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Particle control for long pulse plasma operation in EAST tokamak

G.Z. Zuo[1,*], J.S. Hu[1], W. Xu[2], Y.W. Yu[1], Z. Sun[3], R. Maingi[3], C.L. Li[1,4] ,L. Zhang[1], X.Z. Gong[1]

[1]Institute of plasma physics, HIPS, Chinese academy of Sciences

[2]Institute of Energy, HCNSC

[3]Plasma Physics Laboratory Princeton, Princeton University

[4]University of science and Technology of china

zuoguizh@ipp.ac.cn

Effective control of fuel recycling and impurity particles is very key for achievement of long pulse and high-performance plasmas. High recycling and impurity concentration in the plasma would result in usually degradation of plasma confinement, and uncontrollable plasma density and disruptions. Some advanced vacuum and wall conditioning technologies, have been developed and widely used in EAST to effectively control fuel and impurity particle for extending plasma pulse duration.

In order to enhance particle exhaust rate for improving recycling control capability during long-pulse plasma operation, the new type ITER-like W–Cu divertor with larger conductance was successfully applied in EAST to replace the previous graphite divertor with the higher hydrogen retention characteristic. Based on the new divertor and upgraded pumping system, the effective pumping speed for D_2 of the EAST lower divertor increased ~ 2 times. Several techniques of surface conditionings such as baking, discharge cleaning, silicon/lithium (Li) coatings, and liquid Li, have all been attempted to further improve wall condition [1, 2]. Compared to traditional wall conditionings, it is noted that evaporated Li coating assisted by He-ICRF was testified as the most effective way to suppress impurities, reduce recycling and H/(H+D) ratio to stabilize plasma edge [1,3]. Specifically, the high-Z tungsten core impurity concentration was maintained between 3ppm-15ppm during long H-mode plasmas [4], which is possibly due to the effect of Li film physical isolation and Li vapor shielding between the W substrate and plasma. These results confirm Li coating served as a sacrificial protective layer and can reduce wall material surface erosion [5], which will produce material of 10^3-10^5kg/year in pilot plants. In order to refresh Li coated film with the short lifetime of ~300s to continuously capture particle during long pulse discharge [6], real-time Li injection was successfully applied, which could further reduce the recycling by 30% and kept low tungsten impurity due to decreased tungsten sputtering rate resulting from the reduced divertor electron temperature [7, 8].

By using these advanced vacuum and Li wall conditioning technologies, a record plasma of ~1056s pulse duration with a controlled plasma density of 1.8×10^{19} m^{-3}, the low H/(H+D) ratio to <7%, goal recycling coefficient <1 and core tungsten impurity concentration~5.6×10^{-5} was successfully achieved in EAST, serving as important references for stand-steady plasma operation for ITER and future fusion devices.

References

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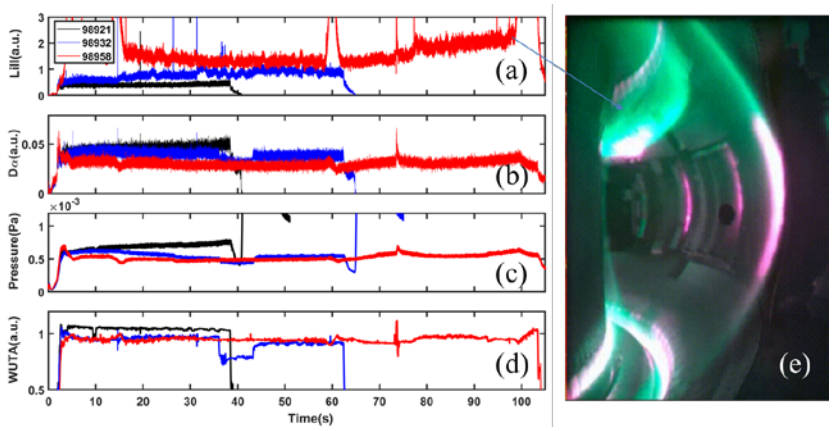

Figure1. Basic plasma parameters for three typical long pulse shots 98921, 98932, and 98958. (a) Li-II emission intensity in the upper divertor; (b) Dα from the upper divertor; (c) Neutral gas pressure in the divertor zone; (d) W-UTA line emission; (e)Li powder injection