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Krypton-induced ELM suppression and internal transport barrier in KSTAR plasmas

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Protection of plasma facing components is a crucial issue for steady operation of future fusion devices. Edge localized modes (ELMs), which are characterized by periodic bursts of energy and particles in high confinement mode (H-mode) plasmas, are considered to be the main cause of heat loads on divertor target plates. It has been reported that divertor impurity seeding with noble gases, such as neon and argon, can mitigate energy loss by ELMs or change from type-I ELMs to type-III ELMs. In this study, ELM suppression by krypton (Kr) impurity seeding in KSTAR is presented. In addition, this presentation reports that Kr seeding can create an internal transport barrier (ITB), which is regarded as one of the advanced operation scenarios of future fusion devices

In KSTAR H-mode plasmas, Kr was seeded by a divertor gas injection system. Due to the long gas pipe line, Kr gas was gradually injected throughout the discharges. The plasma current, toroidal field, and neutral beam heating power were 0.5 MA, 2.5 T and 3.0 MW, respectively. At a low level of Kr (~1.8×10^{18} particles), there was no effect on ELMs and plasma. At an intermediate level of Kr seeding (~1.7×10^{19} particles), ELMs were briefly suppressed and grassy ELMs occurred with a reduction of line-integrated electron density, core electron temperature, and stored energy, respectively. The ELM mitigation phase was sustained for about 1.2 s and plasma energy loss by ELMs was significantly reduced. ELMs were fully suppressed at a high level of Kr seeding (~3.5×10^{19} particles). An ELM-free H-mode was sustained for about 0.5 s, and then an H-L back transition occurred. At intermediate and high level Kr seeding, both the electron density and temperature decreased and the pedestal pressure gradient decreased significantly. An edge stability analysis using ELITE code shows that the growth rate of the peeling-ballooning mode was remarkably decreased with flattening of the pedestal pressure. The mechanism of electron pressure reduction by Kr seeding is being investigated. The effects of high level of Kr seeding with on-axis ECH were also studied. Compared to the non-ECH case, the ELM-free H-mode was sustained until the end of ECH with a slight reduction of electron density and stored energy, respectively, followed by a grassy ELM after ECH. Change of the Kr ion distribution by ECH might cause this difference. A detailed analysis of Kr transport is ongoing.

An ITB was formed at a higher level of Kr seeding (~5.2×10^{19} particles). After Kr injection, electron density, electron temperature, stored energy, and D_α signal gradually decreased and then H-L back transition occurred. As Kr continued to flow into the plasma, it was observed that electron temperature, ion temperature, and stored energy increased abruptly. Electron temperature, ion temperature, and toroidal rotation profiles strongly peaked at the plasma core ($r/a<0.4$), which are a commonly observed feature of an ITB. TRANSP calculation showed that both core electron and ion heat diffusivity profiles also dropped to a neoclassical level after ITB formation. This suggests a reduction of core thermal transport or improvement of core thermal confinement. Two-dimensional radiation profiles obtained by the imaging bolometer diagnostic show off-axis Kr accumulation after ITB formation, while Kr accumulated mainly in the plasma core before the ITB. In order to understand the role of Kr in ITB formation, changes in Kr ion distribution and transport will be analyzed in detail.

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