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Appearance and dynamics of plasma spheroids in a dusty plasma

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Low frequency instabilities are often induced by the growth of dust particles in low pressure plasmas. These unstable phenomena are easily detected on the plasma glow emission: Regions with an enhanced emission appear stochastically or regularly at different places of the plasma. They can be considered as striations of the plasma but their exact nature can only be revealed using high-speed imaging. This diagnostics shows that they consist of bright plasma spots (called plasma spheroids or plasmoids) moving and interacting close to the electrodes or in the plasma bulk. Their dynamics and their mutual interactions (especially their merging or their splitting) are analyzed.

In this work, dust particles are formed by sputtering a polymer layer deposited on the electrodes of a capacitively-coupled radio-frequency discharge [1]. The discharge is ignited in push-pull mode ($\sim$ 3 W) with 4 cm diameter electrodes separated by 3 cm. Two types of gases are used, Argon or Krypton with a typical pressure around 1.5 mbar. After switching on the plasma, ions sputter the polymer material and inject molecular precursors in the gas phase. They initiate chemical and physical reactions leading to dust particle growth. When the dust particle density is huge, low-frequency (a few tens of Hz) instabilities appear [2, 3]. High speed imaging up to 16000 frames per second (fps) reveals that small plasmoids appear during these instabilities. In Ar, they are preferably located at the vicinity of the electrodes [4] while in Kr they originate from this region and propagate in the plasma bulk [5].

In Ar, plasmoids appear stochastically but in some conditions they show a very regular rotation along the electrode circumference [6]. Their number and rotation speed depend of the discharge power. An example of 8 plasmoids rotating in front of each electrode is given in Fig. 1(left) taken at 5000 fps. They are difficult to detect due to their low brightness relatively to the presheath regions. In Fig. 1(right) the image has been processed to evidence these plasmoids moving with typical speeds of about a few m/s.

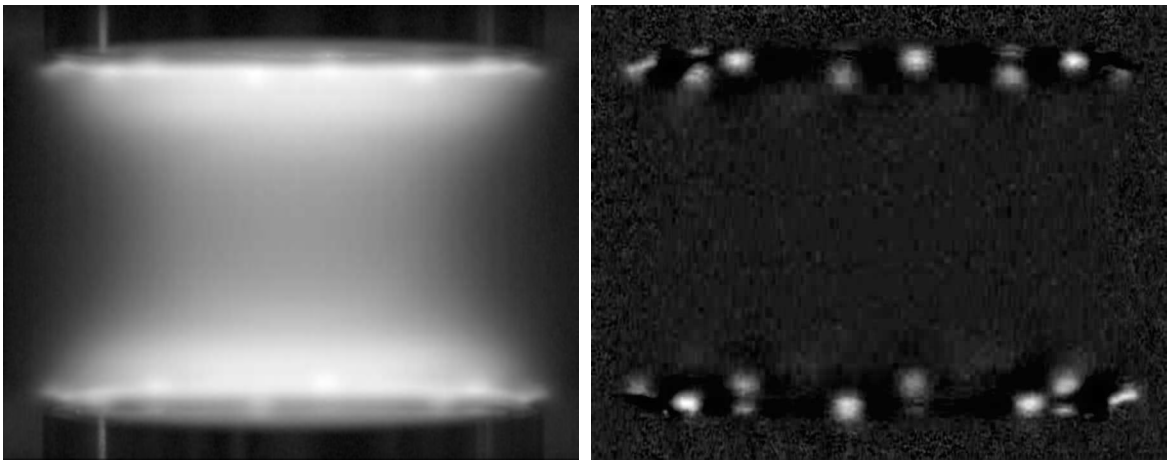

Fig. 1: Left: Plasmoids appearing during dust particle growth instabilities in Ar. They are located at the electrode vicinity and rotate along their circumference. Right: Image processing reveals 8 plasmoids rotating around both electrodes.

In Kr, the dust particle density seems higher than in Ar. The instabilities have slightly different characteristics and it leads to more impressive behaviors concerning the plasmoid dynamics. As shown in Fig. 2, they can now propagate in the plasma center. Complex interactions are shown to exist between the

plasmoids. Attraction and repulsion like behaviors have been observed. The merging of two plasmoids has also been observed. These comet-like shape structures get closer until their envelopes start to merge and finally a unique plasmoid is formed. The opposite phenomenon is also analyzed and consist of the splitting of a single plasmoid into two parts.

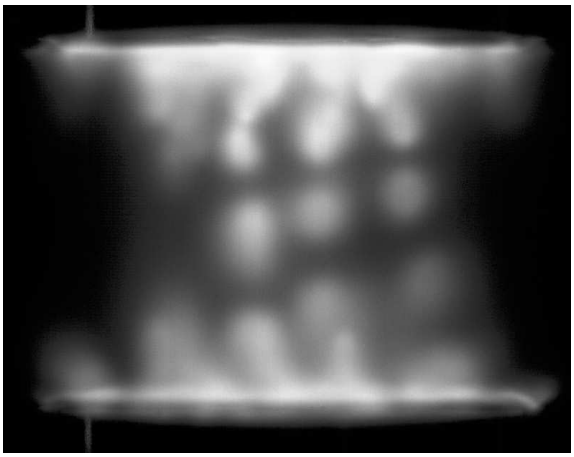

Fig. 2: Plasmoids appearing during dust particle growth in Kr. They originate from the electrode vicinity and propagate in the plasma bulk where they interact with each other.

In this paper we analyzed the appearance and the dynamics of small plasma regions with an enhanced emission in a dusty plasma. It can reveal interesting electrical interactions between these regions that are also observed in other dusty plasma experiments [7]. The potential interest of these analyses is beyond the scope of dusty plasmas as similar structures are observed in a wide variety of plasmas as for example in capacitive-coupled plasmas [8, 9] or dielectric barrier discharges [10, 11].

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