Effects of boron / boron-nitride powder dropping on hydrogen isotopes and helium behaviors in LHD

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Impurity powder dropping (IPD) experiment has been conducted in the Large Helical Device (LHD) to investigate the effects of the real-time wall conditioning on plasma and plasma-wall interactions [1-5]. Boron (B) or boron-nitride (BN) powder is dropped to high temperature plasma with central electron temperature of several keV for 0.5 s to more than 10 s from a top port with the dropping rate of 0.1 to several tens of mg/s. In the experiment, hydrogen (H) or deuterium (D) or helium (He) has been used as a fueling gas.

Suppression of fuel recycling has been observed not only for hydrogen isotopes but also helium [1, 2]. It is well known that hydrogen isotopes are absorbed by a boron film on plasma facing wall. In the case of IPD, absorption on the formed boron film and co-deposition of fueled particles and boron simultaneously work. As a result, it is possible that helium recycling is also suppressed by the co-deposition.

After starting the powder dropping, boron density in plasma increases for a few seconds, and saturate to the value which depends on the dropping rate and plasma conditions. The suppression of recycling proceeds with the same time-scale as the boron density. So, the suppression has been clearly observed during discharges, on times scales longer than 5 seconds, while this effect is less clear on shorter time scales.

The powder dropping longer than 10 s has been conducted in LHD during long pulse discharges, and it has been observed that the suppression lasts during the powder dropping. On the other hand, the suppression reduces with the decrease of boron density in plasma after the termination of the dropping. This observation suggests that co-deposition largely affects the suppression.
In hydrogen short pulse discharges with ~3 seconds duration time, the powder dropping of less than 1 s has been examined. In this case, the suppression is not clear during a discharge. However, electron density after 34 discharges with powder dropping was 18 % lower than that before the dropping experiment with similar fueling [2]. This result suggests that boron layer formed in discharges with powder dropping, and hydrogen absorption on boron layer worked.

A simulation study of boron deposition on plasma facing surface using EMC3-EIRENE, DUSTT, and ERO2.0 codes has been conducted [3], and the results show that boron particles deposit on divertor tiles and on the first wall nearest from plasma.

In the presentation, dependences of the suppression of fuel recycling on powder drop rate, heating power, operational electron density, and working gas are shown, and mechanisms of the suppression is discussed taking into account the simulation results.

[1] F. Nespoli, et al., Nucl. Mater. Energy. **25** (2020) 100842.
[2] F. Nespoli, et al., 28th IAEA Fusion Energy Conference.
[3] M. Shoji et al., Nucl. Mater. Energy **25** (2020) 100853.
[4] T. Oishi, et al., to be published in Plasma Sci. Tech.
[5] N. Ashikawa, et al., 29th International Toki Conference, Poster-3-F2-13 (2020).