Instabilities in Capacitively Coupled Radio-Frequency Discharges

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Abstract—Instabilities in an asymmetric capacitively coupled radio-frequency (CCRF) discharge are observed at pressures above 100 Pa if a circular quartz glass tube is inserted into the discharge parallel to the powered electrode. The instabilities are observed with a charge-coupled-device camera as localized plasma balls. The number of these so-called plasmoids increases with increasing pressure. At different pressures, different modes are observed.

Index Terms—Capacitively coupled RF discharge, instabilities, plasmoids.

In order to measure the radio-frequency (RF) current directly above the powered electrode in an asymmetric capacitively coupled radio-frequency (CCRF) discharge, a
A circular quartz tube is inserted into the discharge parallel to the powered electrode. This glass tube is located 2.5 cm above the powered electrode, and the circle is not completely closed (Figs. 1 and 2). The inner part of the tube is under atmospheric pressure. From outside, a Rogowski coil can be inserted in order to measure the RF current. However, the reported instabilities are observed without a coil inside the quartz and seem to be caused by the presence of the glass tube alone.

Fig. 2 shows a sketch of the experimental setup. Measurements are performed in an asymmetric krypton discharge operated at 25 W. The chamber is a GEC reference cell operated at 13.56 MHz. The electrode radius is 5 cm. The pressure is continuously increased from 10 to 200 Pa. Up to 100 Pa, no instabilities are observed. Above 100 Pa, several bright plasma balls form along the outer edge of the powered electrode. With increasing pressure, the plasmoids start to rotate, and their number increases (Fig. 3). If the pressure is further increased, streams of plasmoids from the top chamber wall, as well as from the guard ring surrounding the electrode toward the center of the electrode, are observed (Fig. 4). At high pressures of about 200 Pa, the stream from the top chamber wall disappears, and the number of plasmoids forming streams from the guard ring to the electrode center increases (Fig. 1). The plasmoids can be either stationary or moving at speeds of up to several 10 cm/s.

These instabilities seem to be correlated with the presence of the quartz tube, since they disappear, if the tube is removed.

Similar phenomena have already been observed in inductive discharges in the transition region from E to H modes [1]-[4]. Here, we propose the hypothesis that the observed plasmoids are related to striations in dc discharges [5]. It can be speculated that the plasmoids follow the gas flow, which is particularly obvious in Fig. 4, where the gas flows from the top of the chamber downward. Pumping out of the chamber is located symmetrically at the bottom.

Further investigations on this optically charming and impressive, but physically poorly understood, phenomenon are definitely needed.

REFERENCES


