Test and analysis of a conceptual first wall with the capability of tritium prevention for DEMO

Laizhong Cai*, Xiaoxiao Zenga, Jianbao Wanga, Jiupeng Songb, Binyou Yanb, Zhe Chena, Xiang Liua, Youyun Liana, Yu Lic, Thomas Morganc, Ming Liud

aSouthwestern Institute of Physics, Chengdu, Sichuan, China
bXiamen Tungsten Company, Xiamen, Fujian, China
cDIFFER, 5600 HH Eindhoven, Netherlands
dXi’an Jiaotong University, Xi’an, China

cailz@swip.ac.cn

First wall, which is facing to plasma directly and experiences energetic particles, neutron radiation, steady state heat loads and transient heat loads, is one of the key components in fusion reactors. Another primary concern on the first wall in DEMO is the tritium accumulation in the plasma-facing areas. Based on the requirements of tritium self-sufficiency and safety regulation of tritium, it is very important to control the buildup in plasma facing components (i.e. first wall) and decrease the tritium inventory. In this work, a sandwich-like first wall structure with a tritium prevention interlayer is fabricated and tested. The interlayer is applied to combine the plasma facing material (W) and reduced activation ferritic/martensitic (RAFM) and also to prevent the permeation of hydrogen and its isotopes.

For the top layer of the first wall, thick coating tungsten is applied due to the intermediate heat load on the first wall, which is fabricated by chemical vapor deposition (CVD) since CVD-W has a better thermal shock resistance. And CLF-1, a kind of RAFM developed by Southwestern Institute of Physics, is used as the substrate of the first wall structure. With a big difference between thermal expansion coefficients CVD-W and CLF-1, the interlayer between them has to mitigate the stress. And the tritium prevention capability of the interlayer is necessary due to the great importance of controlling the tritium buildup, improving the fuel efficiency and conforming to the safety regulation of tritium. TiN, which has the intermediate thermal expansion coefficient in between CVD-W and CLF-1, is selected as the interlayer material since it also has good performance as a tritium barrier.

After the fabrication of the samples, general inspection and material analysis are done immediately. Thermal cycling tests with 11 cycles at 700 °C are performed for preliminary investigation. Then plasma exposure test with a steady state heat load under a particle flux of $2 \times 10^{24}$ m$^{-2}$ s$^{-1}$ and heat flux of up to 7MW/m$^2$ is carried out at Magnum-PSI. Another test with the combination of a steady state heat load of 1.7MW/m$^2$ and a transient heat load of 0.16GW/m$^2$ is also performed. The results show that the structures with a TiN interlayer are good after the thermal cycle tests and plasma exposure tests. The conceptual first wall can bear intermediate steady state heat load and transient heat pulses, and TiN is good for an interlayer to mitigate the thermal stress between CVD-W and CLF-1. Material analysis indicates that the quality of TiN is very important for the mitigation of thermal stress and the permeation of light elements. With the TiN interlayer of bad quality, the sandwich-like structure was detached or split at the interface of the TiN interlayer after sample cutting or thermal cycle tests. More, the permeation of fluorine element, which was introduced during CVD of tungsten, was found in the TiN interlayer with defects.