§16. Density Dependence of Plasma Detachment in Simulated Gas Divertor Experiments of the TPD-I Device

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It is one of the most critical requirements to reduce the heat load to the divertor plate in the next generation fusion devices such as LHD, intended to have long pulse and steady state operation. Dynamic gas target divertor is one of the most important candidates[1-4]. We have already done simulated gas target divertor experiments in the TPD-I device to observe the plasma detachment clearly[5], in which a strong reduction of plasma pressure and heat load to the target plate was observed. In this reports, we present further experimental results to indicate strong dependence of plasma detachments on plasma density n_e.

Gas target experiments are performed by feeding a secondary helium gas into the plasma test region. Figure 1 shows the dependence of the floating potential V_f of the target plate on the gas pressure P. At higher n_e, V_f is decreasing with an increase in P, which is corresponding to decreasing the electron temperature T_e in front of the target. Above $P \sim 2$ Pa, the detached plasma was observed. On the other hand, at $n_e \sim 0.2 \times 10^{19} m^{-3}$, we have not observed the detached plasma even after feeding the secondary gas up to $P \sim 3$ Pa. These experimental results indicate that there is a threshold of n_e for a generation of the plasma detachment.

In order to discuss the density dependence of the detachment, we consider an energy balance of electrons. Electrons mainly lose their energy through ionization, radiation and energy exchange between electrons and ions. Figure 2 shows n_e's dependence of the energy exchange time τ^{ei}_T normalized by the plasma confinement time τ_p. Here, τ_p is determined by $L / 0.2C_s$, where L is a length of plasma column and C_s is ion sound velocity. It is found that at $n_e > 1.0 \times 10^{19} m^{-3}$, τ^{ei}_T is small enough that electrons can transport their energy to ions, whose energy is lost by a charge exchange process between ions and neutral particles. A simple estimation shows that the energy loss mentioned above is more effective than the ionizaiton and radiation loss in a high density plasma. A decrease in T_e leads to smaller value of τ^{ei}_T, which enhances the electron energy loss. This positive feed back is thought to be a reason why there is the plasma density threshold for the detachment.

Reference

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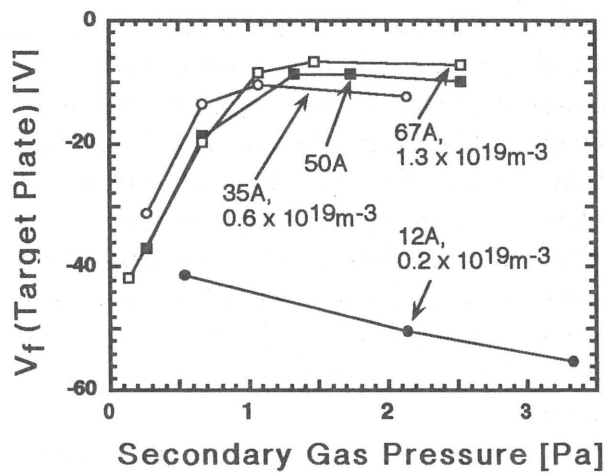

Fig. 1 Dependence of the floating potential V_f on a gas pressure P.

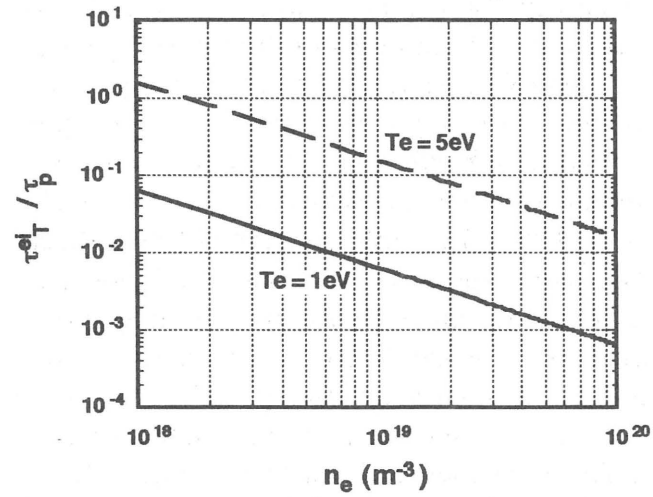

Fig. 2 Dependence of the energy exchange time τ^{ei}_T normalized by the plasma confinement time τ_p on n_e.