Charge-exchange deuterium flux to the main chamber wall and its induced material erosion in EAST

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Erosion of the ITER main chamber first wall (FW) beryllium (Be) armour is expected to affect the lifetime of FW panel, dust formation, and release of Be impurities potentially leading to enhanced sputtering of the W divertor and tritium retention due to co-deposition. The ITER FW panels are shaped to protect leading edges and misalignments, which leads to magnetically shadowed regions, where impurity re-deposition and fuel co-deposition can occur. In addition to plasma ions, charge exchange (CX) neutrals in ITER and future reactors will play an important role on the first wall erosion and overall fuel retention, but the extent to which they contribute is still unknown.

A low-energy neutral particle analyzer (LENPA) based on the time of- flight method has been developed on EAST to measure the flux and energy of neutral particles to the first wall. The LENPA works in the pulse-counting mode and the energy distribution of neutrals is obtained based on the flight-time of particles. A 220 mm diameter chopper disc with 32 equally spaced slots has a maximum rotating speed of 300 Hz, resulting in a LENPA detecting period of 104 μs and a slit half-open time of 1.07 μs. After freely streaming 4170 mm, the chopped neutral particles reach the detector located at the end of LENPA. In the LENPA detection range, more than 85 % of neutral particles are in the energy range of 20–1000 eV. The integrated neutral flux in the energy range of 20–1000 eV increases with line-averaged density in ohmic discharges due to the increased CX reaction rates in a higher density plasma. Compare to the discharges fuelled with SMBI, the discharges without SMBI have more lower energy neutrals at the similar line-averaged density due to higher edge neutral density and proximity of fuelling. Due to the deeper penetration depth by SMBI fuelling, the neutral particles are generated closer to the core plasma and have higher energy. It was found that the neutral flux increases with heating power in all energy range. The mean energy of neutral particles increases significantly compared to the ohmic discharges. The higher ion temperature and edge density in auxiliary heated discharges result in higher neutral flux in all the energy range.

A quartz crystal microbalance (QMB) was installed together with the LENPA system on the equatorial port of EAST [2]. The neutral-induced material erosion rates and the neutral energy spectrum were measured simultaneously by the two real-time and in-situ diagnostics. The neutral-induced Al erosion rates for the 11 long-pulse full discharges are given by experimental measurement from the QMB and the theoretical calculations according to the neutral energy spectrum from the LENPA, which are consistent with each other. It is proved that higher density and heating power can increase the flux and energy of neutral particles, which results in stronger neutral-induced material erosion. The real-time Li powder injection during discharges can reduce the erosion rate due to the lower recycling and the resulting lower neutral flux.