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MODELING OF THE IGNITION OF LOW-PRESSURE GLOW DISCHARGES

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Pulsed glow discharges are commonly used in analytical spectroscopy since with this operation mode higher peak voltages and currents resulting in higher analyte signals can be obtained than in direct current discharges for the same average power applied. In various experiments of pulsed glow discharges a pronounced peak in the electrical current can be observed at the beginning of the pulse. In order to predict this behaviour – experienced also in microsecond pulsed glow discharges in Grimm-type sources – by modeling, in [1] a considerable variation of the gas temperature as a function of time has been assumed. However this approach – as pointed out in [2] too – has overestimated the influence of the temperature and disregarded the capacitive effects due to the measuring circuit. In [3] the experimentally observed discharge transients – following the application of a high-voltage pulse on the initial discharge – reported in [4] have been reproduced by a one-dimensional self-consistent hybrid model (combination of fluid and kinetic treatement of plasma species) taking into account in the calculations the characteristics of the external circuit. This model [3] makes possible to follow the development of the discharge in time through the continuous monitoring of discharge voltage and particle current. Based on this approach, in the present work we use a two-dimensional heavy particle hybrid model to simulate the ignition of low pressure glow discharges in Ar and perform a parametric study of the effect of the elements of the external circuit on the formation of the plasma. The discharge cell considered in the model consists of a cylindrical Cu anode (length: 10 mm, diameter: 4 mm) and Cu cathode.

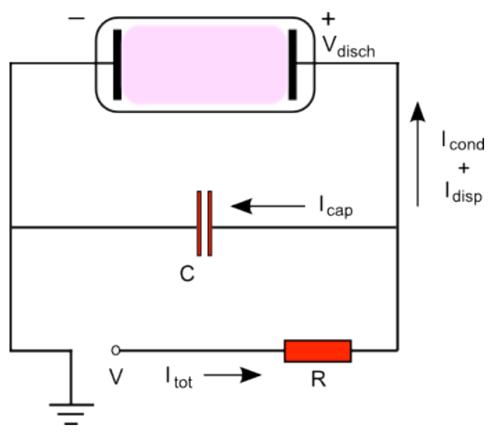

Fig. 1: Electrical circuit and current components considered in the model. R: resistor and C: capacitor formed by the external circuit, V: source voltage, V_{disch}: discharge voltage, I_{tot}: total current, I_{cap}: current of the capacitor, I_{disp}: displacement current and I_{cond}: conduction current.

The scheme of the electrical circuit and the different current components considered in the model are shown in Fig.1. The current components and the voltage of the electrodes are recalculated in each Δt integration step of the fluid model. During each Δt time step, a voltage change of both the capacitor voltage and discharge voltage is generated by the current of the capacitor I_{cap}. The displacement current I_{disp} – as a result of space-charge accumulation – is determined from the change of the electric field in front of the cathode, while the conduction current I_{cond} is defined by the flux of positive ions arriving to and electrons leaving from the cathode surface.

Simulation results for one set of parameters (V = 500 V, p = 600 Pa, R = 20 kΩ, C = 35 pF) are presented in Fig.2: panel (a) shows how the current from the source I_{tot} is divided in time between the circuit components, in panel (b) the time-dependence of the discharge voltage is plotted. At the beginning the capacitor is charged resulting in the increase of the capacitor voltage. During that time the displacement current starts to increase. When the voltage of the capacitor reaches the value of the breakdown voltage, the conduction current starts to rise exhibiting a peak due to the discharging of the capacitor. The discharge stabilizes about 5 μs after turning on the voltage source.

Simulations have been carried out by considering different values for the capacitance and resistance of the electrical circuit. For fixed voltage and pressure conditions, the increase of the circuit capacitance resulted in the extension of the time needed for the stabilization of the discharge, variaton of the circuit resistance influences the current components.

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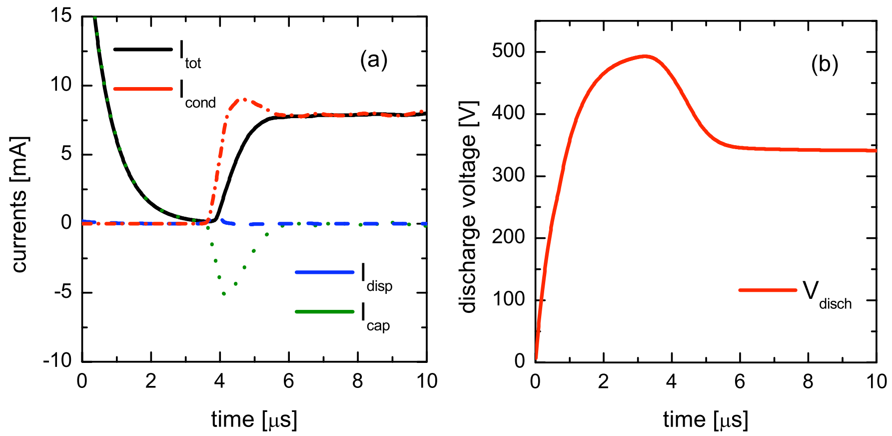

Fig. 2: Simulation results on the time dependence of current components (a) and of the discharge voltage (b) obtained for V = 500 V, p = 600 Pa, R = 20 kΩ, C = 35 pF.

Reference

[1] A. Bogaerts and R. Gijbels 2000 J. Anal. At. Spectrom. 15 895

[2] A. Bogaerts, R. Gijbels and G. P. Jackson 2003 J. Anal. At. Spectrom. 18 533

[3] Z. Donkó 2000 J. Appl. Phys. 88 2226

[4] B. M. Jelencović and A. V. Phelps 1999 J. Appl. Phys. 85 7089