Investigation of the energy flow among electron-ion-neutral in volumetric recombining plasma formation using DT-ALPHA device

Detached divertor can be formed by utilizing electron-ion recombination (EIR). Reaction rate of the EIR becomes large in low electron temperature ($T_e$) region, typically below 1 eV. However, electrons that flow into divertor region have much larger $T_e$ required for EIR. Therefore, electron energy removal is indispensable for enhancing EIR in a divertor plasma. It has been considered that electrons lose their energy through electron impact excitation, ionization, and elastic collision in relatively higher $T_e$ region, whereas temperature relaxation with bulk ions becomes main process of electron cooling in the region where $T_e < 5$ eV. To understand the detached/recombining plasma formation comprehensively, the amount of energy transferred through these collisional processes should be evaluated. However, such a investigation has not been conducted because it requires ion temperature ($T_i$) measurement as well as $T_e$ measurement.

In our previous work, an ion sensitive prove (ISP) was installed and first $T_i$ measurement was conducted [1]. In the present study, validation of $T_i$ measurement by an ISP was investigated. Then the amount of energy transferred among electrons, ions, and neutrals was evaluated.

Experiment was conducted using an RF plasma device DT-ALPHA [2]. In this experiment, a helium ionizing plasma was produced and diagnosed. Before evaluating energy flow, validity of the ISP measurement should be confirmed. Therefore, $T_i$ was also obtained by the Doppler spectroscopy ($T_i^{DP}$). Figure 1 represents the dependence of $T_e$, $n_e$, and $T_i$ on RF heating power $P_H$. As shown in Fig. 1, $T_i^{ISP}$ has similar value with $T_i^{DP}$ and showed a same trend on $P_H$. This result indicates that $T_i$ measurement by the ISP was consistent with that by the spectroscopy. And this confirmation enables us to evaluate electron-ion-neutral energy flow. We evaluated amount of the energy due to several collisional process (electron impact excitation, electron impact ionization, electron-recombination, electron-neutral elastic collision, electron-ion temperature relaxation, ion-neutral charge exchange, and ion-neutral elastic collision). In the presentation, we will report detail of the energy flow evaluation, as well as results of ISP measurement.


Figure 1: Dependence of $T_e$, $T_i^{ISP}$, $T_i^{DP}$, and $n_e$ on RF heating power $P_H$. The target plasma was helium ionizing plasma.