Publ. Astron. Obs. Belgrade No. 84 (2008), 285 - 288 *Contributed Paper*

THE INFLUENCE OF THE SECONDARY ELECTRON EMISSION COEFFICIENT AND EFFECT OF THE GAS HEATING ON THE CALCULATED ELECTRICAL CHARACTERISTICS OF A GRIMM TYPE GLOW DISCHARGE CELL

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Abstract. Electron emission properties of cathode surfaces affect considerably the electrical characteristics of glow discharges. Using a heavy-particle hybrid model in 2 dimensions, we investigate the influence of the secondary electron emission coefficient γ on the calculated discharge characteristics for both 'clean' and 'dirty' cathode surface conditions, and assuming a constant γ parameter as well. The effect of the gas heating and the role of the heavy particles reflected from the cathode on this process is also studied.

1. INTRODUCTION

Modeling is a powerful method to gain a better understanding of the relevant plasma processes in gas discharges and of the behavior of different plasma species under various discharge configurations. Hybrid models – combining the particle simulation of fast plasma species with the fluid treatment of slow plasma particles (Boeuf and Pitchford 1991, Bogaerts et al. 1995) – have successfully been applied for the modeling of various low pressure dc discharges to obtain the potential distribution, the densities, energies and fluxes of the plasma species in a self-consistent way.

In order to reproduce the various discharge characteristics, a correct set of input data has to be specified in the modeling calculations. At this point, the secondary electron emission coefficient of the cathode is a relatively fuzzy parameter, and is often considered to be constant in the literature. Secondary electron emission yields, on the other hand, vary with the surface conditions and with the energy of particles bombarding the cathode (Phelps and Petrović 1999). Energy-dependent electron yield data for the different plasma species can be used to calculate γ self-consistently (Donkó 2001). Electrical characteristics of the discharges are calculated here with such self-consistent γ values for 'clean' and 'dirty' surfaces (for definition of these conditions see (Phelps and Petrović 1999)), as well as with a constant value for γ. However, due to the heavy particle surface sputtering, we expect 'clean' cathode surfaces in Grimm type sources.

Studies of the (pulsed) discharge excitation on the electrical characteristics indicate the importance of gas heating, e.g. (Efimova et al. 2008). Here the effect of energy transferred to the background gas is studied for different voltage and pressure settings for dc discharges.

2. CELL GEOMETRY AND DESCRIPTION OF THE MODEL

In our study we consider a part of the Grimm type glow discharge cell (of the instrument Spectruma GDA 750) in the vicinity of the cathode, where all important plasma processes are expected to take place. The glow discharge cell considered in the simulations has a cylindrical symmetry, the length of the region investigated is 8 mm, the diameter of the cylindrical anode is 4 mm. We describe discharges in pure Ar gas and assume Cu as cathode material. The species considered in the model are the electrons, Ar^+ ions and fast Ar atoms. Fast electrons (if their energy is higher than the excitation threshold of Ar atoms) are simulated with Monte Carlo method, while the slow electrons are treated in a fluid model as well as the Ar^+ ions. The fast Ar atoms and Ar^+ ions in the cathode region are also followed in the Monte Carlo model. As the energy of these individual heavy particles bombarding the cathode is known, and their energy dependent electron emission yields can be found in the literature (see e.g. Phelps and Petrović 1999), the "apparent" secondary electron emission coefficient γ can be adjusted to the current conditions in each Monte Carlo cycle as explained in e.g. (Donkó 2001).

The temperature of the cathode is set to 330 K and the wall temperature is 300 K when gas heating is taken into account, otherwise the background gas temperature is fixed at 300 K. The energy transferred to the background argon gas results from the thermalization of fast heavy particles. The gas temperature distribution is obtained by solving the heat conductivity equation and is used to calculate the density distribution of the background gas atoms, according to the ideal gas law.

A detailed presentation of both the Monte Carlo and fluid models for 1 dimensional case is given in e.g. (Donkó 2001). A description of the heat conduction module and its coupling to the hybrid model can be found in (Bogaerts et al. 2000, Donkó 2001).

3. RESULTS AND DISCUSSION

Simulations have been performed in 2 dimensions for the simplified Grimm-type glow discharge cell geometry. As reported in (Bogaerts et al. 2001), for this type of cell geometry in case of operating conditions of 450-1200 Pa pressures and voltages 600-1000 V, the measured current ranges between 5 and 50 mA. In our study two different pressures (300 and 500 Pa) are considered and for each pressure the effect of the secondary electron emission coefficient and the gas heating is investigated at three voltage values (500, 700 and 900 V). The calculated secondary electron emission coefficient γ is in the range of 0.06-0.18 for 'dirty' cathode surfaces and it is equal

