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ARRIVAL TIME SPECTRUM OF ELECTRON AND ION AVALANCHES AT VERY HIGH E/n IN NITROGEN

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Abstract. In this paper present the results of Monte Carlo simulation (MCS) of electron and fast heavy particle transport in nitrogen at very high E/n (E- electric field, n- gas density). The simulations are aimed at modeling the experimental data of Gylys et al. (1989) for pulsed current and photon waveforms obtained under non- selfsustained conditions. The MCS results are in excellent agreement with the experimental data thus confirming the assumed kinetic scheme whereby most of the excitation and ionization is performed by heavy particles.

1. INTRODUCTION

Phelps and coworkers have performed a number of experiments at very high E/n where they studied non- equilibrium kinetics of electrons and heavy particles (Jelenković and Phelps (1987), Phelps and Jelenković (1988), Gylys et al (1989)). Their experiments were supported by a beam like one dimensional theory (Phelps et al. (1987)).

2. MONTE CARLO SIMULATION

We have developed a three dimensional MCS code for simulation of coupled kinetics of electrons, ions and fast neutrals. The electron collisions are represented by the best total cross sections from the literature both for elastic and inelastic scattering. Differential cross sections from the literature are used in up to 70 different energy segments for each process to describe the anisotropy of scattering. Non- conservative scattering is represented by the best available data for energy partitioning and by following the secondary electrons. Finally electrons that hit the anode may be reflected, the reflection coefficient depending on the initial energy, and secondaries may be released as well. Energy and angular distributions of the back scattered particles are taken from the literature.

Ion collisions are represented by the cross sections, both isotropic and anisotropic, taken from the review by Phelps (1991). In nitrogen we follow molecular and atomic ions, the former making a dominant contribution. The anisotropic cross section set was extended from high energies where charge transfer dominates and from the low energies where polarization interaction dominates to the mid energy range to complete the set of cross sections. Fast neutral cross sections were taken from the review by Phelps as well but the particles were followed only down to thė threshold energy for excitation.

The code is developed in such a way so that both Steady State Townsend, Pulsed Townsend and Time of Flight experimental conditions can be sampled by appropriate integration. The code was tested for moderate and low E/n conditions where it give transport coefficients with the uncertainty of less than 1 %. It was also tested against the transport coefficients for ions in nitrogen and argon.

3. RESULTS

In Figure 1. we show the arrival time spectrum of the particles at the anode. The direct electron and ion contribution is separated from the secondary contributions due to ionization by ions and fast neutrals. The results are in agreement with the time resolved current waveforms obtained by Gylys et al. (1989) but direct comparison cannot be made since the experimental data are obtained with a much poorer resolution so only the position of peaks can be claimed to be consistent. A much better quantitative comparison can be provided with teh integrated (Pulsed Townsend) waveforms. In Figure 2. we show the comparison of our integrated particle flux data with the waveform obtained by emission integration which is identical to that obtained by cur-

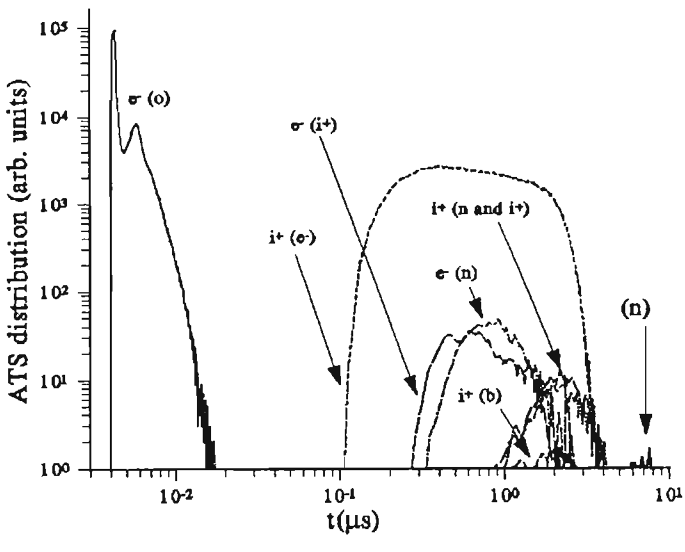

Fig. 1. Arrival Time Spectrum (ATS) of electrons, ions and neutrals induced by 500 000 electrons released from the cathode. $E/n = 52\ kTd$, $nd = 2X10^{19}\ m^{-2}$, $d = 0.04\ m$ (d- interelectrode distance). e^-(o) - ATS for direct electrons arriving at anode; $i^+(e^-)$ - ATS of ions formed in ionizing collisions of direct electrons; $e^-(i^+)$ - electron ATS produced in ions avalanche, e^-(n) - electron ATS produced in fast neutrals transport, both groups arriving at anode; i^+(n, i^+) - ion ATS at cathode formed during the transport of electrons created by heavy particles; (n) ATS of fast neutrals at the cathode; i^+(b) - ATS of ions produced by the backscattered electrons from the graphite anode surface.

rent integration. The sharply rising edge is due to integration of the electrons and the slowly rising is due to ions and electrons produced by ions. Thus the relative magnitude of the two steps gives the ratio of particle multiplication by electrons and by ions. The MCS result is in excellent agreement with the experimental data. The agreement is maintained for all other values of nd.

We may thus conclude that the kinetic model for high E/n ionization proposed by Phelps (1990) which was incorporated into the MCS code and extended by the best available data for differential cross sections, gives excellent agreement with the pulsed waveform and integrated waveform data of Gylys et al. (1989).

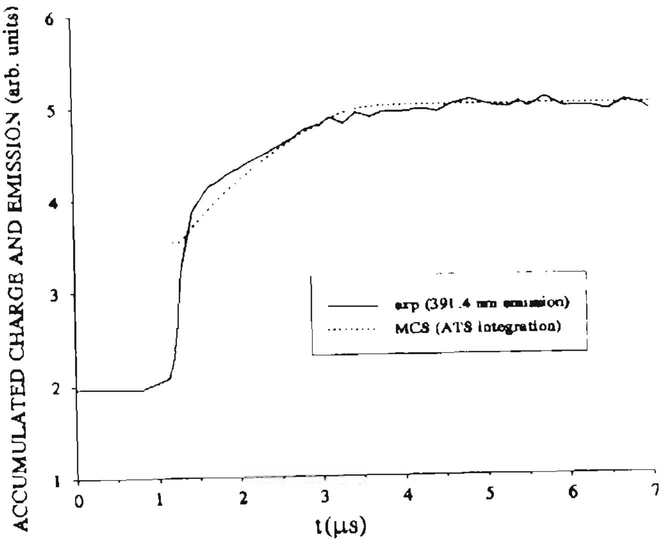

Fig. 2. Waveform of the integrated ATS for electrons and ions (MCS) and emission of 391.4 nm band of N_2^+ obtained in experiment. $E/n = 52\ kTd$, $nd = 3.9X10^{19}\ m^{-2}$, $d = 0.04\ m$.

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