Temperature impact on W surface exposed to He plasma in LHD and its consequences for the material properties

E. Bernard, R. Sakamoto, N. Yoshida[a] , H. Yamada

National Institute for Fusion Science, Toki, Gifu 509-5292, Japan
[a] Kyushu University, Kasuga, Fukuoka 816-8580, Japan

elodie.bernard@nifs.ac.jp

A new temperature controlled material probe was designed for the exposure of W samples to He plasma in the LHD (Large Helical Device). TEM (Transmission Electron Microscopy) analysis allowed the study of the impact of He irradiation under high temperatures on W µstructure: bubbles and dislocation loops are formed at the surface with a high density and increasing size as temperature increases. Bubbles were observed much deeper than the heavily damaged surface layer, rising concerns about the consequences for the material properties conservation.

Choice of plasma-facing materials for next generation fusion machines, such as ITER and DEMO, has to take into consideration the intensive fluxes of light elements, such as He and H isotopes, which the first wall materials will be subjected to. This irradiation can let to important damages at the surface, affecting the properties and life span of the materials, hence the efficiency of the reactor. For W, one of the most promising candidates, incident He particles can drastically affect the surface: formation of dislocation loops, bubbles or W-fuzz was observed. These changes at the material surface can modify the mechanical properties and increase hydrogen retention in the structure; understanding of He damages in W are thus of prime importance in a context of spreading use of this material.

One key parameter to examine in this aim is the material temperature: indeed, W operation temperature in fusion can reach up to 500 ºC, and temperature rise affects vacancy and interstitial mobility in the material, which has a strong impact on the final microstructure of the material after irradiation as preliminary studies in laboratory confirmed.

In this prospect, we exposed W samples to He plasma in LHD thanks to a new temperature controlled sample-holder. Samples were exposed to estimated fluences of $\sim 10^{23}$ He/m^2 at temperatures ranging from 65 to 600 ºC. Structure was observed via TEM. TDS (Thermo Desorption Spectrometry) performed after H laboratory implantation of samples exposed to LHD He plasma allowed to estimate the differential H trapping in the material due to the He damages.

The impact of high temperatures (and fluence) on the He irradiation damages observed was accessed for the first time in real-plasma exposure conditions. Both dislocation loops and bubbles appeared from low to medium temperatures and saw an impressive increase of size (factor 4 to 6) most probably by coalescence as the temperature reaches 600 ºC, with 500 ºC appearing as a threshold for the bubbles growth. Annealing of the samples up to 800 ºC highlighted the stability of the dislocation damages formed by He irradiation at high surface temperature, as bubbles and dislocation loops seem to conserve their characteristics.

Additional studies on cross-sections showed that bubbles were formed much deeper (70-100 nm) than the heavily damaged surface layer (20-25 nm), rising concern about the impact on the material mechanical properties conservation and potential additional trapping of H isotopes.