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Fuel particle balance for steady state operation on all-metal fusion experimental device, QUEST.

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Steady state operation of fusion magnetic devices is one of the crucial issue for realizing fusion power plants. In our presentation, issues related to plasma wall interaction (PWI), especially fuel particle balance will be introduced. Recently metallic plasma facing materials (PFM) has been incorporated in many magnetic fusion devices to avoid large amount of tritium retention [1,2] which has been observed in carbonic PFM devices. Installation of metallic PFM is advantageous in two ways. The static retention in the PFM means a simultaneous increase of dynamic retention in the plasma discharge. Therefore, the importance of understanding PWI with metallic PFM is growing. High temperature plasma is likely to have a significant impact on the PFM surface. It found that the altered surface plays a significant role in fuel particle dynamics in the PFM, because the surface is the intermediate region for incoming and outgoing fuel particle [3,4]. The property of the altered surface of the specimen exposed by QUEST plasmas was investigated with ellipsometry, transmission electron microscopy (TEM), X-ray photoelectron spectroscopy (XPS), gas discharge optical emission spectroscopy (GD-OES), nuclear reaction analysis (NRA), and colorimetry. From these observations, it was revealed that the PFM was covered with a deposition layer of a few tens nm in thickness due to PWI [5], and a model to express properties of metallic PFM for fuel particle balance was proposed [6]. The model called hydrogen barrier model (HB model) includes the deposition layer and the presence of a transport barrier region for hydrogen atom at the boundary of the deposition layer and PFM substrate.

QUEST [7] is a spherical tokamak with all-metallic PFM and has the capability for steady state operation. In fact, a 1 h 55 min discharge was obtained with the assist of a hot wall to control the temperature of the PFM and with proper fueling control based on feedback from the H_{alpha} signal [6,8]. Here, we try to investigate the particle balance of this long-pulse discharge with the HB model. The calculation is composed of three regions. These are the plasma, non-plasma region that surrounds the plasma, and the PFM. Fuel particles are continuously circulating during the plasma discharge, and the calculation takes account of the state of the hydrogen, as to whether it is in the form of molecules, atoms, or several types of ions. In the calculation, two types of PFM are considered. One is a PFM with HB and the other one is PFM which perfectly reflects fuel particles such as H atoms (FR model). The results show that the time evolution of electron density with the HB model is gradually increasing up to 1000 s and this behavior has never been seen in the FR model. The saturated value of density is a little higher than that derived from the FR model. This difference results from increased out-flux due to charge exchange (CX) H that penetrates through the non-plasma region and directly reaches the PFMs. In the case of the FR model, most of H exists as H atom in the non-plasma region, but H_2 is dominant in the case of the HB model. The large time response of the density would make it difficult to control the output power in fusion plants and so a proper wall model should be developed even in all-metal PFW devices. The model calculation with the HB model including the real physical parameters obtained with microscopic observations in QUEST is consistent with the behavior of long duration discharge obtained on QUEST.

In summary, the wall model indicates there is significant impact in the time response of the plasma density even in an all-metal PFW device such as QUEST. This result suggests the importance of the need for a suitable wall model that takes account of H recycling from the deposition layer.

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