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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 scm), 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 µm in diameter. The particle presence in the reactor is
put in evidence by laser light scattering. The laser beam
(Ar^+, λ=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.

REFERENCES

[1] I. Géraud-Grenier, V. Massereau-Guilbaud and
A.Plain, Analysis of particulates generated in a
radiofrequency methane plasma by laser light scattering
and optical spectroscopy, Eur. Phys. J. AP, 8, 53-59,
(1999).
[2] V. Massereau-Guilbaud, I. Géraud-Grenier and
A.Plain, Determination of the electron temperature by
optical emission spectroscopy in a 13.56 MHz dusty
methane plasma: Influence of the power, J. Appl. Phys,
106, 113305-1-7 (2009).
[3] I. Géraud-Grenier, V. Massereau-Guilbaud and
A.Plain, Characterization of particulates and coatings
created in a 13.56 MHz radiofrequency methane plasma,
[4] V. Massereau-Guilbaud, I. Géraud-Grenier and
A.Plain, Influence of particulates generated in a CH₄
low pressure radiofrequency discharge on dc self bias voltage,