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Plasma Diagnostics and Control with Tracer Encapsulated Solid Pellet (TESPEL) in Magnetically Confined High-Temperature Plasmas

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A Tracer-Encapsulated Solid Pellet (TESPEL), an impurity-embedded hollow pellet, was developed at NIFS, Japan, to promote precise impurity transport studies in magnetically confined high-temperature plasmas. The outer shell of TESPEL is made of polystyrene ($-CH(C_6H_5)_nCH_2-$). Typical dimensions of TESPEL are as follows: the outer diameter (O.D.): 700 μm, the inner diameter (I.D.): 300 μm, and the amount of embedded impurity: an order of 10^{17} particles. When TESPEL is injected into high-temperature plasma, the outer shell of TESPEL first ablates and ionizes. Then, a known number of impurities contained in the core of TESPEL is deposited in a three-dimensionally localized region in the high-temperature plasma. Therefore, the initial behavior of impurities supplied by TESPEL can provide pure information on impurity transport within the core plasma, without being affected by edge plasma effects (such as impurity screening in the Scrape-Off-Layer (SOL) region). Currently, the TESPEL injection systems are operating in LHD [1] at NIFS, Japan, W7-X [2] at IPP-Greifswald, Germany, and TJ-II [3] at Ciemat, Spain, and will also be installed in JT-60SA at QST, Japan soon.

Advantages of TESPEL technology is the flexibility of the impurity embedded in it. As long as solid and not harmful to the human body, any impurity can be injected into the plasma using TESPEL. Taking this advantage, various kinds of impurities, from low-Z to high-Z, have been injected into the core region of magnetically confined high-temperature plasmas by using TESPEL. For instance, in the large-sized devices, such as Large Helical Device (LHD) at NIFS and Wendelstein 7-X (W7-X) at IPP, the impurity accumulation into the core plasmas and its mitigation have been investigated utilizing the TESPEL containing vanadium (V) or iron (Fe) [4, 5]. On the other hand, in the medium-sized devices, such as the TJ-II at Ciemat, the much smaller TESPEL (O.D: 300 μm, I.D.: 100 μm) containing aluminum (Al) was used for impurity transport studies [3]. The size flexibility of TESPEL is used not only to match the TESPEL method to the device size, but also to make the variation of the impurity deposition location. In the LHD, there is a magnetic island O point on the TESPEL injection line, so the impurity transport in the magnetic island O-point was investigated by adjusting the TESPEL size [6]. Moreover, in the LHD, for the studies of atomic physics and EUV light sources, 30 impurities of the 50 elements in the 5th and 6th periods of the periodic table have been injected into the magnetically confined high-temperature plasmas [7]. A disadvantage of the TESPEL method is that it inevitably causes perturbations in the plasma. However, this characteristic has been utilized in the TESPEL method to study a transient heat transport caused by a cold pulse propagation invoked by the TESPEL injection [8]. One of the striking results of such a transient heat transport study using the TESPEL is the discovery of the nonlocal transport phenomenon in the helical plasmas [9]. And recent experiments in the W7-X revealed that plasma performance transiently improves after TESPEL injection. This is somewhat different from that caused by non-local heat transport (e.g., observed even in the high-density state, and peaked electron density after the injection) and indicates new possibilities for plasma control. Moreover, by matching a sightline of neutral particle analyzer with the TESPEL injection line as much as possible, spatially resolved energy distribution of the high energy particles is obtained by a pellet charge exchange method [10].

At the conference, we will give an overview and summary of what can be measured and what kind of plasma control is possible by injecting TESPEL into magnetically confined high-temperature plasma.

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