Injected impurity transport and confinement during improved confinement discharge induced by lower hybrid current drive[*]

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Lower hybrid power was injected into a medium density Ohmic(OH) plasma. The impurity transport and confinement in lower hybrid current driven (LHCD) plasmas in HL-1M tokamak were studied. The impurity transport coefficients (diffusion coefficient D and inward convect velocity V) were calculated by simulating different impurity ionized lines obtained using VUV spectrometer. The outside transport D decreases to $0.5m^2/s$ in LHCD discharge from $1.0m^2/s$ in OH discharge. In both cases D inside ($r/a < 0.3$) is found to be smaller close to neoclassical predictions. The impurity confinement time τ_{imp} is estimated from the characteristic decay time of the line intensity of the injected metal impurity. During OH plasmas τ_{imp} is about 17ms, while in LHCD period τ_{imp} goes up to 30ms. The improvement of impurity transport and confinement is related to the change of edge plasma electric potential profile Vp(r) which is induced by LHCD and detected by Mach probes.

1. INTRODUCTION

The main goal of LHCD on HL-1M tokamak is to achieve steady state tokamak operation. So it is important to study the impurity behavior in LHCD plasma either for controlling them or as a diagnostic for plasma characters [1]. In HL-1M experiment it is found that the particle confinement is improved by LHCD as in other devices [2]. The improved impurity transport and confinement have also been obtained. This was also found in JIPP T-IIU device [1]. The physical mechanism is partly explained as the change of edge plasma electric potential profile. Other reasons are not clear.

2. EXPERIMENT CONDITION

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The experiments were carried out in hydrogen discharges. The main plasma parameters were: R=1.02 m, a=0.26m, I_P~100 k A, $\overline{N}_e \sim 1.3 \times 10^{19}/m^3$, Bt~ 2T, Te(0)~ 0.6-1.0keV. An RF wave with a frequency of 2.45 G Hz, a pulse length of 80ms and a power of 160-400 kW was injected into plasma. The metal impurities were injected into plasma by Laser Blow-Off system [3]. The time and amount of injection can be controlled easily. In experiment the brightness of spectral line emission of impurity ions were obtained by VUV spectrometer, the electron density by laser interferometer, T_e by the laser scattering system as barrier as ECE, H_α by monochrometer and Vp(r) by Mach probes.

3. EXPERIMENT RESULTS

When LH power is injected into a medium density ($\overline{N}_e \sim 1.5 \times 10^{13} cm^{-3}$) OH plasma, LH driven current is generated: the loop voltage V_L decreases sharply and the plasma current Ip increases slightly. The ion saturation current I_i measured by a double probe decreases and $\overline{N}_e$ of central chord increases. That means the central electron density Ne(0) increases. The H_α decreases as shown in Fig. 1. All these shows that the particle confinement is improved.

Figure 2 shows the brightness of four VUV lines (Al XI 55.00 nm, Al X 33.27nm Al IX 28.24nm Al VIII 38.11nm) detected in LHCD discharge and the simulation results of each line. The dash lines represent the results of simulation. Comparing the peaks of Fig. 2 (d), (c), (b),(a), one can easily see the process of impurity Al developing and ionizating from the outside to the central plasma. Using a impurity transport code to solve the transport eqation and calculate the line brightness, the diffusion coeficient D and convect velocity V were obtained [4].

The values of D and V which best reproduce the temperal evolution of the VUV lines in Fig. 2 are shown in Fig. 3. The D and V during OH discharge are also shown in Fig. 3. From Fig. 3 one can see that in OH and LHCD discharges the D(r) and V(r) (D~ 0.05 m^2/s, V~ 0.1m/s) close to neoclassical predictions in the central region of plasma are smaller than that in the outer region where the transport is abnormal. During LHCD plasma D (~0.5m^2/s) outside is smaller than that without LHCD (D~ 1.0m^2/s). That means LHCD helps to slow down the impurity transport in the anomalous transport region.

We detected the change of edge plasma electric potential profile $V_P(r)$ by Mach probes shown in Fig.4, which causes a barrier of D in the region (in Fig. 3) to deter the impurity development to the center.

