§53. Impurity Transport Study by Means of Tracer-Encapsulated Solid Pellet Injection on LHD

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In order to realize a practical fusion reactor, impurity transport is still one of the important issues to be clarified. In recent Large Helical Device (LHD) experiments, Tracer-Encapsulated Solid PELlet (TESPEL) [1] injection has been implemented for the study of impurity particle transport [2]. TESPEL consists of polystyrene (-CH (C_6H_5) CH_2-) as an outer shell (typically ~ 0.7 mmϕ) and tracer particles as an inner core (typically ~ 0.2 mm size). In LHD, metallic impurity accumulation has been found only in hydrogen discharges with a line-averaged electron density n_{e_bar} around 2 x 10^{19} m^{-3} [3]. In order to estimate the transport properties of this phenomenon quantitatively, the transport analysis using the TESPEL injection has been done. The behavior of the emission lines from the highly ionized Ti tracer impurity, Ti Kα ($E_{He\text{-}like}$ ~ 4.7 keV) and Ti XIX (λ = 16.959 nm), have been observed by an X-ray pulse height analyzer (PHA) and a vacuum ultra violet (VUV) spectrometer, respectively. As seen in Fig. 1, the decay time of Ti Kα measured by PHA2O increases gradually as the value of n_{e_bar} increases from 0.3 x 10^{19} m^{-3} to 1.9 x 10^{19} m^{-3}. There are points above 3.0 x 10^{19} m^{-3}, which have a considerably longer decay time. This is consistent qualitatively with the experimental results by observations of the behavior of an intrinsic impurity [3]. In order to estimate transport coefficients at the higher electron density, the impurity transport code, MIST has been used. The trial and error analysis with MIST indicates that the temporal evolution of the emissions of Ti Kα and Ti XIX is in fairy good agreement with the case of diffusion coefficient D = 600 cm^2/sec and convective velocity at the edge V(a) = -76 cm/sec (the inward) (see Fig. 2). From the point of view of global behavior, the Ti impurity transport with n_{e_ber} = 3.5 x 10^{19} m^{-3} can be explained with the value of D = (300 ~ 900) cm^2/sec and V(a) = - (19 ~ 114) cm/sec. In this case, the inward convection should be taken into account. In order to examine the experimentally deduced convective velocity, the neoclassical convective velocity is calculated. In case of n_{e_bar} = 3.5 x 10^{19} m^{-3}, the neoclassical convective velocity at ρ = 0.7, (52.7 ± 46.6) cm/sec, has the opposite sign (the outward), compared with the experimentally deduced one at ρ = 0.7, -53.3 cm/sec. Therefore, the estimated convective velocity cannot be explained in case of n_{e_bar} = 3.5 x 10^{19} m^{-3} solely by the effects of the pure neoclassical impurity transport and the effect of some kind, which originates the inward flux, should be taken into account additionally.

Moreover, by taking advantage that TESPEL can produce very localized particle source, the local deposition of tracer particles inside a magnetic island, which is expanded by Local Island Divertor coils, has been accomplished. In that discharge, the effects of the magnetic island on the impurity particle transport have been observed.

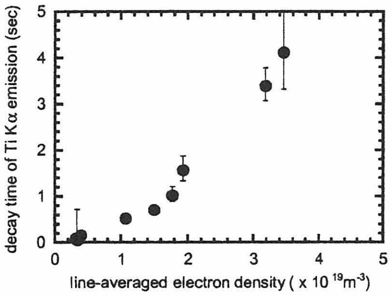

Fig. 1. The dependence of the decay time of Ti Kα emission on the line-averaged electron density in the case of balanced NBI heated plasmas.

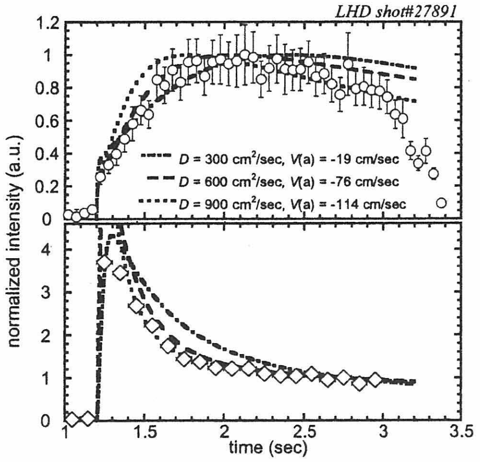

Fig. 2. Comparison of normalized temporal evolution of (a) Ti Kα emission (open circles) measured by the PHA2O and (b) Ti XIX emission (open diamonds) done by the VUV spectrometer with those calculated by MIST with several sets of D and V at the value of n_{e_bar} = 3.5 x 10^{19} m^{-3}.

References:

1) Sudo, S.: J. Plasma Fusion Res. **69**, (1993) 1349
2) Tamura, N. et al.: J. Plasma Fusion Res. SERIES **4**, (2001) 442
3) Nakamura, Y.: Proc. 28th EPS Conf. Controlled Fusion Plasma Phys. **25A**, (200) 1481 (Funchal, Portugal)