SUMMARY OF Ph.D. DISSERTATION

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Title

Study of Flow Structure and Transport Process of Heavy Metal Impurity in Tokamak Edge Plasmas

Abstract

In tokamak fusion devices, the high energy plasmas leaking from the core region are transported to the divertor plate through the edge plasma region and are neutralized in the divertor region. For the development of future fusion reactors, understanding the flow structure of edge plasmas and the transport process of impurities sputtered from plasma facing components such as the divertor plate are very important from the viewpoints of reducing heat and particle loads to the divertor plate and sustaining the high confinement of the core plasma. The purpose of this study is to clarify the flow structure and the transport process of the impurities, especially heavy metal impurities in the tokamak edge plasmas.

Chapter 1 is introduction. The background and purpose of this study is described.

In Chap. 2, the physical model of the edge plasma simulation code used in Chap. 3 and 4 is summarized. The code has following characteristics: (1) the effect of drifts is taken into account, and (2) the dynamics of the neutral particles is treated by a kinetic model.

In Chap. 3, the basic characteristics of edge plasma flow without drift effects are analyzed. The high Mach flow (HMF) appears in the divertor region when the edge plasma is detached from the divertor plate. The tendency agrees well with the experiment in large tokamak device JT-60U. The pressure gradient force associated with the detachment is one of the possible causes for the formation mechanism of the HMF.

In Chap. 4, the effects of drifts are analyzed on the flow structure investigated in Chap. 3. At the middle of the edge plasma layer, the flow reversal which is observed in experiments is reproduced by the numerical simulation. The drifts drive the ion particle flux that is parallel to a magnetic line of force in order to satisfy the current continuity. This particle flux possibly explains the flow reversal.

Chapter 5 summarizes the physical model of a Monte-Carlo impurity transport code “IMPGYRO”. Since the Larmor radius of heavy metal impurity ions is large, not only the guiding center motion, but also the gyro-motion has to be taken into account. Therefore, the IMPGYRO code is developed with the effects of the Larmor gyration, to analyze the transport processes of heavy metal impurities. The IMPGYRO also takes into account most of the important processes of heavy metal impurities, such as Coulomb collisions, multi-step ionization/recombination processes, and the self-sputtering.

In Chap. 6, the effects of the edge plasma flow on the impurity transport process are analyzed using the IMPGYRO. The HMF associated with the detachment, plays a role such as a friction force which confines the tungsten impurities in the divertor region. The incident angles of the tungsten calculated by the IMPGYRO are widely distributed. The estimated self-sputtering yield is 121% for the vertical incidence, while it is 12% for the case with angle distribution calculated by IMPGYRO. It is shown that the distribution of the incident angle has an important role to estimate the amount of impurity particles generated by the self-sputtering.

In Chap. 7, summary and conclusion of this thesis are given.