The ignition of low-pressure capacitively coupled discharge

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Radiofrequency discharges, especially capacitively coupled discharges, are highly used in both science and industry. Main reasons for that are etching and deposition, in which ion bombardment (induced by high electric field in sheaths) plays an important role. Sheaths in stationary CCP control the discharge character by means of the stochastic heating [1], gamma processes [2] and field reversal [3]. However in the early stages of CCP, sheaths are not fully developed and a strong electric field affects the whole interelectrode space. This means that during ignnition the plasma heating mechanisms and its whole nature needs to develop from a bulk-field driven to a sheath-driven character. CCP ignition needs to be carefully described as it considerably differs from its well studied stationary state. But works describing RF breakdown are rare, even though ignition of DC and low-frequency discharges are well described by Townsend and streamer theory.

Still, works describing some parts of the CCP ignition were done. It was shown that CCP undergoes sequence of various heating modes [4, 5]. In the phase of rise of electron concentration, which lasts typically $\sim 10\,\mu$s [6, 7], the temperature of electrons reaches significantly higher value from what is known in the stationary value [5, 8, 9, 10]. Similarly, the plasma potential can reach an unusually high value during the CCP ignition [11]. It was also found that in asymmetric discharge that development of sheaths last approximately tens of μs [8]. However, most of the papers focused on CCP ignition were concentrated on geometrically symmetric discharges and, consequently, were not able to describe the evolution of DC bias. That is why we studied ignition of an asymmetric CCP by means of combination of two probe techniques: The standard RF compensated Langmuir probe used for the study of electron energy distribution and the probe with no RF compensation used for study of the frequency spectrum of floating potential [12, 13, 14].

A series of 15 measurements in various positions in the discharge (with a step 2 mm) were done with the uncompensated probe to obtain both the temporal and spatial dependence of floating potential during the plasma ignition. The behaviour of the amplitude of the fundamental RF (13.56 MHz) and DC components of the probe voltage are shown in the fig. 1. The measurements demonstrate the development of the bulk plasma in the center of the interelectrode gap (as the region with a weak electric field), the development of sheaths with strong field and the non-monotonic evolution of the floating (and plasma) potential.

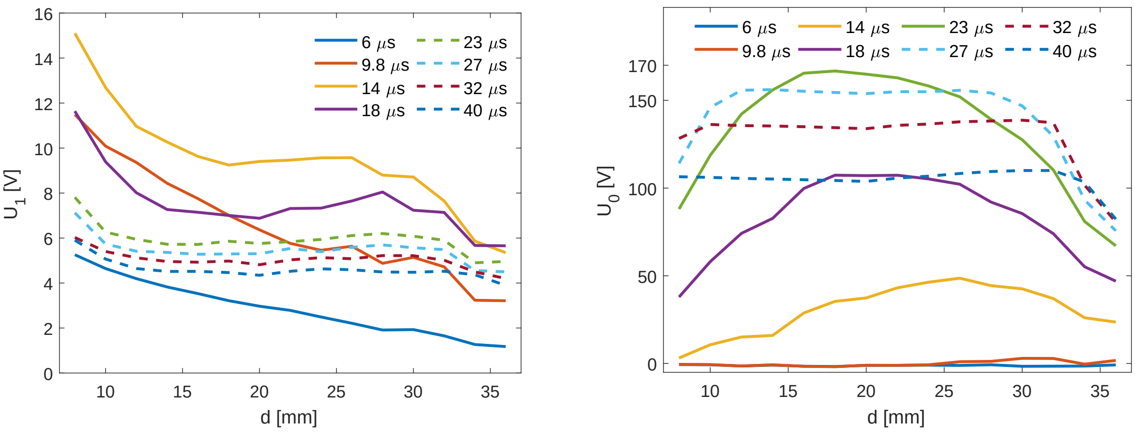

Fig. 1: Amplitude (left) and mean value (right) as functions of position in various moments of the discharge pulse.

RF compensated Langmuir probe was used to get probe VA characteristics in various times during ignition. Second derivation of the VA characteristics has to be done in order to obtain electron concentration and electron energy distribution. The EEDF revealed existence of several groups of electrons: the relatively cold bulk electrons and at least two groups of electrons with unusually high energy. The fig. 2 presents the development of electron concentration and mean energy for these various electron groups.

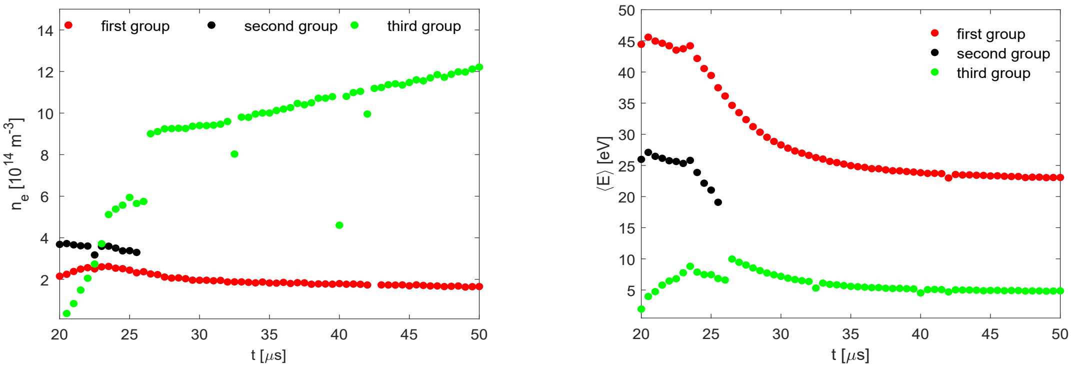

Fig. 2: Electron concentration (left) and energy (right) during discharge for various peaks from VA characteristic.

These measurements are supported by simple quantitative model, which describes the discharge asymmetry evolution. The sheaths with homogeneous ion concentration and negligible electron concentration, a negligible field in the bulk plasma and a monofrequency sinusoidal discharge current were assumed in the model. The model reproduced well the slow evolution of the DC bias.

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