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Fuel recycling control for long pulse H-mode operation in EAST superconducting tokamak

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Fuel recycling is one of critical issues for long pulse plasma operation in tokamaks, due to their strong effects on plasma density control and plasma confinement. Fuel recycling control for long pulse H-mode operation is studied in EAST, the effects of first wall baking, discharge cleaning, in-vessel cryopumps, silicon and lithium materials coating, and real-time lithium powder injections on fuel recycling control are investigated and compared in detail.

The results show that long term first wall baking and discharge cleaning provides a necessary clean wall condition with a high ultimate vacuum of 3.6×10^{-6} Pa and low outgassing rate ~ 1.5×10^{-4} Pa m3/s for plasma operation. The use of In-Vessel Cryopump (IVCP) could decrease global recycling coefficient (R_{global}) from ~1.0 to ~ 0.8 during Ohmic Heating (OH) plasmas, and it provides high particle exhausting rate of 10^{20}- 10^{21} D-atoms/s in high-power plasma operations for fuel recycling control.

Long-term silicon coating (SiD_4) is more powerful than first wall baking and discharge cleanings, which reduces H/(H+D) ratio gradually to a value as low as 8%. 102 s long pulse L-mode plasmas with a core electron temperature of >5 keV is obtained in EAST under silicon coating wall condition with ~ 38 hours accumulated silicon coating, and without any use of lithium. However, the result shows that fuel recycling is gradually increased at the end of the discharge due to the increase of first wall temperature, indicating insufficient control of fuel recycling by silicon coating for long pulse operation.

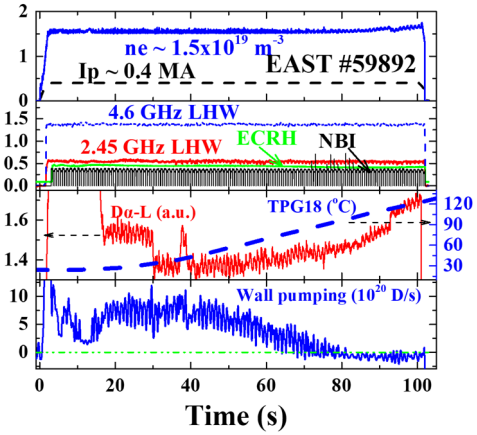

Figure 1. Long pulse L-mode of EAST #59892 under silicon coating wall condition.

Lithium coating is more effective and more efficient than silicon coating to further reduce H/(H+D) ratio to 3%, real-time Lithium Powder Injection (LPI) could reduce R_{global} from by 0.94 to 0.82 under lithium coating wall condition.

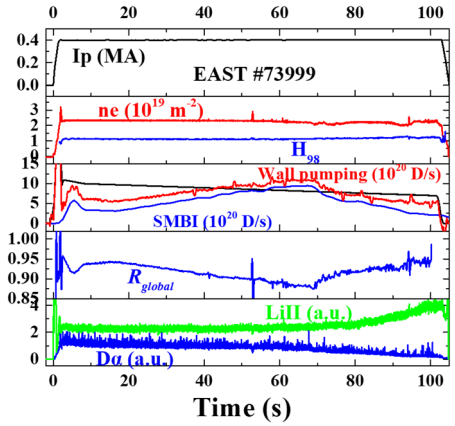

Figure 2. 101 s H-mode of EAST #73999 under lithium coating wall condition.

By integrating the above control methods, long pulse H-mode plasmas with low fuel recycling are achieved in EAST and extended gradually to 101 s in 2017, and recycling flux is well controlled with a global recycling coefficient of 0.88 – 0.94 during the whole discharge. Moreover, in the long pulse H-mode discharges, fuel recycling simply indicated by Dα emission is always decreasing along with plasma operation, together with a slight increase of Li-II emission. Probably it's because the increased first wall surface temperature during long pulse operation leads to more evaporation of coated lithium on first wall surface into edge plasma, and further results in an enhanced fuel recycling especially in the later phase of long pulse.

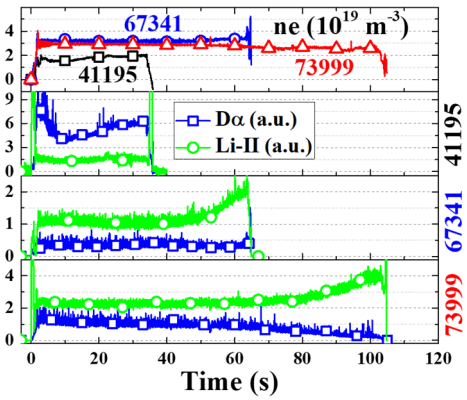

Figure 3. Fuel recycling control and Li-II emission during EAST long pulse H-mode plasma operation.

References

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