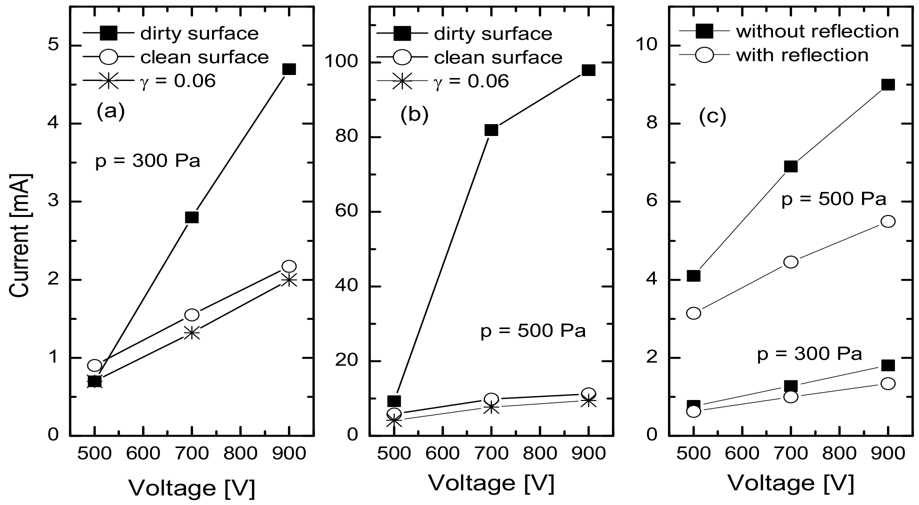

Figure 1: Currents obtained by using the self-consistently calculated γ for 'clean' and 'dirty' cathode surfaces and assuming (constant) $\gamma = 0.06$ for (a) 300 Pa and (b) 500 Pa. The effect of the gas heating is neglected in both cases. (c) Currents obtained with gas heating calculations: the effect of the reflection of heavy particles from the 'clean' copper cathode surface.

to ≈0.07 for 'clean' copper cathode at all conditions under study (Figure 1(a)-(c)). These values of γ are in accordance with the simulation results of (Bogaerts and Gijbels 2002). As a consequence of neglecting the effect of the gas heating on the background gas density and through this on the collision processes in the discharge, considerably higher current values have been obtained compared to the expected ones for both pressures investigated (Figure 1(a) and (b)). Taking into account the gas heating process in the calculations, the currents approximate the experimental values. A decrease with 15-40 % of the currents has been calculated as the effect of heavy particle reflection from the cathode surface. The results of gas heating calculations are plotted in Figure 1(c). Several characteristics of the discharge calculated for $p = 500$ Pa pressure and $V = 700$ V voltage operating conditions are presented in Figure 2. Here we have assumed a 'clean' copper cathode surface and considered the effect of the gas heating in the model. Reflection of fast heavy particles from the cathode is taken into account. In Figure 2(a) the two-dimensional distribution of ion density is plotted indicating maximum value inside the negative glow, with values around 3×10^{13} cm^{-3}. Figure 2(b) shows the potential distibution and reveals the formation of the sheath & negative glow stucture. A plasma potential of ≈ 9 V (above the anode potential) is formed in the negative glow. The power input per unit volume is displayed in Figure 2(c). The energy transferred to the background argon gas is mainly concentrated within a narrow region close to the cathode. Consequently, a major increase of the gas temperature can be observed in this part of the cell as it visible in Figure 2(d).

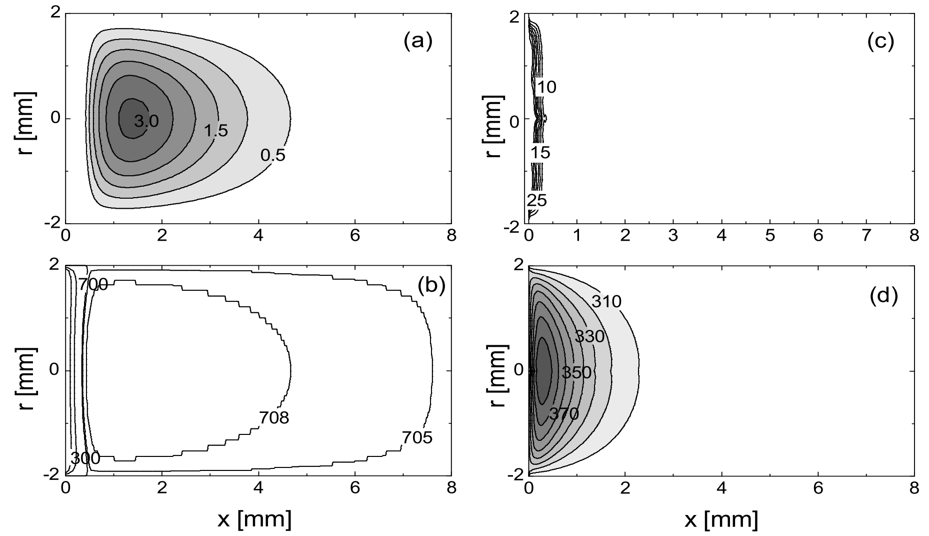

Figure 2: Results of the two-dimensional hybrid model coupled with gas heating calculation for 'clean' Cu cathode surface, at p = 500 Pa, V_{anode} = 700 and V_{cathode} = 0 V. The cathode is situated at the x = 0 plane. (a) Density distribution of argon ions. The labels on contour lines give the density in units of 10^{13} cm^{-3}. (b) Potential distribution (in Volts). (c) Distribution of the power input into the background gas. Values are in units of Wcm^{-3}. (d) Gas temperature profile (in Kelvins).

4. CONCLUSIONS

Our simulations have certified the relevance of the correct choice of the used secondary electron emission coefficient in the model and have confirmed the importance of the gas heating in order to obtain realistic results for the calculated electrical characteristics of the Grimm type discharge cell.

Acknowledgements

This work has been supported by the MRTN-CT-035459 GLADNET project.

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