Figure 5 is the comparison of Al XI lines in OH and LHCD discharges. Because the characteristic decay time of the line intensity is a measure of the confinement time τ_{imp} of the injected impurity [5], from Fig. 5 one can see that the impurity confinement time τ_{imp} during LHCD is about 30ms, improved from 17ms in OH discharge.

The physical mechanism of improved impurity confinement during LHCD is not yet known clearly. One certain mechanism is the change of $V_P(r)$ in edge plasma which causes a barrier of D to arrest impurity ions in that region, as discussed as above; One possible mechanism is the reduction of electrostatic turbulence in the outer region which causes abnormal transport; Another possible mechanism is the pinch effect.

Figure 6 shows the confinement time of injected impurity τ_{imp} versus the LH power during the same condition ($\overline{N}_e$=1.3 × $10^{19}/m^3$, I_p~96 k A, Te (0)~ 600 e V, Bt= 1.9T). From this figure one can see that τ_{imp} can get the maxium value when the LH power is about less than 160kW under this condition, then decrease with the increase of LH power.

4. CONCLUSION

In LHCD discharge, with the particle confinement improved the injected impurity transport coefficient decreases and impurity confinement time goes up.

5. ACKNOWLEDGEMENTS

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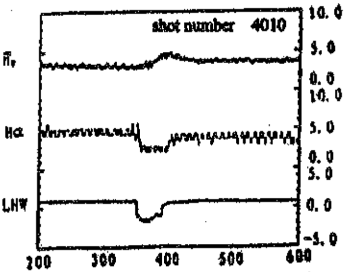

Fig. 1 Time evolution of the plasma parameters during LHCD.

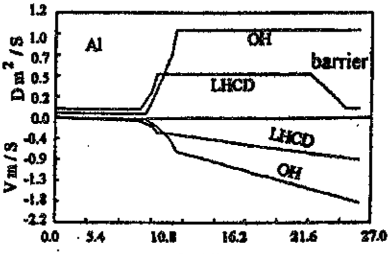

Fig. 3 Radial profile of D and of V used to simulate the injection on Al into an Ohmic plasma and LHCD plasma.

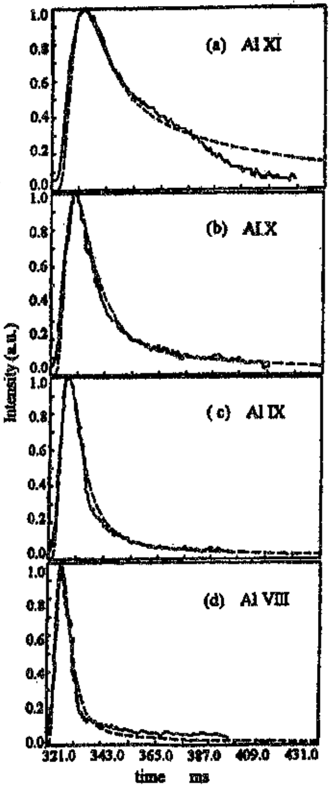

Fig. 2 The brightness of four VUV lines (Al XI 55.00nm, Al X 33.27nm, Al IX 28.24nm, Al VIII 38.11nm) around the time of Al injection (321.0ms) with the background emission subtracted. The dash lines represent the results of simulation.

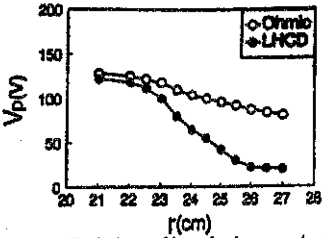

Fig. 4 Radial profile of plasma electric potential during Ohmic and LHCD plasma.

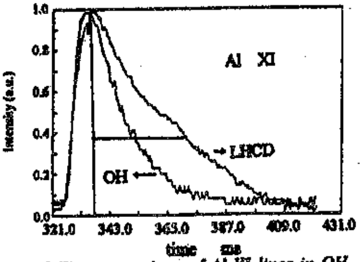

Fig. 5 The comparison of Al XI lines in OH and LHCD discharges.

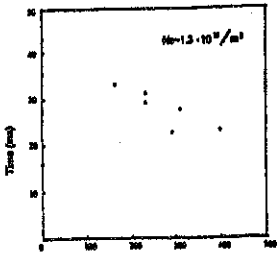

Fig. 6 The impurity confinement time versus the LH power under the same condition.