Instabilities in cc-rf oxygen plasma

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Instabilities are investigated in low density oxygen cc-rf plasmas driven at 13.56 MHz. They are analyzed by means of three different diagnostics. Firstly, they are measured as electron density fluctuations by means of 160 GHz microwave interferometry [1]. Secondly, the instabilities are recorded by spatio-temporal resolved Langmuir probe measurement as fluctuation of floating potential and ion saturation current. Thirdly, it is used a ICCD camera to investigate the optical emission intensity fluctuations. Thereby, two different time scales are considered. It concerns the time resolved intensity measurement during the instability (TROES) averaged over rf cycles, and the rf phase resolved (PROES) measurements at different phase position within the instability cycle.

Introduction and Experiment

This contribution concerns investigation about instabilities observed in a 13.56 MHz cc-rf oxygen plasma. Thereby, the fluctuation of plasma parameters can be measured for specific total pressure and rf power values. The used discharge chamber is discussed in detail by Dittmann *et al.* [2]. Firstly electron density fluctuations are investigated by means of 160.28 GHz Gaussian beam microwave interferometry. The high microwave frequency enables one to describe the free space propagation by means of Gaussian beam theory and leads to a sufficient spatial resolution of 10 mm. The Gaussian microwave beam is aligned axial 20 mm above the powered electrode in the plasma bulk. The temporal resolution amounts to about 200 ns. This diagnostic tool directly provides the line integrated electron density fluctuations. Secondly, it is used a Langmuir probe system to measure the fluctuations of floating potential and ion saturation current. Thereby, the complete probe setup (measuring probe) is axial and radial movable with a spatial resolution in the millimeter range. The probe tip is connected via a capacitance with a shunt to drive the probe with the rf modulated plasma potential. Moreover, a passive compensation filter system is implemented to filter the 13.56 MHz and the second harmonic. Additionally, a second probe is required used as reference and trigger probe. Therewith, the signals from the measuring probe are related to each other in rigid manner. Only therewith, it is possible to determine the spatial resolved floating potential fluctuations temporally resolved for several phases of the instability in the entire plasma volume. Thirdly it is used an ICCD camera princeton instruments, PI-MAX2 to measure the optical emission intensity time resolved (TROES) during an instability as well as to investigate the rf phase resolved optical emission (PROES) for different phases of the instability.

Instabilities

The electron density fluctuations were observed within the complete range of investigated total pressure between 10 and 100 Pa. Whereby, the instabilities appear only for special rf power values. Vice versa it means that it exist areas without instabilities, so-called stability islands. At pressure greater than 60 Pa the entire plasma is dominated by instabilities at used rf power from 10 to 100 W. The peak to peak values of the line integrated electron density fluctuations are of about $\Delta\tilde{n}_e = 0.2$ to $3.5 \times 10^{15}\ \mathrm{m}^{-2}$ and can be in the same order of magnitude as the mean electron density $\tilde{n}_e$. The power spectra of the instabilities show that they are non harmonic. For the entire parameter set the frequency is in the range from 0.1 to 3 kHz. Moreover, the instabilities need typical start up time in the millisecond range to develop. This is in good agreement with the investigation of Descoeudres [3]. From investigations

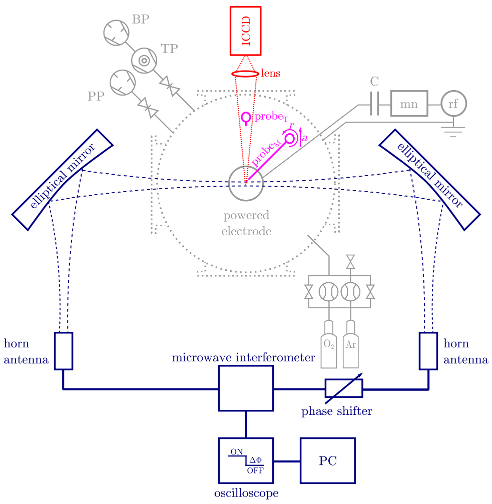

Fig. 1: Schematic top view picture of the discharge setup with the 160 GHz interferometer, the probe diagnostics and the ICCD camera.

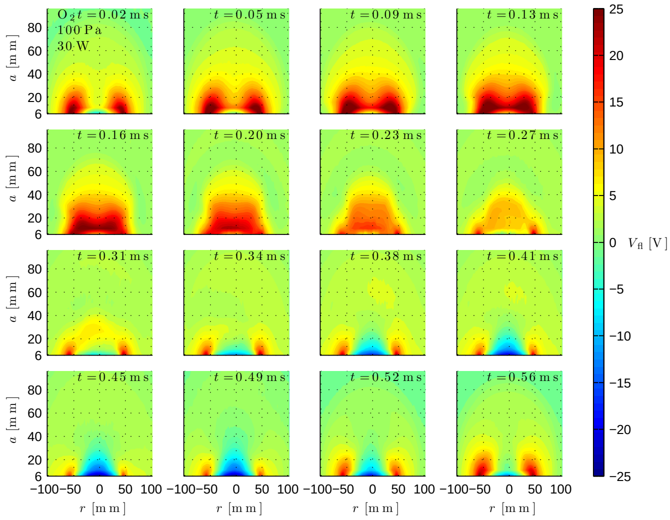

Fig. 2: Spatio-temporal resolved fluctuation of the floating potential during an instability for 100 Pa and 30 W. The fluctuations are measured with a axial (a) and radial (r) movable Langmuir probe.

with the electric probe setup, the temporal fluctuations of floating potential can be mapped axial and radial resolved within the plasma volume. This is shown in figure 2 at the processing parameter 100 Pa and 30 W as an example. The floating potential differs from -25 to 25 V. The instability rises over at time of 0.2 ms and reaches its maximum, and subsequently achieves its initial state after further 0.3 ms. Thereby, the instability collapses abruptly. Additionally, the fluctuations seems to be initiated within the plasma sheath and reveal a kind of oscillation but no wave phenomenon in contrast to oxygen plasma in positive column of dc glow discharge [4, 5]. Biasing the probe strongly negative shows that also the ion saturation current is fluctuating. To get more information about the mechanism behind the instability it was additionally applied an ICCD camera to record the optical emission intensity fluctuations during the instability. The intensity measurements reveals informations about the excitation mechanism in the rf sheath. It becomes apparent that during an instability the excitation mechanism changes. Additionally, it was investigated the rf phase resolved excitation mechanism for different segments (minimum and plateau) of the instability. Here, changes in the excitation dynamics are found for different phase position within the instability.

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