§9. Accurate Determination of Iron Density in LHD Discharge with Impurity Accumulation

Morita, S., Dong, C.F., Goto, M., Wang, E.H., Murakami, I., Yamamoto, N.

Vertical profiles of line emissions from iron as an intrinsic impurity have been measured with a space-resolved EUV spectrometer in LHD. The line emissions from different charge states of iron ions are widely distributed in the whole radial location from plasma center to plasma edge as a function of ionization energy. The measured chord-integrated vertical profiles of the iron line emissions are reconstructed into a function of magnetic surfaces using a three-dimensional equilibrium code, VMEC, considered finite β effect. The local emissivity profiles are obtained with absolute emissivity, as shown in Fig. 1. The spectrometer sensitivity is absolutely calibrated using EUV bremsstrahlung profile. The iron density profile is obtained from the emissivity profile using effective intensity coefficient, which is accurately calculated based on the collisional-radiative model.

The analysis is done for NBI discharges with hydrogen pellet injection, as shown in Fig.2. A sufficient density increase is observed during the pellet injection, and the density takes the maximum value of 2.2×10^{14}cm^{-3} at *t*=4.2s. The iron spectra are dominated by only FeXV and FeXVI during the pellet injection due to the reduced temperature. The intensities of FeXXIII and FeXXIV in higher charge stages are quickly increased after the pellet injection with recovering the temperature, whereas the intensities of FeXV and FeXVI in lower charge stages are weakened. The time behaviors of iron line emissions suggest a sign of impurity accumulation.

Here, we propose an alternative method for the impurity transport study based on the measurement of impurity density profile which can exhibit more reliable way [1]. The Fe^{23+} density profile at plasma core obtained from Fig.1 is simulated with Fe^{15+} ion density profile at plasma edge. Figure 3(a) shows the simulated Fe^{23+} ion density profile as a parameter of D=0.05, 0.2 and 1.0m^2/s. Here, V(a)= -1m/s is used, which is already evaluated in the former impurity transport study [2]. It is clear that the Fe^{23+} density profile can not be reconstructed by changing D values. On the contrary, the Fe^{23+} ion density profile can be well simulated by varying V values from -1 to -10m/s with fixed D=0.2m^2/s (see Fig.3(b)). The best reconstruction of the experimental Fe^{23+} profile is obtained at V=-6m/s indicating a clear evidence of impurity accumulation, while the Fe^{15+} is fitted with V=-3m/s (see Fig.3(b)). The total iron density (N_{Fe}) is finally analyzed by integrating over the whole plasma volume and all the charge states of iron ions, which can be simultaneously obtained from the transport calculation. Thus, the iron density is determined to be 3.3×10^{-5} to the total electron density (N_e), i.e., $N_{Fe}= 3.3\times10^{-5}\times N_e$, of which the value indicates an extremely low iron contamination in LHD plasmas. The accumulation is not observed for light impurity such as carbon as well as the tokamak result.

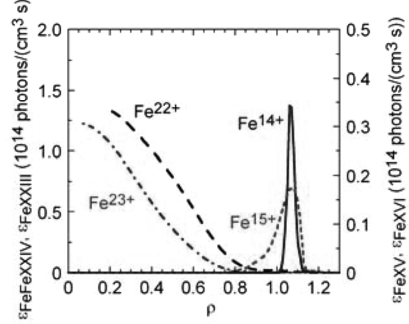

Fig.1 Absolute local emissivity profiles of FeXV, FeXVI, FeXXIII and FeXXIV.

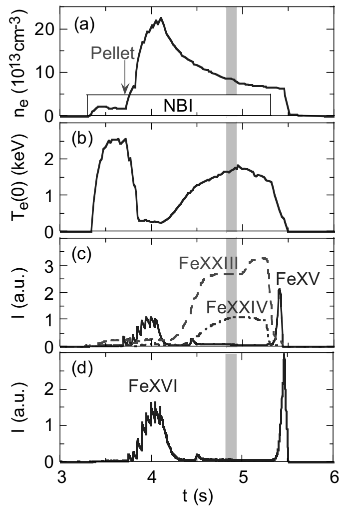

Fig.2 Time traces of NBI discharge in R_{ax}=3.63m. Eight hydrogen pellets are injected during t=3.7-4.2s.

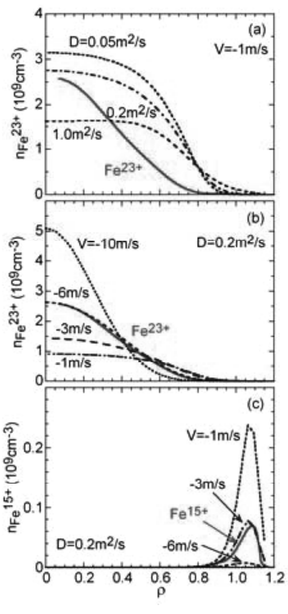

Fig.3 Simulated Fe^{23+} density profiles with different values of (a) D and (b) V and (c) Fe^{15+} with different V. Measured profiles are traced with solid line.

1) Dong, C.F., Morita, S. et al., JJAP **51** (2012) 010205.
2) Nozato, H., Morita, S. et al., PoP **11** (2004) 1920.