23P-5F-01

極限的高熱負荷照射環境下で使用されるW系材料特性評価
Characterization of W-based materials used in extreme high heat load irradiation environments

若井栄一 1)、能登裕之 2)、叶野翔 3)、牧村俊助 4)、石田卓 4)、柴山環樹 5)
WAKAI Eiichi1)、NOTO Hiroyuki2)、KANO Sho3)、MAKIMURA Shunsuke4)、ISHIDA Taku4)、SHIBAYAMA Tamaki5)

1)原子力機構, 2)核融合研, 3)東大, 4)高エネルギー研, 5)北大
1)JAEA, 2)NIFS, 3)Univ. of Tokyo, 4)KEK, 5)Hokkaido Univ.

1. Introduction
It is important to evaluate the safety and longevity of the materials used in the reactor wall materials and divertors, which are in close proximity to high-temperature plasmas, as well as in devices that receive high-density high-energy particle beams, such as those under the most intense beams in high-energy accelerators, in order to withstand high thermal loads and irradiation. In this study, we investigated the following properties of an innovative nanoparticle-dispersed W material with a grain size of about 1-2 μm and high strength, which was fabricated by mechanical alloying and high-temperature isostatic pressure sintering at the National Institute for Fusion Research.

2. Specimens
The materials with chemical composition of pure W and W-1.1wt%TiC were prepared, and mechanical alloying (MA) process were performed for 64 hr in 360 rpm using by WC ball with 1.6 mm or 3.0 mm. After MA treatment, these specimens were formed by cold isostatic pressing and hydrogen reduction was carried out in a hydrogen stream. The HIP treatment was carried out under the conditions of 1750°C and 186 MPa for 1.5hr. This was followed by annealing at about 1800 °C for about 1.5 hrs in a vacuum (1×10^{-3} Pa).

3. Microstructures of the specimens
The grain sizes of W-1.1wt%TiC treated with 1.6 mm WC ball and W-1.1wt%TiC treated with 3.0 mm WC ball were about 5-6 μm and about 1-2 μm, respectively. In the latter case, the titanium particles with about were formed in the matrix and the size was about 100 nm; Titanium oxide particles were formed on grain boundaries and the size was about 100 – 500 nm.

4. Nano Indentation
For the nano-indentation, a Berkovich-type indenter was utilized for the specimens. The indentation depth was 0.15 μm. The nano hardness of pure W, W-1.1wt%TiC(1.6 mm WC ball case), and W-1.1wt%TiC(3.0 mm WC ball case) were tentatively about 6, 2, and 31 GPa, respectively.

5. Ion Irradiation Experiment
For the evaluation of irradiation resistance, tungsten ion irradiation experiments were carried out at 500°C to about 0.66 dpa at the damage peak by 2.9 MeV W^{2+} ions from the Tandetron accelerator at the High Fluence Irradiation Facility, the University of Tokyo (HIT). After the irradiation, nano-indenters were used to examine the hardness for specimens. The nano-hardness of the specimens were increased by the irradiation as tentative evaluation..

6. Innovative materials challenges
The research for innovative materials is very important and high entropy Fe alloy and high entropy W alloy considering low activation are under developing to improve high strength, ductility, and irradiation resistance and the content will also be shown in this conference.

7. Summary
The characterization of W-based materials used in extreme high heat load irradiation environments was evaluated including irradiation damage. The research for innovative materials is very important and high entropy Fe alloy and W alloy considering low activation are under developing to improve high strength, ductility, and irradiation resistance.

Acknowledgement
This study was supported by Kakenhi (21H04668 and 21H04480), NIFS collaboration study, and the Japan-U.S. Science and Technology Cooperation Program (High Energy Physics).