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Physical insights and process development of magnetized Capacitively Coupled plasmas

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Technological high-frequency plasmas are employed in a variety of high societal relevance applications, such as semiconductor manufacturing, solar cell production, and environmental purposes. Often such plasmas are magnetized, i.e., an externally applied magnetic field is used to ensure electron confinement and high plasma densities. Magnetized radio frequency (RF) plasmas represent complex multicomponent and nonlinear systems, whose fundamentals are not understood in many cases.

This study delves into the fundamental comprehension of electron heating and dynamics, with a focus on resonance effects in magnetized RF capacitively coupled plasmas under extremely low pressure, through both theoretical analysis and experimental investigation. Figure 1 displays the space- and time-averaged plasma density as a function of the externally applied transverse magnetic fields. The plasma density first increases strongly and then decreases with increasing the magnetic field for all frequencies, i.e., a sharp maximum is found at 2.6 G for 13.56 MHz, at 4.8 G for 27.12 MHz, at 8.0 G for 45 MHz, and at 10.8 G for 60 MHz. The formation of these maxima requires a significant enhancement of the electron power absorption, which is induced by a resonance between the cyclotron motion of electrons and the RF sheath expansion near each electrode.[1-2] The resonance effects are strongly related to the applied magnetic field and the driving frequency, which do not depend on the initial velocity of the electrons, and allow the majority of electrons in the plasma to be affected. The resonance effects are expected to be highly relevant to both fundamental and applied plasma science.

Furthermore, the radial distributions of plasma density and the incident angle of ion bombardment on the bottom electrode are significantly altered by the application of an additional static magnetic field induced by direct current (DC) coils positioned above the reactor.[3]

The study helps to understand the electron heating and transportation effects in low pressure magnetized RF capacitively coupled plasmas, potentially advancing the industrial utilization of magnetized RF plasmas across diverse fields.

References

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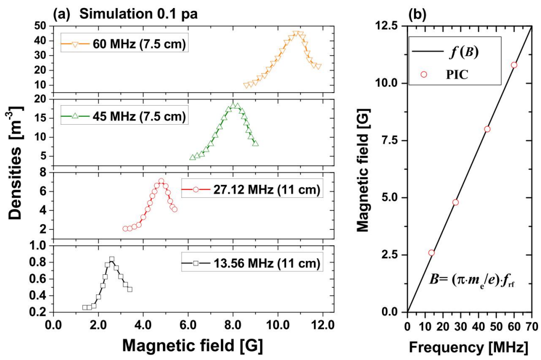

Figure1 (a) Averaged plasma density (unit in $10^{15}m^{-3}$) as a function of the transverse magnetic fields for different frequencies and electrode gaps resulting at 0.1 Pa for a driving voltage amplitude of 300 V; (b) Externally applied magnetic field at which the highest plasma density is found as a function of the driving frequency obtained from (a) (red points) and from the resonance relation (solid line).