Electric properties of an atmospheric pressure RF hydrogen microdischarge

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In this work we present results of the experimental study of the high pressure DC and AC microdischarges over wide range of frequencies in Hydrogen. The microdischarges have been generated between two plan-parallel molybdenum electrodes in a high vacuum chamber filled with pure Hydrogen gas. From the Paschen curves the breakdown voltages have been measured as a function of the frequency range (from 1kHz up to 4.3MHz) and the electrode distance (from 2.5 μm up to 100 μm) while the gas pressure was constant at 930mbar.

1. Introduction

The non-equilibrium plasma sources operating in the glow mode, are highly desired in many applications [1, 2]. However at high pressure, stable diffuse glow discharge is a challenging problem due to their transition to an arc [3, 4]. One of the ways how to stabilize it, is to spatially confine it to the dimensions below 1 mm, leading to the so-called microplasmas [3]. Many mechanisms and phenomena occurring in microdischarges are not clearly understood especially in case of AC discharges. The most promising field of applications of microdischarges are material processing, plasma medicine, chemical synthesis etc. [5-7]. Therefore the knowledge of the physical phenomena occurring in the microdischarges, are very important [8-12]. The main goal of this work is to study the breakdown phenomena of high pressure microdischarges over wide range of frequencies and electrode distances in Hydrogen. Comparison to the breakdown phenomena between low frequency AC and high frequency AC discharges are presented.

2. Experimental setup

2.1. Experimental apparatus

The experimental apparatus consists of vacuum chamber with four glass window and two *xyz* and tilting manipulators of electrodes. Its schematic view is shown in the Figure 1.

The Paschen curves and the Current-Voltage waveforms were measured by 300MHz oscilloscope connected to high-voltage probe and to current probe for frequency range from 1kHz up to 4,3MHz. Moreover, direct current (DC) measurements were carried out for comparison to AC microdischarges. The distance between the electrodes was set by micrometer linear feedthrough from 2.5 μm to 100 μm.

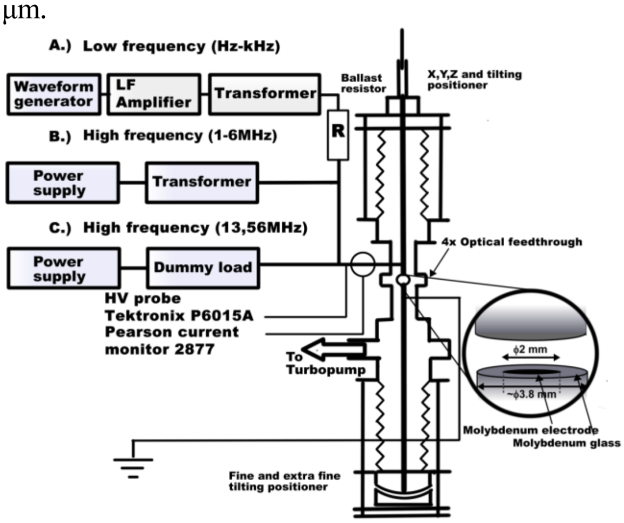

Figure 1: Vacuum chamber for microdischarges with different type of power supplies.

2.2. Experimental results

In this experiment the breakdown voltages of the microdischarges have been studied according to two parameters (distance between electrodes and frequency). The breakdown voltage has been measured as function of electrode distance and frequency at constant pressure of 930mbar shown in Figure 2.

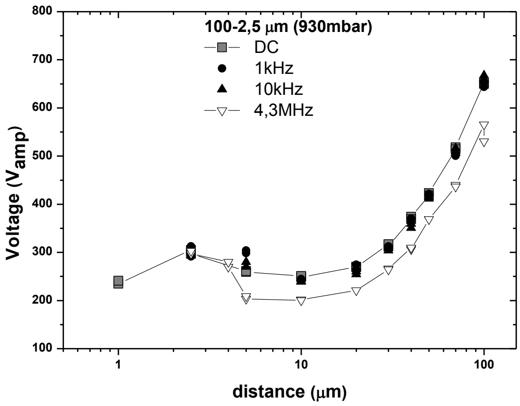

Figure 2: Breakdown voltages (V_{amp}) for different electrodes distances at pressure of 930mbar.

The highest values of the breakdown voltages were measured for the DC electric field (see in Figure 2). For the AC discharges V_{amp} was taken. If we consider the AC voltage amplitude, the breakdown voltages for DC and kHz AC are more or less identical. For RF frequencies the breakdown voltage is weakly dependent on the frequency, the electrons with high drift velocities are lost on the walls but the ions are trapped in the gap. It is due to their lower drift velocity than of the electrons [13].

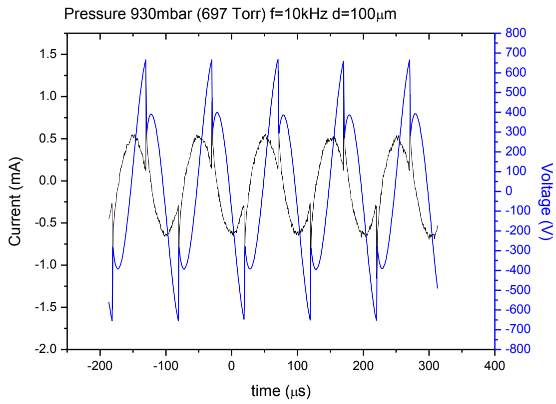

Figure 3: The current-voltage waveform of the discharge at frequency 10 kHz.

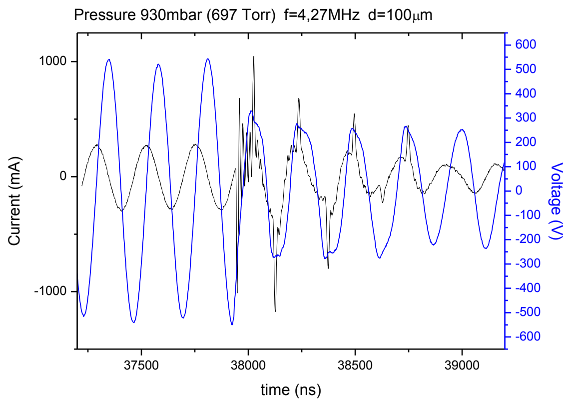

Figure 4: The current-voltage waveform of the discharge at frequency 4.3 MHz.

In Fig. 3 and Fig. 4 you can see the current-voltage waveform of the discharge at constant electrode distance of 100 μm at 10 kHz and 4,3MHz respectively.

2.3. Discussion and Conclusion

The experimental results of high pressure AC microdischarges in Hydrogen have shown the differences in electrical properties. No significant effects on breakdown voltages were measured at low frequencies (up to 10kHz). At higher frequency (4,3 MHz) the values of the breakdown voltage are lower. We assumed, the frequency above 4,3MHz is high enough so that the ions are trapped in the gap and the electrons with higher drift velocities are lost to the wall. At 10 kHz the current-voltage is periodical and has the similar form in every period. When the breakdown is ignited voltage between the electrodes are decreased due to lower resistance and both waveforms are exhibit minor distortion. At 4,3MHz after the breakdown is ignited, the voltage amplitude decrease.

Acknowledgments

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3. References

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