Distributed microwave plasma sources: coupling modes and operation at high pressure for large area deposition

A. Martín Ortega, A. Bès, S. Béchu, A. Lacoste

LPSC, Université Grenoble Alpes, CNRS/IN2P3, 53 rue des Martyrs, 38026 Grenoble Cedex, France

The 2D and 3D distribution of a set of elementary plasma sources enables its use in large area deposition and etching processes. Existing sources, working at 2.45 GHz, provide uniform plasma conditions at low and very low pressures (up to a few Torr). A new challenge is to extend the uniformity of the plasma at higher pressures, where the diffusion is limited by the scaling laws. We will describe the transition between inductive and capacitive coupling modes as a function of frequency (2.45 GHz, 915 MHZ and 352 MHz), gas pressure, source geometry and input power. The understanding of the transition should allow the efficient design of new sources operating at high gas pressure. Interest in this technology will be pointed out through some examples of applications.

1. Introduction

The distribution of individual microwave (MW) plasma sources on a 2D or 3D network allows for the scaling-up of high density plasma processes in the low and very low (few Torr down to mTorr) pressure range [1]. The typical configuration consists on a coaxial applicator which also provides the impedance coupling, ended in a permanent magnet which facilitates the sustainability of the discharge [2]. While this technology has been long studied for low pressures, where fairly uniform and extended plasma can be obtained, its use at higher pressure remains a challenge. Indeed, an increase in pressure will not only reduce the plasma extension according to the scaling laws, but will also change the absorption mode of the electromagnetic wave by the plasma.

Most of the existing MW plasma sources operate with generators of 2.45 GHz of frequency. The use of new sources operating at lower frequencies, such as 915 MHz and 352 MHz, might enable the use of the distributed plasma sources at higher ranges of pressure.

2. Coupling modes

A transition between capacitive and inductive coupling modes can be found when operating the plasma sources at 2.45 GHz as a function of the pressure and absorbed power [2]. This transition occurs at high input power when operating at low (mTorr) gas pressure, with the transition power threshold being greatly reduced at higher pressures. The transition was also found when operating the source at 915 MHz but not at 352 MHz. At lower pressures (mTorr), the transition usually appears together with a change in the spatial distribution of the plasma. At higher pressures (Torr) no sudden change in the spatial distribution for the two different coupling modes is observed.

A possible explanation of the transition based on the comparison between the skin depth and the dimensions of the plasma will be investigated. The larger skin depth of MW at 352 MHz would explain the absence of the inductive coupling mode found at 2.45 GHz. The transition will also be explored at 915 MHz.

3. Plasma extension at high pressure

The extension of the plasma depends on two factors: the plasma diffusion and the power absorption region. While at lower pressures the diffusion is large enough to ensure an extended plasma, at higher pressures the power absorption is localized close to the microwave injection plane, where the critical density is reached.

The decrease of the MW frequency from 2.45 GHz to 915 MHz increases the size of the absorption region by increasing the skin depth. The plasma extension could be further increased by using MW at 352 MHz, but the use of this frequency might be prevented by the absence of the more efficient inductive mode. In addition, the microwaves may propagate along the surface of the applicator and chamber walls, increasing the lateral extension of the plasma.

3. References

[1] A. Lacoste, T. Lagarde, S. Bechu, Y.Arnal and J. Pelletier, P. Sources Sci. and Tech. 11 (2002) 407.

[2] Baele, S. Bechu, A. Bes, J. Pelletier and A. Lacoste: P. Sources Sci. and Tech. 23 (2014) 064006.