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# Particle Collecting in a 13.56 MHz Radiofrequency Methane Discharge

Véronique Massereau-Guilbaud, Isabelle Géraud-Grenier and André Plain

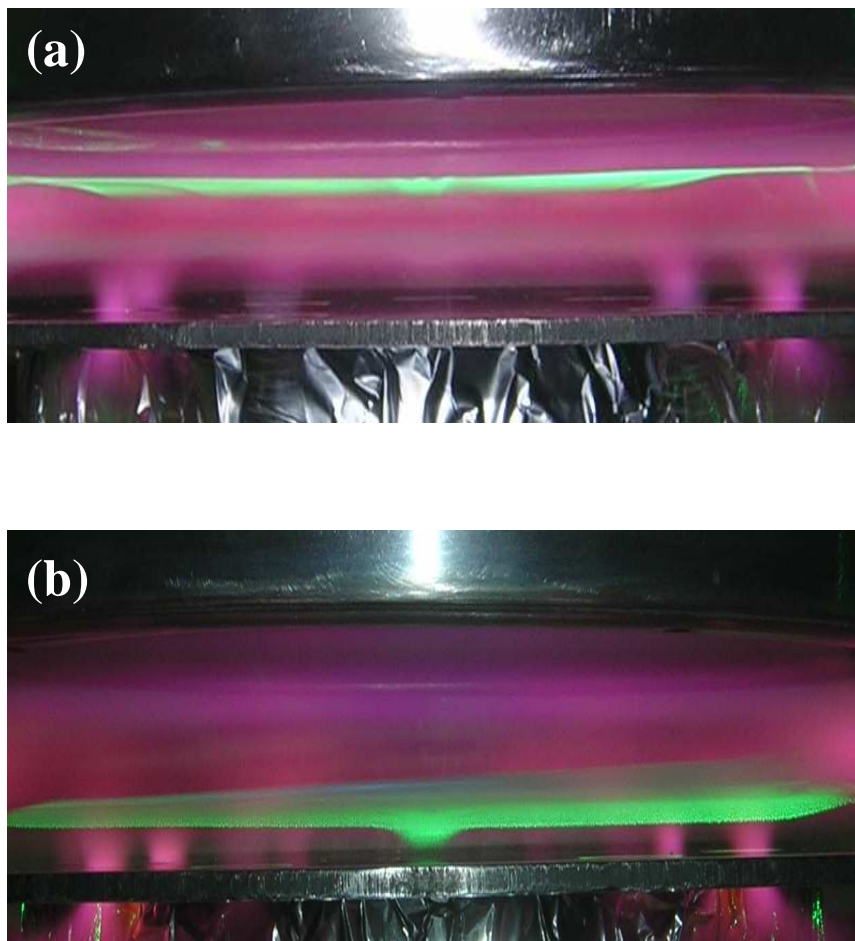


Fig. 1: Particle trapping near the electrodes in RF methane plasma (RF = 80W, pressure 130 Pa and flow rate 5.6 sccm) put in evidence by laser light scattering: (a) under the RF electrode 200 s after the plasma is switched on, (b) above the grounded electrode 300 s after the plasma is switched on. The particle cloud form follows the electrical field lines.

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### **Abstract –**

**Radiofrequency methane plasmas are widely used for deposition of amorphous hydrogenated coatings a-C:H in PECVD reactors. According to our experimental conditions, particles are also generated in the plasma. The study of the chemical nature of these particles requires a sufficient quantity to be collected at the end of the experiment. We show that a modification of the electrical field lines above the grounded electrode improves particle collecting.**

In the last few decades, dusty plasmas have been extensively studied. Dusty plasmas are ubiquitous in the universe and in industrial discharge devices. The particles can alter the quality of deposited thin films or etching works by surface contamination. The study of particle formation in plasmas is useful in understanding the numerous universe plasmas in astrophysics.

The amorphous hydrogenated carbon a-C:H particles are generated by PECVD in a classical planar radiofrequency (RF) (13.56 MHz) methane discharge. The discharge is switched on between two parallel plane electrodes with a 4.5 cm electrode gap: the upper one is connected to the RF generator and the lower one to the ground [1]. Vacuum is achieved to a residual pressure below  $10^{-3}$  Pa using a diffusion oil pump connected to a primary rotary pump.

The particle formation and behavior have been studied for the following experimental parameters: pressure (20-146 Pa), RF incident power (40-120 W), methane flow rate (2.8-14 sccm), discharge duration 900 s.

The particles are negatively charged within the plasma resulting from the difference in mobility between electrons and ions. As long as the particles are present in the plasma, they fundamentally modify the optical and electrical plasma properties [2]. They have a spherical shape and are 1-2  $\mu\text{m}$  in diameter. The particle presence in the reactor is put in evidence by laser light scattering. The laser beam ( $\text{Ar}^+$ ,  $\lambda=514.5$  nm, green color) is directed through the reactor parallel to the electrodes and can be moved along the vertical axis of the reactor. Figure 1 shows the particle trapping near the electrodes. At the end of the experiments, the particles are collected in order to determine their chemical nature by Infrared spectroscopy or X-ray photoelectron spectroscopy (XPS) analyses [3]. However, no particle falls onto the grounded electrode when its surface is completely plane. We will show that an improvement of our system allows to collect the particles. Before that, we must recall the particular behavior of the particles through the discharge [4]. A hundred seconds after the discharge is switched on, the first particles are detected at the boundary between the RF sheath and the plasma bulk. First, the particles are trapped in a disk parallel to the RF electrode following the electrical field

lines (fig 1.a) resulting from the different forces [1] acting on them: the gravity force, the thermophoresis force, the electrical forces and the ion drag force. In the particle disk located under the RF electrode, the first three forces drag the particles towards the bottom of the reactor and the last one towards the RF electrode. At the beginning of the experiment, the equilibrium between the electrical and the ion drag forces leads to particle levitation within the plasma near the RF electrode. The other forces are negligible. During the experiment, the RF electrode is continuously submitted to an ion bombardment leading to a heating of the electrode. The temperature gradient between the two electrodes increases so does the thermophoresis force. Consequently, when the particles grow, both the gravitational and thermophoresis forces drag the particles towards the bottom electrode. The particles drop down from the center of the upper disk through the plasma along a filament-like trajectory following the vertical axis of the reactor. They are again trapped in a parallel disk above the grounded electrode. When the surface of the grounded electrode is completely plane, the electrical field lines are parallel to this electrode. All the particles leave the disk falling onto the bottom of the reactor and are pumped by the diffusion oil pump. We have drilled a hole in the center of a plate put on the grounded electrode in order to modify the electrical field lines. Finally, when the particles are heavy enough, they leave the disk following the electrical field lines and they are dragged into the hole (fig 1.b).

In this paper, we have presented the particle trapping near the electrodes. The surface of the grounded electrode must possess at least one hole to modify electrical field lines in order to collect particles.

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