electron kinetics, in particular in the ionization rate coefficients, for discharges in Ar-O₂-N₂ and in He-O₂-N₂, sustained by a microwave field of frequency $f=\omega/2\pi=2.45$ GHz.

The electron energy distribution function (EEDF) is calculated by solving the homogeneous electron Boltzmann equation using the two-term expansion in

spherical harmonics. The angular field frequency ω is assumed sufficiently high so that the EEDF is nearly stationary (Ferreira and Loureiro 1989). The electron Boltzmann equation is solved taking into account elastic collisions, excitation and de-excitation of rotational levels, inelastic and superelastic collisions with vibrationally excited molecules, excitation of the electronic states and ionization. Notice that electrons collide with the parent gases, but also with O and N atoms resulting from dissociation. The effects produced by electron-electron Coulomb collisions are taken into account following the same procedure as in (Sá et al. 1992).

Some results for the $Ar-O_2$ mixture are presented in Figs. 1 and 2. A detailed analyses of the ternary mixtures will be presented at the conference.



Figure 1: EEDFs calculated for $E/N=15\times10^{-16}$ Vcm² (thick curves) and 55×10^{-16} Vcm² (thin curves), for different Ar content in the mixture.

Fig. 1 shows the Electron Energy Distribution Functions (EEDFs) calculated for two values of the reduced electric field, $E/N=(E_0/\sqrt{2})/N$, 15×10^{-16} and 55×10^{-16} Vcm², for three different Ar-O₂ mixture compositions. The oxygen dissociation degree was kept constant, $[O(^{3}P)]/[O_2(X)]=1$. As it can be seen, addition of a relatively small content of oxygen into pure Ar is enough to significantly change the EEDF and, consequently, the electron ionization and excitation rate coefficients. Moreover, the high energy tails of the EEDFs are less populated as oxygen is introduced in the mixture, as a result of a higher global cross section in oxygen. That being so, for constant electron density (and not counting for the magnitude of the electron ionization cross sections), the electric field sustaining the discharge should be higher near pure oxygen than near pure argon.



Figure 2: Electron impact ionization rate coefficients, as a function of the mixture composition, for $E/N=15\times10^{-16}$ Vcm² (thin lines) and 55×10^{-16} Vcm² (thick lines).

Fig. 2 depicts the ionization electron impact rate coefficients as a function of the mixture composition. At constant reduced electric field all the electron impact rate coefficients decrease with the fraction of oxygen in the mixture, in accordance with the changes in the EEDFs revealed in Fig. 1. Close to pure argon, ionization from the 4s excited states may give a non-negligible contribution to ionization. As a matter of fact, although the concentration of these states is much lower than that of ground-state $Ar({}^{1}S_{0})$ atoms, the corresponding electron impact ionization coefficient is much larger, making electron stepwise ionization quite relevant.

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