Topic number: 10

Chaotic behavior of dc microdischarges with parallel-plate geometry

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Discharge stability is one of the important requirements for the proper functioning of micro-discharge devices. Recently, the attention on stability and different discharge modes of microdischarges were triggered by several studies, like self-pulsing microplasma in microhollow cathode discharge [1] and micro plasma jet instabilities [2], including analysis of different discharge stages: chaotic, bullet und continuous mode [3]. The earlier investigations on large scale DC low-pressure discharges have made a large effort in understanding the sources of discharge current oscillations and constrictions [4]. Here we extend this type of analyses to the small scale, high pressure discharges with an aim to understand the basic processes that influences the stability of microplasmas.

The electrode system consists of parallel-plate highly-polished stainless-steel electrodes with variable distance. The electrode diameter is d = 5 mm and the distance 1 mm. The working gas is argon at pressure p = 10 Torr so that pd is 10 Torr mm (1 Torr cm), at which point the Paschen curve has a minimum breakdown voltage of about -240 V. The electrodes are tightly fitted in to the vacuum-sealed Plexiglas chamber to avoid long-path breakdown [5]. High negative voltage is applied to the cathode to ignite the discharge and the discharge current is controlled by changing voltage and/or by changing the loading resistance, (as described earlier [4]). Voltage-current waveforms are simultaneously measured by means of digital oscilloscope and archived in the computer for latter evaluation.

Characteristic voltage (upper waveform) and current (lower waveform) waveforms are presented in Fig. 1. The two different oscillating modes can be recognized: low frequency with increasing frequency (f_r) and high frequency with increasing amplitude (f_s). The low frequency oscillations are relaxation oscillations, during which the discharge periodically ignite and choke. The mean value of the current during this oscillation mode is 54 μA. After 10 ms the discharge spontaneously switches to seemingly stable regime through spontaneous oscillations that in the first millisecond decay and after 5 ms appear again and start to grow in the amplitude. The mean current changes from 140 μA to 130 μA when the discharge again switches to relaxation oscillations mode. Afterwards, the whole process repeats.

The current-voltage characteristic of the microdischarge is presented in Fig. 2. Two different discharge modes can be distinguished: low frequency relaxation oscillations and high frequency growing oscillations.

The most exciting observation by the relaxation oscillations is that their frequency increases spontaneously from 1.78 kHz to 2.11 KHz, without any change in input parameters. Power spectrum of current relaxation oscillations (Fig. 2) shows characteristic chaotic behaviour of dissipative dynamical systems. The similar nonlinear dynamical were previously observed for thermionic discharges with volume ionisation [6], double plasma devices [7] and recently in cold atmospheric pressure plasma jet [3]. The oscillation modes and their behaviour depend on the current density and other discharge parameters such E/n and should be further investigated.

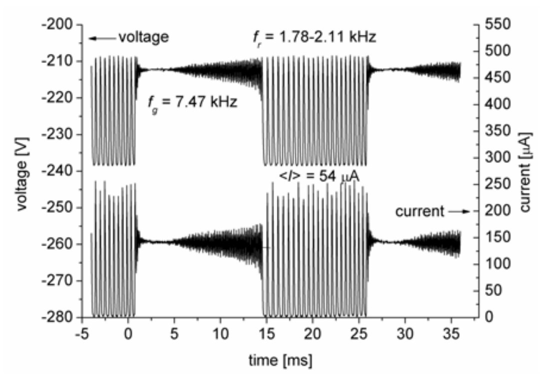

Fig. 1: Voltage (upper waveform) and current (lower waveform) oscillations in parallel plate microplasma with continuous argon flow. Discharge parameters are: pressure p = 10 Torr, electrode distance d = 1 mm.

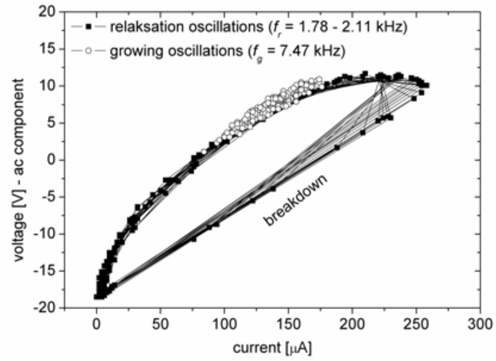

Fig. 2. Voltage-current characteristic of the microdischarge with the same discharge parameters as on the Fig. 1. Two different oscillations modes can be distinguished: relaxation oscillations (solid squares) and growing oscillations (opened circles).

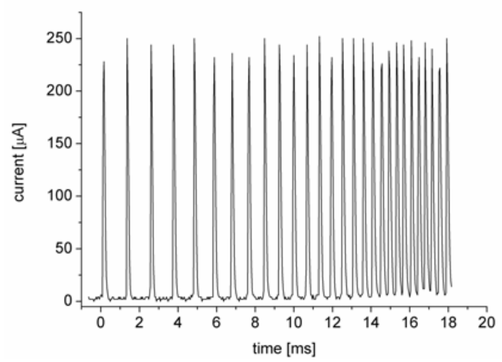

Fig. 3: Current relaxation oscillations with continuously increasing frequency. The discharge conditions are the same as on the Fig. 1.

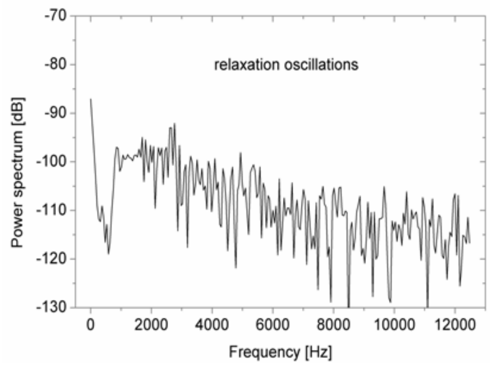

Fig. 4 Power spectrum of current oscillations from Fig. 3. The spectrum is characteristic for chaotic regime of dissipative dynamical systems

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