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トレーサー内蔵ペレットを用いたプラズマ計測
Plasma Diagnostics with Tracer-Encapsulated Solid Pellet

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The diagnostic method of a tracer-encapsulated solid pellet (TESPEL [1]) has been developed, since the first TESPEL injection experiment was carried out at CHS for the purpose of the impurity transport study [2]. After the TESPEL injection experiments at LHD started in 2000 [3], it has been found that the TESPEL method is available for the various diagnostic purposes. TESPEL consists of polystyrene as an outer layer and of specific material as a tracer in the core. The TESPEL diameter ranges 400 ~ 900 μm, and amount of the tracer particles is typically ~ 10^{17} particles. This is less by a factor of 10^4 than the bulk plasma particles. On the other hand, the amount of C and H particles contained in the polystyrene shell with a diameter of 720 μm is about 1×10^{19} particles for each. Thus, when these ions are fully stripped, the total electron number introduced by TESPEL contributes to the density increase of only 0.2×10^{19} m^{-3}, which is still smaller by a factor of more than 10 than the bulk plasma density in case of the impurity transport study.

The special features of TESPEL are: (a) the local deposition of tracers inside the plasma is possible, (b) the deposited amount of the tracer inside the plasma can be known precisely, (c) a relatively wide selection of the tracer material is possible, and (d) the flexibility due to a relatively wide range of the size contributes to the variable penetration depth. Owing to these advantages, the following various studies have been carried out: (1) impurity transport, (2) thermal transport with non local feature under certain condition, (3) high energy particle observation with pellet charge exchange method, (4) particle behavior inside the magnetic island O-point with intentionally-implanted tracers by means of the TESPEL and (5) spectroscopic study with interested atoms contained in the core of the TESPEL. As for (1), the triple tracers of V, Mn and Co are deposited by the TESPEL inside of the LHD plasma, and simultaneously Ar supersonic gas puffing was implemented for simulating the impurities coming from the outside of the plasma as shown in Fig. 1. In the medium density case (n_e= 3-4×10^{19} m^{-3}) it was found that the Ar particles could penetrate into the plasma core, while the tracers decayed in ~0.5 s [4] as shown in Fig. 2(a). In contrast, in the high density case (n_e= 5-7×10^{19} m^{-3}) it was found that the

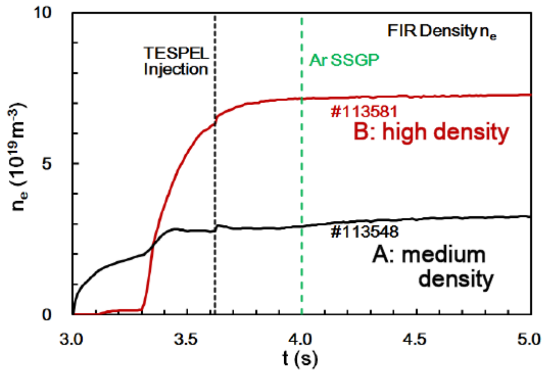

Fig. 1 FIR density for two density cases.

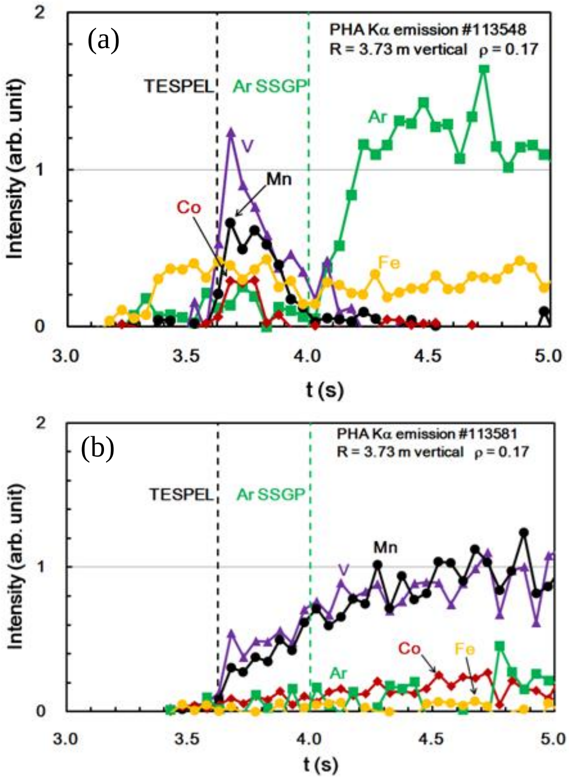

Fig. 2 Kα emissions from the tracers, gas-puffed Ar and intrinsic Fe for (a) medium and (b) high density cases.

