Experimental Study Towards Taming Mixed Ion Species Plasmas in 3D Magnetic Fields

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In possible magnetically confined fusion reactors, various impurities from low to high atomic number (Z) elements could exist simultaneously inside the high-temperature plasma. The primary low-Z impurity in a fusion plasma is helium (He, Z = 2), which will be produced as a by-product of the deuterium-tritium (DT) fusion reaction. And the major possible high-Z impurity in the same plasma would be tungsten (W, Z = 74), which would be used in plasma-facing components. Therefore, for the possible magnetically confined fusion reactor, it is crucially important not only to maintain the high temperature required for fusion reactions but also to control adequately each ion of bulk hydrogen isotopes and impurities. A slight deviation of the hydrogen isotopes ratio, i.e., deuterium-tritium (D-T) ratio from 50:50 in the core fusion plasma, can affect the fusion power in the D-T fusion reactor. Also, the concentration of impurities over the acceptable level in the core fusion plasma can be a showstopper of the fusion reactor. Therefore, the understanding of the physical mechanisms governing the radial profile of hydrogen isotopes and impurities in the magnetically confined high-temperature plasmas is essential to realize the D-T fusion reactor.

In recent years, experiments with hydrogen isotope (hydrogen and deuterium) mixture plasmas have been performed in some tokamaks (e.g., JET[1], AUG[2]) and stellarators (TJ-II[3], and LHD). In the LHD, a transition between hydrogen isotope mixing state (almost flat profile of hydrogen isotope ion density ratio) and hydrogen isotope non-mixing state (non-uniform profile of hydrogen isotope ion density ratio) of hydrogen isotope has been discovered in the study of deuterium ion transport in hydrogen plasmas and vice versa[4, 5]. We also have investigated the transport of impurities, such as carbon and titanium in such hydrogen isotope mixture plasmas. Here, the carbon impurity intrinsically existed in the LHD plasmas because the divertor target plates are made of carbon, and the trace of titanium impurity was injected externally by using a tracer-encapsulated solid pellet (TESPEL).

In this contribution, we will present an overview of the most recent results of experimental studies in the multi-ion species (hydrogen, deuterium, and impurities) plasmas in the LHD. And we will discuss the prospects of such studies.

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