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Comparison of the energy and particle confinement of hydrogen and helium plasmas during ECRH on LHD

LHDにおける電子サイクロトロン共鳴加熱時の水素及びヘリウムプラズマの熱及び粒子閉じ込め性能の比較

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The property of the energy and particle confinement of hydrogen and helium plasmas during ECRH was compared on the Large Helical Device (LHD). The heat diffusivity was estimated using TASK3D-a TRsnap, which does power balance analysis. There is no difference in the heat diffusivity of electrons in hydrogen and helium plasmas. Meanwhile, the central ion temperature was higher in hydrogen plasmas than in helium plasmas. Density modulation experiments were also performed to analyze the particle transport property. The particle diffusion coefficient was larger for helium plasmas than for hydrogen plasmas in the edge region.

1. Introduction

In tokamaks, the energy confinement generally improves with the increasing in the isotope mass [1]. Meanwhile, in helical devices, the clear difference of the mass dependence of confinement has not been reported [2]. On LHD, the deuterium experiments will start in 2016. Before the deuterium experiments, we compared the properties of the energy and particle transport of hydrogen and helium plasmas during ECRH. There are differences in not only mass but also charge between hydrogen and helium. The comparison of the transport properties of the hydrogen, helium and deuterium plasmas lead to clarify the effects of mass and charge on the transport properties. The isotope mass effects on the confinement contradict most transport theories, such as gyro-Bohm diffusion. Recently, several theories, which are related to zonal flow and anomalous transport, to explain the isotope mass effects have been proposed [3]. Various ion experiments were important to examine these theories and to clarify the mass and charge effects on the confinement.

2. Heat transport analysis

Hydrogen and helium ECRH plasmas experiments were performed. The helium glow discharge was done before helium plasma experiments for wall conditioning. Plasmas were sustained only by ECRH, without NBI, to form helium rich plasmas for helium plasma experiments. The total injection power of ECRH was set at about 1 MW. The ratio of hydrogen H/(H+He) measured by spectroscopy was 90 % for “hydrogen” plasmas and 10 – 30 % for “helium” plasmas. The experiments were performed where 0.4×10^{19} m^{-3} $< n_{e,ave} < 3 \times 10^{19}$ m^{-3}.

The electron heat diffusivity was evaluated using TRsnap [4], which is a part of TASK3D-a [5] for power balance analysis. ECRH power evaluation is essential for power balance analysis. In the plasma edge region, the magnetic shear and the electron density gradient largely affects evaluation of ECRH absorbed power profile using ray-tracing code. So far, the accuracy of the absolute value of ECRH power evaluated experimentally is higher than that calculated by ray-tracing. On the other hand, the profile is evaluated broader than the real ECRH profile [6]. It is caused because experimentally evaluation of the ECRH absorbed power profile includes effects of the heat transport. Therefore, the absolute value of absorbed power of ECRH was evaluated experimentally. And, the shape of the ECRH power profile was evaluated using ray-trace code LHDGauss [7] and TRAVIS [8-9]. Figure 1 shows the density dependence of the electron heat diffusivity at the minor radius $\rho \sim 0.6$ and the central ion temperature of hydrogen and helium plasmas measured by crystal spectroscopy and charge exchange spectroscopy. There is no difference in the electron heat diffusivity between hydrogen and helium plasmas. Meanwhile, the central ion temperature was higher for hydrogen than for helium ECRH plasmas. It may indicate the ion diffusivity of helium plasmas is lower than hydrogen plasmas.

3. Particle transport analysis

Density modulation experiments were also performed to do the particle transport analysis. Gas puffing was modulated at 1.25 Hz. The particle diffusion coefficient and convection velocity were determined by fitting the Fourier component and stationary component of the change in the electron density with experimental results [10]. The particle source was estimated by 3D Monte Carlo simulation code EIRINE [11]. The particle diffusion coefficient and convection velocity were evaluated taking into account of the particle source. Figure 2 shows profiles of the particle diffusion coefficient and convection velocity. The particle diffusion coefficient was larger in helium plasmas than in hydrogen plasmas, in the edge region. Outward convection velocity was larger in helium plasmas than in hydrogen plasmas, in core region. And, inward convection velocity was larger in helium plasmas than in hydrogen plasmas, in edge region. The total particle transport is dominated by diffusive flux in the edge region. Therefore, the particle transport is larger for helium plasmas than for hydrogen plasmas in edge region due to larger particle diffusion.

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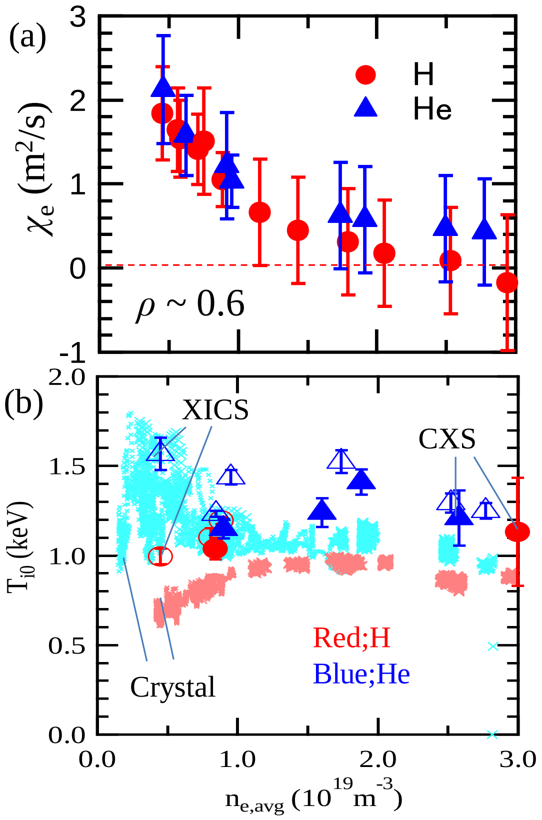

Fig.1. Electron density dependences of (a) the electron heat diffusion coefficient at ρ ~ 0.6 and (b) the central ion temperature for hydrogen and helium plasmas.

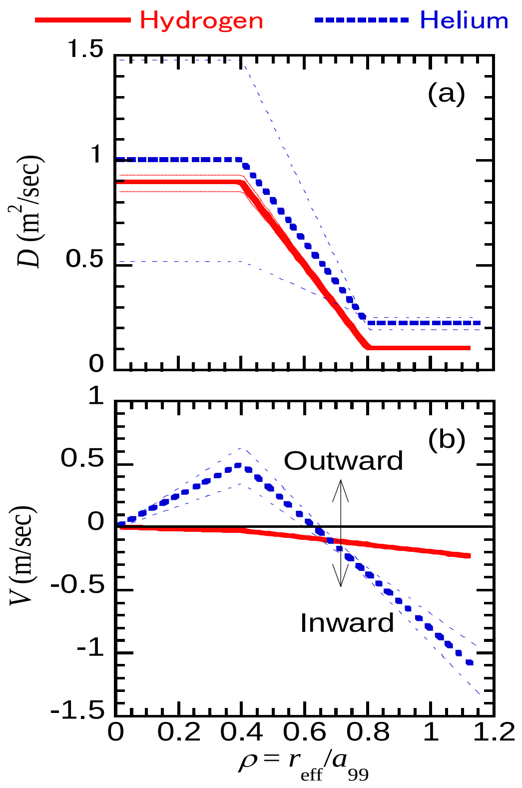

Fig.2. Profiles of (a) the particle diffusion coefficient D and (b) convection velocity V for hydrogen and helium plasmas.