§16. High Efficiency RF Induction Plasma Generation

Uesugi, Y., Hanaoka, E., Tanaka, Y. (Kanazawa Univ.),
Ohno, N. (Nagoya Univ.),
Tanaka, M. (Kyushu Univ.)

Radio frequency inductively coupled plasmas(ICPs) at atmospheric pressure have been applied to thermal decomposition of toxic materials, generation of functional nano particles using their high temperature and highly reactive properties. It is very important for industrial applications of high power ICPs to have a high thermal efficiency as well as well controlled plasma properties.

In this study thermal efficiency of high power ICPs at atmospheric pressure range is estimated from equivalent circuit analysis of the induction coil circuit[1] and calorimetric measurements of plasma heat load to the wall. In Fig. 1 an experimental setup for RF input power measurement and calorimetric measurement of the plasma heat load is shown schematically. From the loading impedance measurements of the induction coil it is shown that the conversion efficiency defined by plasma absorbed power(P_{abs})/RF fed power to the coil(P_{inv}) is 0.7~0.8 in Ar and Ar+H_2 plasmas at pressure range of 100~760 torr. Taking account that the conversion efficiency of the MOSFET inverter from AC power to 400~450 kHz RF power is about 0.95 total thermal efficiency of RF ICPs at atmospheric pressure range is 0.66~0.76 in the present experiments. This efficiency tends to decrease with gas pressure because the inductive coupling between induction coil and generated plasma becomes weak due to edge cooling of introduced cold gas.

In Fig. 2 plasma heat load to each part of the device obtained from calorimetric measurements is shown when Ar gas flow rate is changed keeping the gas pressure constant. At low Ar gas flow rate ~ 70 slpm about 60 % of the absorbed power is delivered to quartz tube surrounding core inductively heated plasma and 35% to metal vacuum chambers in the downstream. When Ar gas flow rate is increased up to 100 slpm, the power flow pattern is drastically changed. Heat delivered to the quartz tube is reduced to ~30 % and that delivered to downstream chamber rises to 60 % as shown in Fig. 2. Cold sheath gas introduced from the top flange effectively cools the edge region of ICPs and reduces the thermal interaction between the edge plasma and tube. Consequently, most of the plasma thermal energy is delivered to the downstream region. These experimental observations agree well with those estimated from the electromagnetic fluid simulation. In Ar and H_2 mixture plasma, however, H_2 gas flow rate has little effects on the power flow pattern although simulations gives significant effects on it. This discrepancy might be related to the radiation losses. Some of the radiation losses is not measured in the present experiments. Now we are trying to measure the radiation losses from core plasmas.

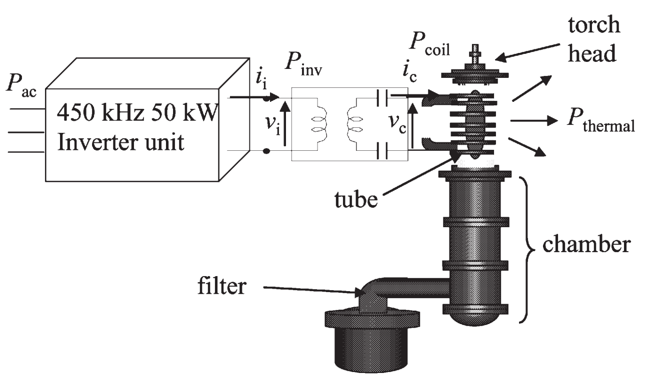

Fig. 1 Experimental setup of RF power and plasma heatload measurements.

Reference

[1]Uesugi, Y., Ukai, H., et al., IEEJ Trans., FM, **125**(2005)749.

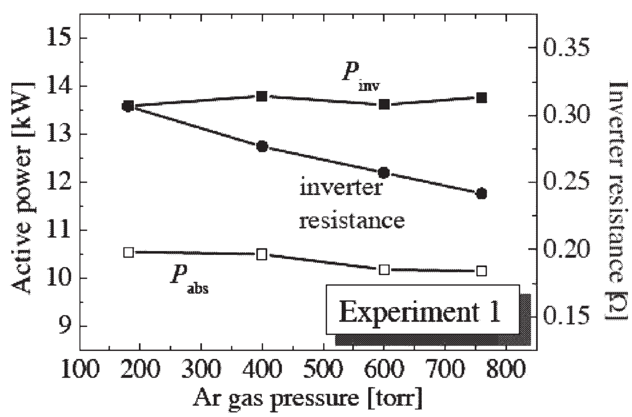

Fig. 2 Gas pressure dependence of the loading impedance of the induction coil including the matching circuit and plasma absorbed power.

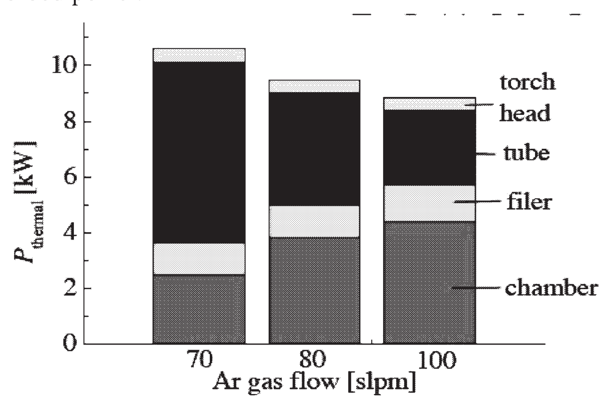

Fig. 3 Change of power flow distribution when Ar gas flow rate is changed. Total gas pressure is kept constant at 230 torr.