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EX/P5-18: Low Concentration of Iron as First Wall Material in LHD Plasmas with Edge Ergodic Layer

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Experiments of Large Helical Device (LHD) have been successfully conducted during past 14 years, based on the first wall fully covered with rectangular protection plates made of stainless steel, basically having no serious impurity problem. The impurity behavior of iron has been quantitatively studied with a spectroscopic system newly developed for measuring two-dimensional distribution of extreme-ultraviolet (EUV) impurity lines. The iron density in core plasmas is found to be fairly low, at least five orders of magnitude smaller than the electron density. The highest density of iron is observed during impurity accumulation triggered by pellet injection. The central density of Fe^{23+} ions analyzed from FeXXIV profile reaches $2.6 \times 10^9 \text{ cm}^{-3}$ during the impurity accumulation phase with appearance of a large inward convective velocity of $V = -6 \text{ m/s}$, whereas it is only $3 \times 10^8 \text{ cm}^{-3}$ before the accumulation occurs. No accumulation is observed for light impurities. The accumulation is mainly caused by the density gradient. These results are very similar to tokamak ones, but only the value of the iron density is different between tokamaks and LHD. The stochastic magnetic field layer of LHD can effectively fulfill its function as the impurity screening in collisional regime of $10 < L_K/L_{ee} < 100$, where L_K is the Kolmogorov length and L_{ee} the electron mean free path. In 3D edge transport simulation the impurity screening is observed in the edge boundary region, where the L_K is nearly 10m. The iron with slower velocity is ionized at outer region of the stochastic layer where the parallel thermal gradient (i.e. thermal force) is smaller. Therefore, larger values of L_K/L_{ee} for heavier ions like iron enhance the friction force along magnetic field, leading to an efficient impurity screening. In LHD the radiation loss from iron is smaller than 1MW in usual discharges ($P_{\text{NBI}} = 20\text{-}30 \text{ MW}$), which is often comparable to radiation from carbon originated in divertor plates. These transport processes interacted with magnetic field structure are of primal reason why the density of iron impurity is fairly low in LHD. The screening effect developed in edge stochastic layer intrinsically existing in LHD works well for materials of the first wall. The present result strongly suggests tolerant use of high-Z materials to the first wall of LHD-type reactor.

Country or International Organization of Primary Author

Japan

Primary author: Mr MORITA, Shigeru (Japan)

Co-authors: Dr SUZUKI, Chihito (National Institute for Fusion Science); Dr DONG, Chunfeng (National Institute for Fusion Science); Dr KATO, Daiji (National Institute for Fusion Science); Mr WANG, Erhui (The Graduate University for Advanced Studies); Prof. KOIKE, Fumihiro (Kitasato University); Dr ZHOU, Hangyu (Southwestern Institute of Physics); Dr SAKAUE, Hiroyuki (National Institute for Fusion Science); Prof. MURAKAMI, Izumi (National Institute for Fusion Science); Dr FUJII, Keisuke (Kyoto University); Prof. HASUO, Masahiro (Kyoto University); Dr KOBAYASHI, Masahiro (NIFS); Prof. GOTO, Motoshi (National Institute for Fusion Science); Prof. YAMAGUCHI, Naohiro (Toyama University); Dr ASHIKAWA, Naoko (National Institute for Fusion Science); Dr YAMAMOTO, Norimasa (Chubu University); Dr SHIKAMA, Taiichi (Kyoto University); Prof. CUI, Zhengying (Southwestern Institute of Physics); Prof. MASUZAKI, suguru (National Institute for Fusion Science)

Presenter: Mr MORITA, Shigeru (Japan)

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