§19. Transient Response of the Induction Coil Loading in the Initial Startup Phase of rf Indiction Thermal Plasmas

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Generation and sustainment of rf induction thermal plasmas in atmospheric pressure range requires high voltage in the initial startup phase and high rf power during the steady state sustainment phase. The high rf electrostatic filed induced between induction coil conductor wound around a glass discharge tube generates surface electrostatic discharges in which the discharge current flows through the dielectric glass tube. After several hundreds microseconds the electrostatic discharges grow sufficiently to change to a volumetric elec-tromagnetic discharge which is maintained by the inductive electric field as shown in Figs. 1. During this discharge mode transition the loading impedance of the induction coil changes significantly, which shows coupling characteristics between induction coil and generated plasmas. This loading impedance change of the induction coil leads a deviation from a series resonance condition of the LCR output circuit including the induction coil, which strongly affects the output characteristics of a semiconductor rf inverter power supply.

In this study transient response of the induction coil loading impedance in the initial startup phase of the rf thermal plasma generation is studied experimentally[1~3]. Dynamic interactions of the rf inverter power supply with generated rf plasmas are also investigated and strong deterioration of the inverter output efficiency is found experimentally. It is shown by the loading impedance measurement and the fast camera observation that characteristic features of the induction plasmas dynamically developing from the initial streamer-like electrostatic discharges to the volumetric electromagnetic thermal plasmas are clearly found. Preliminary frequency tracking experiments show a successful improvement of the inverter output efficiency and absorbed rf power in the generated plasma[4]. Figures 2 show time traces of the rf inverter dc and rf power(top), and the LCR series resonance frequency of the induction coil circuit and gate driving frequency of the inverter(bottom). With the ignition of the thermal plasma the LCR series resonance frequency deviates from the driving frequency, which reduces the power coupling efficiency strongly as shown in the figure. When the driving frequency of the induction coil is changed close to the resonance frequency, the coupling efficiency is greatly improved. It is found that the frequency feedback using Phase Locked Loop(PLL) may work well to keep a good power coupling between the inverter power supply and generated thermal plasmas.

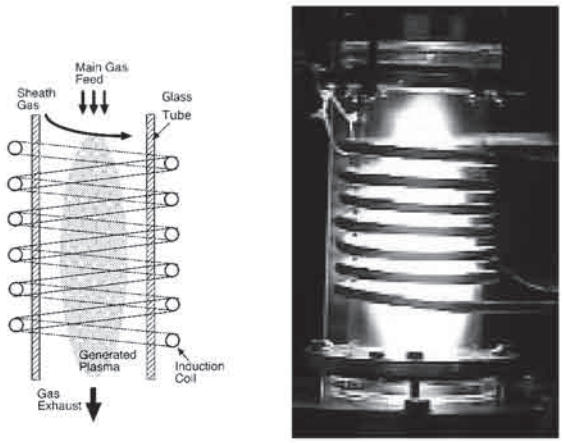

Fig. 1 Schematic structure and typical picture of the rf indction plasma torch

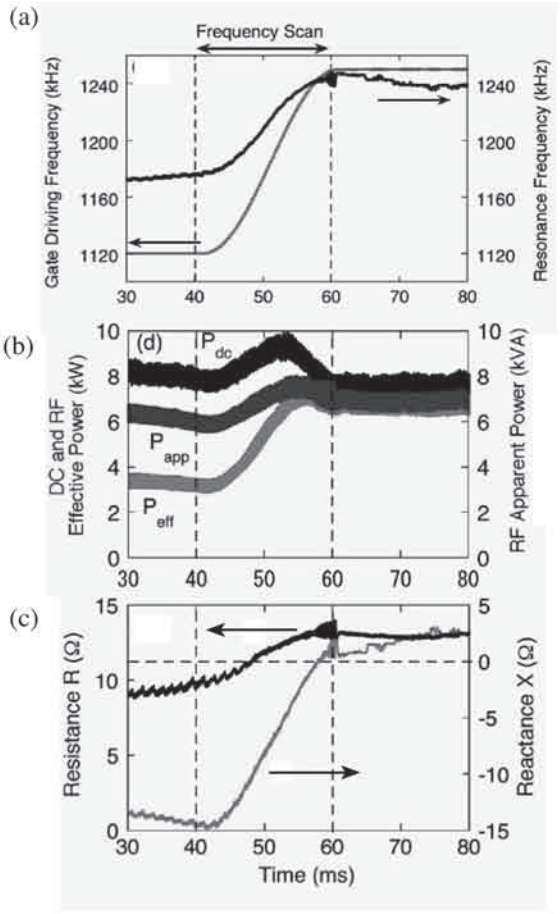

Fig. 2 Time traces of the output and resonance freuquencies(a), inverter output power(b) and loading resistance and reactance(c) when the driving frequency is changed.

References

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