§15. Impurity Transport Study with TESPEL in LHD

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Understanding of impurity transport processes is important in order to achieve stationary fusion plasma conditions. It is important to find out control methods of impurity transport to avoid impurity accumulation, together with accurate prediction of impurity behavior under the reactor-relevant condition. Furthermore, there is an interesting issue in the impurity transport study, namely whether there is unique feature of impurity transport in non-axisymmetric device such as LHD or not.

For investigating above issues, Tracer-encapsulated Solid Pellet (TESPEL) is originally considered to diagnose impurity transport with depositing the impurity tracer locally in the plasma[1)-4)]. Features of TESPEL are: (1) local impurity deposition is possible inside the plasma, (2) penetration depth can be varied by changing the size of the outer polystyrene shell, (3) relatively small amount of impurities, (3) deposited amount of the tracer in the plasma can be known precisely, and (4) wide selection of tracer material (even in powder form) is possible.

In the last experimental campaign, we first utilized double tracers in TESPEL in order to compare the behaviors between the different impurities. It has an advantage to observe the impurity behaviors under the exact same plasma condition. The implemented combinations of tracers are: (1) iron (Fe: Z=26) and tin (Sn: Z=50), and (2) Fe and titanium (Ti: Z=20). The target plasma is mainly heated by NBI and the NBI power is modulated for the purpose of the charge exchange recombination spectroscopy. The other conditions are B= 2.75 T, R_{ax}= 3.6 m, γ= 1.254, and the typical average density is 3.5×10^{19} -5.5 $\times10^{19}$ m^{-3}. The observed temporal intensity evolution measured by the soft X-ray Pulse Height Analyzer: PHA in the shot of #97826 is shown in Fig. 1. These are characteristic soft X-ray spectral lines of Sn Lα (3.4 keV) and Fe Kα (6.4 keV) with temporal resolution of 200 ms for the central chord of PHA. In this case, the tracers amounts are 2.1 x 10^{17} particles for Fe and 9.7 x 10^{16} particles for Sn, respectively. It is remarkable that the Sn Lα remains rather long time (at least ~2 s) compared to Fe. The bolometric power increase in this case is 1 MW higher than the case of the double tracers of Fe and Ti. Figure 2 shows the case of the double tracers of Fe and Ti (#97833). In this case, the tracer amounts are 2.0 x 10^{17} particles for Fe and 1.6 x 10^{17} particles for Ti, respectively. The characteristic soft X-ray spectral line of Ti Kα (4.7 keV) is clearly observed in contrast with #97826. The bolometric power increase in this case is only 0.2 MW higher than the case without TESPEL injection. So, the Sn particle contribution to the bolometric power in case of #97826) is very large. The radiation power rate can be estimated as 1 MW / 10^{17} Sn particles. Such estimation is owing to the TESPEL feature of the well defined tracer amount. As seen in Fig. 2, the intensity of Fe Kα is increasing for 2 s, while Ti Kα intensity is rather saturated in the late phase (t= 5 – 6 s). This suggests that impurity with the higher Z value is longer staying in the plasma core region. Thus, the validity of the double tracer method with TEPEL has been proved by the 2009 experimental campaign. We will accumulate the data in the next experimental campaign with the appropriate combination of the tracers.

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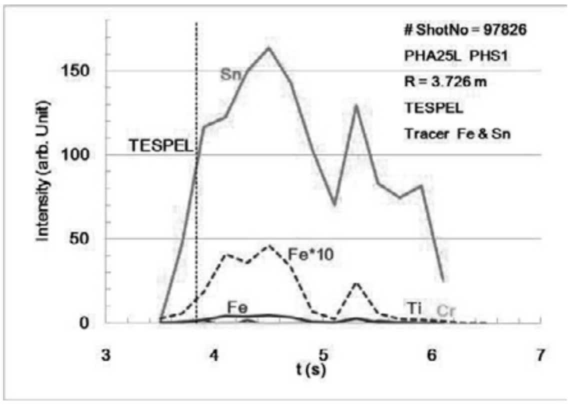

Fig.1 Temporal evolution of characteristic soft X-ray spectral line intensity in case of double tracers of Fe and Sn (#97826).

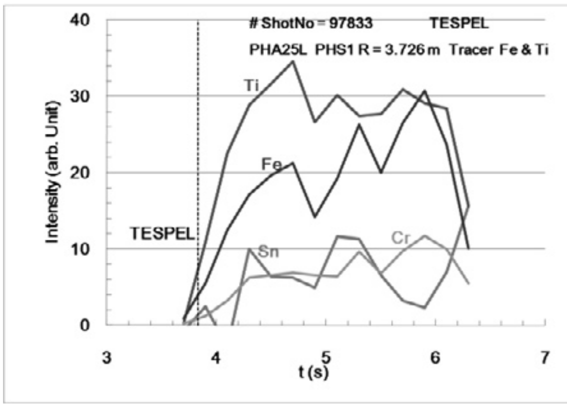

Fig.2 Temporal evolution of characteristic soft X-ray spectral line intensity in case of double tracers of Fe and Ti (#97833).