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Control of fuel particle recycling using the hot wall on all-metal plasma facing wall in QUEST

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QUEST (Q-shu University experiments with Steady-state Spherical Tokamak) [1] is a medium sized spherical tokamak (ST) (R=0.64m a=0.4m, BT<0.25T @R=0.6m) in Kyushu University. The heating sources for plasma are two RFs which are capable of operation with 28GHz, 350kW, a few second and 8.2 GHz 50kW, CW. Plasma facing walls (PFWs) are mainly composed of stainless steel type 316L and stainless steel type 316L coated with atmospheric plasma sprayed tungsten (APS-W). QUEST has been equipped with a hot wall coated with APS-W [2], which is capable of controlling its temperature locally even during the discharge through the combination use of heater and water cooling up to 723K that is expected to be the operation temperature in Japanese DEMO. QUEST could demonstrate 6 h discharges [3] with the hot wall in a limiter configuration with low power range (<40kW).

Results from QUEST show that the wall temperature considerably influences fuel recycling property including wall saturation, leading to density runaway and termination of discharge. Higher wall temperatures have led to shorter discharges in the range of 393K(2h15min)-673K(40min) in the same condition of plasma and PFWs. This tendency can be explained as a result of the plasma-induced deposition layer that modifies surface recombination accompanied by a transport barrier for fuel hydrogen [4], locating at the boundary between the deposition layer with substrate. The surface recombination coefficient of the deposition layer mainly composed of plasma-sputtered carbon is increasing with its temperature and consequently, active surface recombination gives rise to wall saturation in early stage of the discharge. This must be resolved to obtain SSO.

In 2021, QUEST successfully demonstrated long duration discharges with wall temperature of ˜673K. Unfortunately, a number of heaters of the hot wall was not working during the discharge, because they have made a damage for long time operation since 2015, but almost half of the hot wall reached to up to 673K and the rest of them was around 573K or less. In this situation, we could try to regulate the hot wall temperature and the local hot wall temperature kept in 673K was cooled down by 90 K on two occasions in the discharge during wall saturation and the global recycling rate was recovered down to less than unity each occasion, and consequently, the pulse duration extended from 40 min to 230 min. This is a good example of real time controllability of fuel recycling with local PFW temperature control.

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Primary author: HANADA, Kazuaki

Co-authors: IDEI, Hiroshi; KUZMIN, Arseniy; HASEGAWA, Makoto; IKEZOE, Ryuya; KOJIMA, Shinichiro; KURODA, Kengo; MIYAMOTO, Mitsutaka; ONCHI, Takumi; OYA, Makoto; OYA, Yasuhisa; SHIKAMA, Taichi; TAKAGI, Ikuji; YONEDA, Nao; YUE, Qilin; YOSHIDA, Naoaki; HATAYAMA, Akiyoshi; HOSHINO, Kazuo; NAGASHIMA, Yoshihiko; IDO, Takeshi; NAKAMURA, Kazuo; WATANAVBE, Hideo; TOKUNAGA, Kazutoshi; KONO, Kaori; HIGASHIJIMA, Aki; EJIRI, Akira; GAO, Xiang; LIU, Haiqing; NAGATA, Takahiro; KAWASAKI, Shoji; MURAKAMI, Sadayoshi; ONO, Masayuki; QIAN, Jinping; RAMAN, Roger; SHIMABUKURO, Shun; TAKASE, Yuichi

Presenter: HANADA, Kazuaki

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