Publ. Astron. Obs. Belgrade No. 89 (2010), 269-272 *Contributed Paper*

THE EFFECT OF METASTABLE ATOMS ON THE SECONDARY ELECTRON PRODUCTION IN ARGON

MARIJA SAVIĆ, MARIJA RADMILOVIĆ-RAĐENOVIĆ
and ZORAN Lj. PETROVIĆ
Institute of Physics, University of Belgrade, POB 68 11080 Zemun Serbia
E-mail: smarija@ipb.ac.rs, marija@ipb.ac.rs, zoran@ipb.ac.rs

Abstract. This paper contains the Monte Carlo simulations obtained for the conditions of a gas breakdown in argon with all possible agents that may induce secondary electron production including the contribution of the metastable atoms. The paper is focused on argon. Two metastable levels are included in the simulation following the work of Phelps and Petrović (1999).

1. INTRODUCTION

Until recently, the role of metastable atoms in secondary electron production has been neglected or taken as a singular process added in addition to the contribution of ions. However, Phelps and Petrović (1999) have revised the Townsend's theory and pointed out that secondary electrons yields explaining the breakdown. Paschen curves may be reproduced from the binary collision data that include contribution of ions, fast atoms, metastable atoms and photons of different kinds with cathode or by gas phase ionization mainly by fast neutrals. That model also had to include processes that modify the fluxes of particles and secondary electrons such as backdiffusion, resonant photon trapping and status of the cathode surface. The calculation was based on a simple beam like model of transport that could fail to represent some of the pertinent physical properties of the particles especially when nonhydrodynamic transport is involved which is always the case close to the metal surfaces or when strongly energy dependent processes are important.

In order to develop a standard and comprehensive procedure for modeling low pressure breakdown we have used a Monte Carlo code, developed and tested at the Institute of Physics, Petrović and Ristivojević (unpublished). The code that was utilized follows different kinds of particles and all their relevant products between electrodes during breakdown. The calculations were performed for argon by using the set of cross sections that involves 27 inelastic (excitations) processes as used by Petrović and Stojanović (1998). Initial conditions for breakdown, pressure and voltage are taken from the same Paschen curves used by Phelps and Petrović (1999).

2. RESULTS AND DISCUSSION

In the development of the tool for analyzing data for other gases we test all the results against those of Phelps and Petrović (1999). The results show the partial secondary electron emission enhanced by the metastables at the level of around 10% at practically all mean energies (E/N). In our calculations we assumed two kinds of surfaces: clean and dirty as proposed by Phelps and Petrović (1999). For high-boiling-point metals a "clean" surface means that the surface has been heated to ~2000 K in a very good vacuum and following that procedure measurements were made with the surface at room temperature under constantly maintained high vacuum. Such a heat treatment is often called 'flashing'. Sometimes intensive etching may produce similar results. "Dirty" metal surfaces are those with varying degrees of surface exposure to oxygen, to water, to ambient gas, or to unspecified contamination. Those include the surfaces with best possible external mechanical and even chemical treatment, polishing and ultrasonic baths.

Metastable atoms are formed in a few different steps. The effect of different mechanisms of metastable production on the secondary electron yields are shown in Fig. 1 and Fig. 2 for clean and dirty surface, respectively. In the first step, metastables are produced by populating directly metastable levels, $1s_5$ and $1s_3$ (in Paschen notation). In our model, population is included by using cross sections for electron-background atom collisions, mentioned earlier. Secondary electron coefficient for metastables is γ=0.02 as proposed by Phelps and Petrović (1999). The obtained simulation results are presented by dash dot dot lines.

