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Experiments and simulations for power exhaust by impurity seeding on EAST

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Power exhaust will be a critical issue for EAST and future tokamak devices with high heating power because the heat flux from the upstream plasma onto the divertor targets will exceed the maximum capability of the divertor targets. Seeding the noble extrinsic impurities to increase the radiation in divertor and Scrape-Off Layer (SOL) regions through ionizations and charge exchanges of the impurity particles, namely realizing the radiative divertor plasma operation, can effectively mitigate the high particle and heat fluxes and promote the divertor detachment to avoid overheating of the targets [1]. To systematically investigate the behavior of different radiating candidates such as Ne and Ar, for power exhaust in the current and future devices, both experimental and numerical simulation studies have been carried out on EAST during the past years.

Since EAST upgraded its top divertor into ITER-like full tungsten PFCs in 2014, the earlier study on Ar seeding showed that Ar can effectively reduce particle and heat fluxes on the divertor targets and promoted plasma detachment by Ar/D_2 mixture seeding in the divertor region [2], which were also verified by SOLPS simulation. However, core contamination and tungsten sputtering were observed during Ar seeding which led to a clear reduction of plasma stored energy and core confinement. Therefore, Ne was considered to be a new option during the past two years, by taking the current plasma parameters and edge plasma conditions into account.

Ne/D_2 mixture with different ratios was seeded from the divertor region as the radiators, and the divertor plasma detachment and the reduction of the heat flux on the targets can be achieved effectively as a result. Different gas puffing methods have also been investigated. Using multi-pulse method could effectively avoid excessive impurities entering the plasma core region and causing contaminations there. However, this method was less effective in achieving the plasma detachment. Based on the experiences of different proportions and different injection methods, the radiation feedback control experiments and the detachment feedback control experiments were explored respectively. Finally we successfully realized the feedback control of the total radiation power and the electron temperature near the strike point on the target with the simultaneous Ne seeding from the divertor gas puff inlet and midplane SMBI, and the detached plasma can be efficiently obtained while avoiding excessive impurities entering the plasma core [3]. Tungsten sputtering was also investigated during the neon seeding experiments. Because of the acceleration by the sheath, the neon and self-sputtered tungsten could cause the tungsten physical sputtering. By using the lower Ne impurity ratio mixture, the sputtering of tungsten on the target could be suppressed greatly. In addition, divertor detachment operation and better wall conditioning also help to inhibit the growth of divertor tungsten sputtering to some extent.

The Ar/Ne seeded radiative divertor experiments in EAST were also validated by SOLPS modeling [3, 4]. The simulation results basically agreed well with the experiments which show that Ar and Ne have relatively good performance in reducing particle fluxes and heat load on targets. Although the simulated midplane plasma parameters perfectly matched the experimental results greatly, it is still difficult to match parameters well on both targets when ignoring drifts. Through reconstruction of radiation distribution by SOLPS code, most of the radiation caused by Ne/Ar impurity distributed in the region inside the separatrix in agreement with the AXUV measurements.

On one hand, the above experimental and simulation results could extend our understandings of impurity seeding scenarios and underlying physics. More importantly, reasonable predictions of impurity seeding regimes in future devices, such as ITER and CFETR, can be deduced from these studies.

References:

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