§11. Study on Association and Recombination in High-Heat Flux Plasmas with Polyatomic Molecular Gases Using Two-Temperature Chemically Non-Equilibrium Modeling

Tanaka, Y., Uesugi, Y. (Kanazawa Univ.),
Ohno, N. (Nagoya Univ.)

In fusion tokamak device, it is important to control high heat-flux plasma to the divertor plates by neutral molecular gas injection. Interactions between molecular gases and high heat-flux are very complex phenomena involving dissociations and formation of molecular gases. To understand these phenomena, numerical simulation is useful. In this work, two-temperature chemically non-equilibrium modeling was made of Ar-CH_4-O_2 plasma with high heat-flux [1]. Mixture of CH_4-O_2 provides combustion reactions, thus it is desired to understand interactions between CH_4-O_2 and plasmas in the plasma assisted combustion field.

In this model, totally 22 species such as CO_2, HO_2, O_2, O_2^+, CH_2O, CHO, CHO^+, CO, CO^+, H_2O, OH, O, O^+, CH_4, CH_3, H_2, H_2^+, H, H^+, Ar, Ar^+ and electron, and 200 reactions among them were accounted for. Ionization reaction rate were calculated as a function of electron temperature using electron impact ionization cross sections[2], assuming Maxwell velocity distribution function for electrons. Mass, momentum and energy conservation equations were solved to obtain temperature, gas flow and chemical species fields. Transport and thermodynamic properties such as thermal conductivity, viscosity etc. were calculated at each position using the calculated composition, the collision integrals between species by means of the first approximation of Chapman-Enskog method. Fig.1 shows the cross section of the RF plasma torch which was used in the present calculation. The 98%Ar-1%CH_4-1%O_2 gas was supplied as a sheath gas.

Fig.2 depicts the spatial distribution of the electron and heavy-particle temperatures in 98%Ar-1%CH_4-1%O_2 plasma at 20 kW. It was found that the electron temperature is close to the heavy-particle temperature at all calculation space except near the torch wall in this calculation condition. Fig.3 shows the radial distribution of the power balance for heavy particles at an axial position z=155mm, i.e. mid-coil position. Positive value in vertical axis means the input power, while negative value is the power loss. From this figure, heavy particles receive power through elastic collisions with electron at radial position *r*=20 mm. That power is transferred by radial convection and radial thermal conduction to the axis. The transported power to the axis is then transferred mainly by axial convection. The reaction heat is contributed to heavy particle temperature decreased at *r*=23mm. This is due mainly to the contribution from the dissociation of molecules.

[1] S.A.Al-Mamun, Y.Tanaka and YUesugi, Thin Solid Film, 2009, doi:10.1016/j.tsf.2009.11.052
[2] http://physics.nist.gov/cgi-bin/Ionization/atom

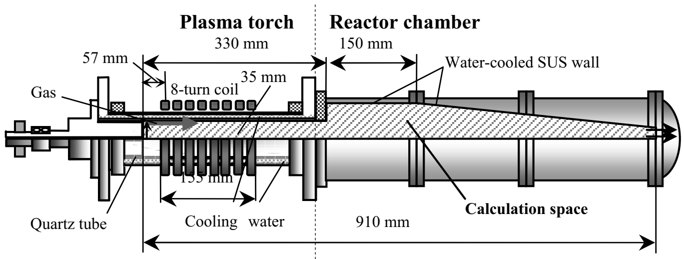

Fig.1 Plasma torch configuration and calculation space

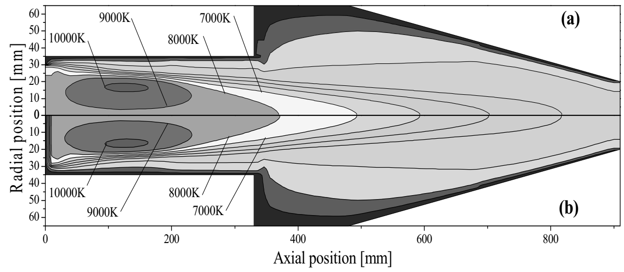

Fig.2 Two-dimensional temperature distributions of Ar-CH_4-O_2 induction plasmas at atmospheric pressure; (a) electron temperature, (b) heavy particle temperature.

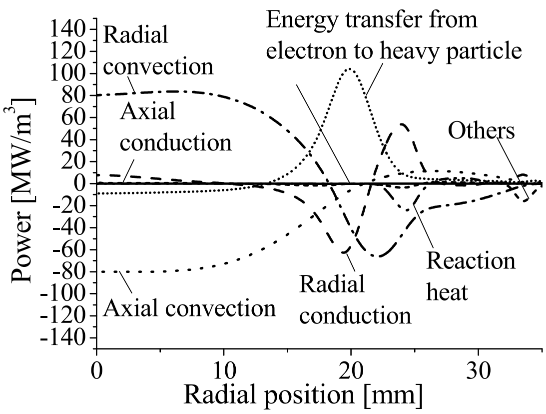

Fig.3 Radial distributions of energy balance of heavy particles at an axial position of 155 mm