§4. Impact of Carbon Impurities on the Confinement of High Ion Temperature Discharges in the Large Helical Device

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An achievement of high ion-temperature (Ti) plasmas is one of the most important goals in the research of fusion devices. In realizing the helical-type fusion reactor, it is important to investigate the confinement properties of high-Ti plasmas in the helical type magnetic confinement devices. In the Large Helical Device (LHD), the development of high-Ti scenarios has been intensively conducted and high-Ti plasmas exceeding 7keV were achieved[1, 2]. These high-Ti discharges were achieved with a formation of an ion transport barrier triggered by an injection of carbon pellet and subsequent intensive additional heating by Neutral Beams (NB). Although the confinement improvements and the Ti rise were drastic after the pellet injection, it was difficult to maintain the improvement. The temperature was decreased rapidly after it had reached its maximum. To understand this drastic change of Ti, it is necessary to investigate the mechanism of the confinement improvement.

Since the confinement improvement was triggered after the carbon pellet injection in those discharges, it is natural to consider the role of carbon impurities on the confinement improvements. To clarify the role, the amount of the carbon impurities introduced to plasmas were scanned by varying the number of its injection in a discharge or the size of the pellet, and the changes of thermal confinement properties with these variations were examined. In all cases, strong correlation between the density of carbon impurities and the thermal diffusivities of plasmas were found.

Figure 1(a) shows variations of central ion temperature and electron density in a series of experiments for scanning the carbon pellet size, where, a cylindrical shaped carbon pellet of different diameter and length was injected in each discharge. The length of the pellet was set equal to the diameter of the pellet and the size of the pellet was expressed by the pellets' diameters (ϕs). As shown in the figure, there seems to be a dependence of achievable maximum ion temperatures on the electron densities. Among these discharges, the highest ion temperature was achieved at ne(0)~1.35x1019m-3. The achievable maximum ion temperature became lower at higher density, e.g., the maximum ion temperature achieved at ne(0)~1.7x1019m-3 is approximately 5.5keV. This tendency indicates the electron density plays a certain role in the confinement improvement of these discharges. On the other hand, various ion temperatures were obtained for a same electron density in a single discharge, e.g., the ion temperature drastically changed at ne(0)~1.3x1019m-3 in the discharge where a carbon pellet of ?=1.2mm was

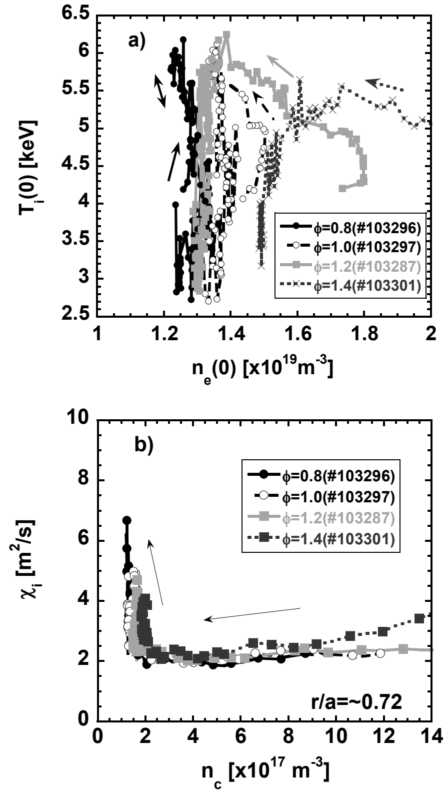

Fig. 1(a) Variations of central ion temperature and electron density in Carbon pellet size-scan experiments. (b) Variations of thermal diffusivities with the change of carbon density at r/a=~0.72, where the foot of internal transport barriers locate. Arrows in the figures indicate the direction of time.

injected. This means the main player of the confinement improvement is not the electron density although it plays a certain role. In Fig. 1(b), thermal diffusivities were plotted against the carbon densities at r/a=~0.72, where the foot of internal transport barrier locates. Surprisingly, these curves for four discharges are almost identical. During the reduction process of carbon densities, the thermal diffusivities were reduced gradually until the carbon density (n_c) reached ~$4x10^{17}m^{-3}$. After the density became below ~$4x10^{17}m^{-3}$, the diffusivity started to increase gradually. The diffusivity was increased rapidly at n_c=~$1.5x10^{17}m^{-3}$.

Figure1(b) indicates that the density of carbon impurity plays an important role in the confinement property of high-Ti discharges on LHD since the dependence of thermal diffusivity on the carbon density were almost identical even if the amount of the carbon introduced in each discharge was different. The figure also indicates that the existence of a threshold value in the density where the ion thermal confinement property degraded drastically below the number, i.e., n_c=~$1.5x10^{17}m^{-3}$.

1) Nagaoka, K., et al.: Fusion Sci. and Tech. **58**(2010)46
2) Takahashi, H., et al.: Nucl. Fusion **53**(2013)073034.