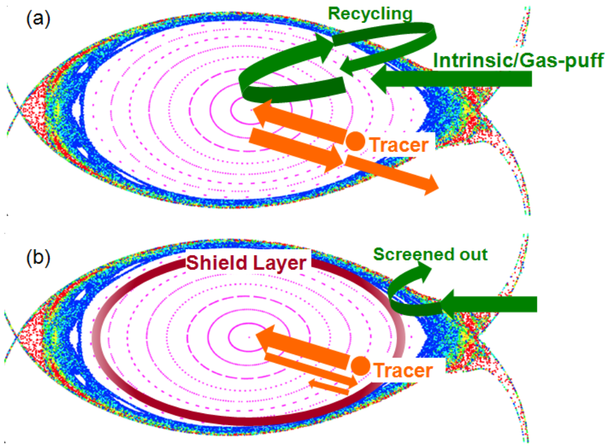

Fig. 3 Schematic view of the impurity transport for (a) medium and (b) high density cases.

Ar particles were strongly suppressed, while the tracers were kept for a long time (no decay for the period of 1.5 s) as shown in Fig. 2(b). From these results, schematic view of the impurity transport for the medium and high density cases is deduced as shown in Fig. 3. TESPEL injection into the intentionally produced magnetic island shows a long impurity confinement inside the magnetic island as shown in Fig. 4 [5]. Also, significant reduction of thermal transport is observed inside the magnetic island O-point [6] using the TESPEL technique.

The local active fast neutral particle analyzer (NPA) using the pellet charge exchange (PCX) method has a good spatial resolution as shown in Fig. 5, where the resonance layer is changed for the ICRF heating [7].

Owing to the feature of the flexibility of the

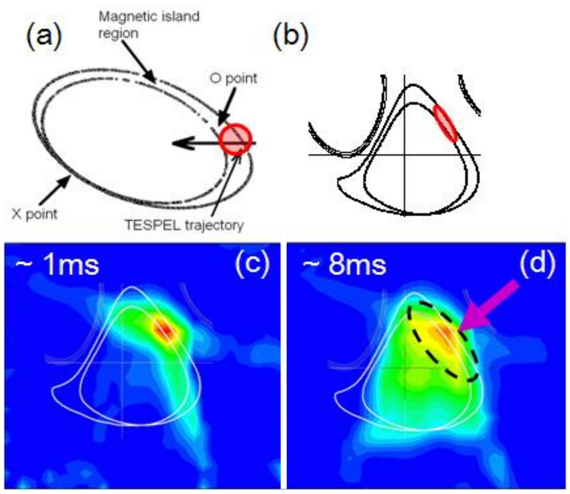

Fig. 4 (a) Tracer impurities were injected into the magnetic island with a TESPEL method. (b) Corresponding cross section of 2-D measurement of tracer emission with the AXUVD array systems. Reconstructed images of the 2-D emission at (c) t= 1 ms and (d) t= 8 ms after TESPEL injection.

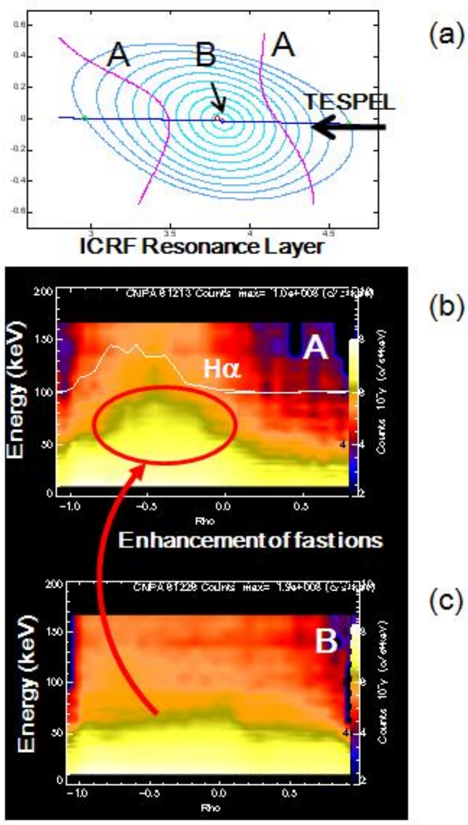

Fig. 5 Standard resonance layer case A and central heating case B for ICRF are shown in (a). The case A indicates more fast particle production as shown in (b) than the case B as shown in (b).

TESPEL size, a small pellet is used for non-local transport study. Under a certain condition, the rapid electron temperature increase in the plasma core was observed, while the edge temperature was decreased [8].

Spectroscopy with interested atoms put as tracer in TESPEL has been studied, especially in the range of EUV spectra from Sn, W, Gd and Nd [9] and the other heavy atoms. The recent achievements on the various subjects will be reviewed.

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