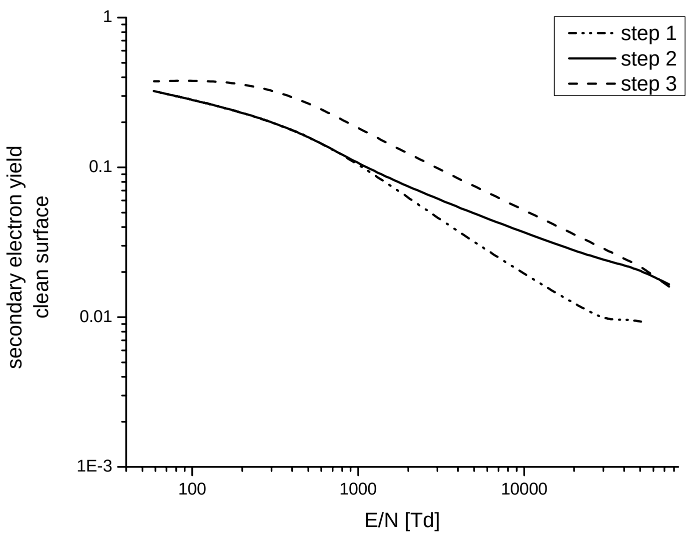

Figure 1: Partial secondary electron yield as a result of metastable bombardment of the clean cathode surface.

In order to improve our model, we include metastable production via fast atom-background atom collisions, (Phelps 1991). This step (step 2 in our notation in Figs. 1 and 2) is embedded by involving a cross section that describes heavy particle collisions that lead to metastable production. We can expect some increase of the number of secondary electrons that are released from cathode due to more metastables that are involved in simulation as depicted by solid lines. This contribution is increasing at high E/N.

Furthermore, in the third step we include electron deexcitation of electrons from higher to metastable levels that can be regarded as cascading. Probabilities for deexcitation of excited electrons are calculated from Einstein's coefficients in accordance with the equation:

$$W_{k,i} = \frac{A_{[i]}^{[k]}}{\sum_{j=0}^{n} A_{[j]}^{[k]}}, \qquad (1)$$

where i is apropriate metastable level, electron is deexcited from level k, while j represents all levels to which is posible electron transitions from level k. The achieved simulation results are shown by dash lines. As expected, there is noticeable increasing of the number of secondary electrons that are released from cathode due to more metastables that are involved in simulation. This contribution is constant at all E/N.

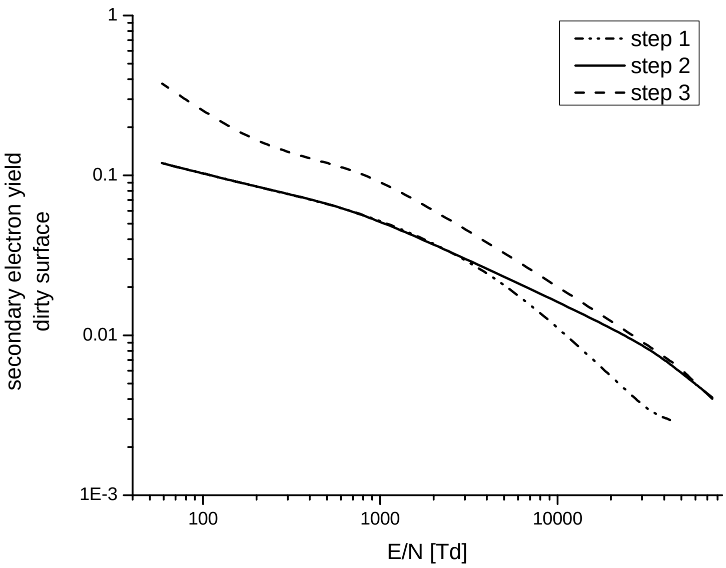

Figure 2: Partial secondary electron yield as a result of metastable bombardment of the dirty cathode surface.

Results, presented here, indicate that precise modeling of low pressure breakdown and also of plasmas that may be strongly dependent on secondary electron production such as DC discharges and high power RF discharges, requires taking into account contribution of metastable atoms to the secondary electron emission and thereby to the breakdown voltage.

Acknowledgements

The present work has been carried out under MNTRS 141025 project.

References

Petrović, Z. LJ., Ristivojević, Z., (unpublished).
Petrović, Z. LJ., Stojanović, V. D.: 1998, *J. Vac. Sci. Technol. A,* **16**, 329.
Phelps, A. V.: 1991, *J. Phys. Chem. Ref. Data 20*, **3**, 557
Phelps, A. V., Petrović, Z. LJ.: 1999, *Plasma Sourc. Sci. Technol.*, **8**, R1.