§14. Impurity Transport Study with TESPEL in LHD

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Tracer-encapsulated Solid Pellet (TESPEL) is originally considered to diagnose impurity transport with depositing the impurity tracer locally in the plasma[1]. 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, (4) deposited amount of the tracer in the plasma can be known precisely, (5) wide selection of tracer material (even in powder form) is possible.

With multiple tracers contained in a TESPEL, it becomes possible to compare the behaviors of the different impurities simultaneously under the same plasma condition. As for a proof-of-principle experiment, we injected such a TESPEL containing triple tracers: V, Mn and Ni, for the first time, in the last experimental campaign. The lines (Li-like and the other lines) from these three tracers in the vacuum ultra violet region (in the range of 15 – 27 nm) are simultaneously observed with time resolution of 50 ms as shown in Fig. 1, where intrinsic Fe ion emissions are also observed. Atomic numbers of triple tracers and Fe are: V (Z=23), Mn (Z=25), Ni (Z=28), and Fe (Z=26).

Kα lines of these tracers are also simultaneously observed with a soft X-ray pulse height analyzer (PHA) with time resolution of 50ms. The Kα transition energies of V, Mn, Ni, and Fe are 4.95, 5.90, 7.48 and 6.40 keV, respectively. The temporal developments of these lines observed in a central vertical chord are obtained as shown in Fig. 2. The TESPEL is injected at t=3.69s. The electron temperature in the plasma core region is 2.5-2.7keV. The electron temperature and density profiles remain almost constant during t=3.7-4.3s. So, we can analyze the feature of tracer behaviors during this time period. From the decay time of the Kα lines and Li-like lines, it suggests that the emissions from the Ni ions decay slower than Mn and also than V. The time scale of the same shot of Fig. 2 is expanded in Fig. 3 to see the rise-up phase of Kα line intensities of the triple tracers. The Kα lines of the different PHA systems with vertical and horizontal chords are also shown in Fig. 3, and the behavior of the Kα lines based on these independent PHA systems shows apparently similar temporal developments. V increases fastest, and Ni increases slowest. Also it is suggested that the Ni particles are accumulated in the plasma core based on the line emissions during the plasma termination phase. Thus, with the above observations, the method of multiple-tracer TESPEL injection is demonstrated to be useful for impurity transport study.

1) S. Sudo, N. Tamura, … , K. Sato, H. Funaba, … , S. Mutoh et al., "Multi-Functional Diagnostic Method with Tracer-Encapsulated Pellet Injection", Plasma Fusion Res., Vol.2, S1069-1 –S1069-4, 2007.

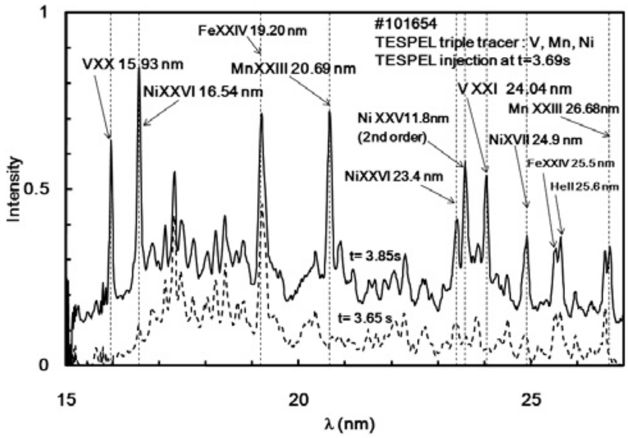

Fig.1 Line emission spectra measured by SOXMOS before and after injection of a TESPEL with triple tracers of V, Mn and Ni in the wavelength range of 15 – 27 nm. Intrinsic Fe is also observed.

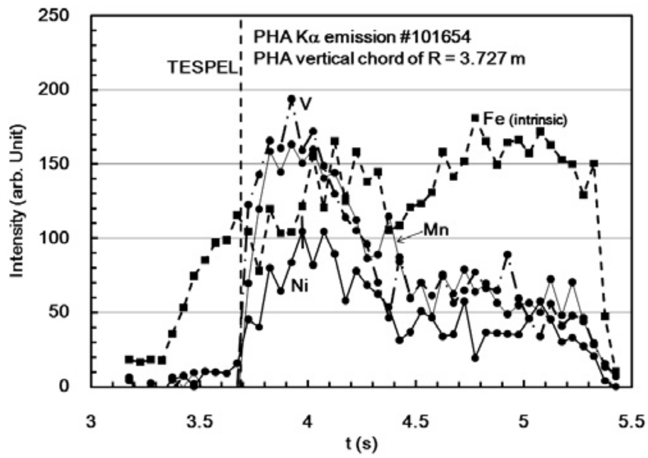

Fig.2 Temporal developments of Kα line intensities of the triple tracers: V, Mn and Ni in case of n_e(line average)=4.8 x 10^{19} m^{-3} at t= 4.0 s. The emission of Fe as an intrinsic impurity shows different behavior from the tracers.

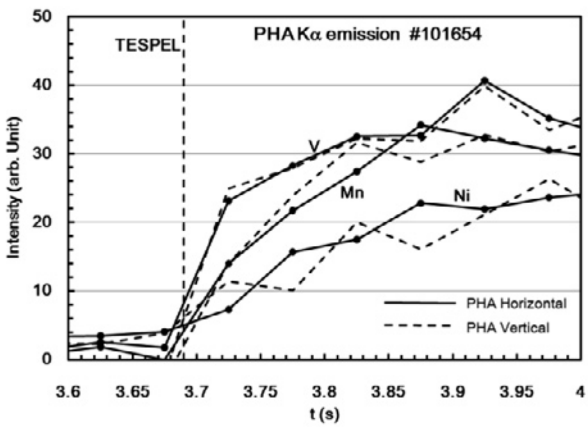

Fig.3 The rise-up phase of Kα line intensities of the triple tracers in the same shot shown in Fig. 2. V increases fastest, and Ni increases slowest.