Contribution ID: **1115** Type: **Regular Poster**

INFLUENCE OF RADIATION AND THERMAL EFFECTSON THE STRUCTURE AND PROPERTIES OF TUNGSTEN

Friday 14 May 2021 18:25 (20 minutes)

In this work, high-purity tungsten was subjected to various types of effects corresponding to the processes of fusion - fission neutrons and thermal effects in the hydrogen and helium atmosphere at a temperature of 1000 K, irradiation by hydrogen and deuterium plasmas.
An important task in the ITER project implementing is to select structural materials with the most appropriate characteristics that ensure the fusion reactor safe operation.
Serious concerns about the currently known varieties of commercially manufactured tungsten are caused by its stability and resistance to thermal loads in a tokamak reactor, especially in the presence of neutron and plasma radiation. In this case, the material destruction and increased surface erosion may occur, which will lead to the entry of tungsten into the central discharge zones and deterioration of plasma retention. During the plasma irradiation at T<900 K and fluence >1023 He (H)/m2 helium and hydrogen blisters are formed in tungsten. The references data analysis shows that the formation of blisters, bubbles and cracks on the surface creates obstacles to the tungsten use in thermonuclear installations. One of the important issues of using tungsten as a plasma-facing material is the lack of experimental results on neutron damage at high fluences, especially in the hydrogen isotopes atmosphere [1-3]. Tungsten will become a key structural material for plasma-facing materials of future fusion installations. Its physical characteristics under neutron irradiation, plasma and thermal effects strongly affect the service life of these installations.
In this regard, determining the mechanisms of the structures formation and changes in the tungsten properties under prolonged radiation and thermal exposure is an important scientific and experimental task.
In this paper, the implementation of plasma irradiation on tungsten was performed on an imitation test-bench with a plasma beam installation (Figure 1), designed in the Institute of Atomic Energy Branch of the Republican State Enterprise "National Nuclear Center of the Republic of Kazakhstan"(Kurchatov) [4,5]. The task of long-term radiation and thermal effects was performed under the conditions of a reactor test in a hydrogen and helium media at the WWR-K research reactor (Institute of Nuclear Physics, Almaty) [6,7].

Indico rendering error

```
Could not include image: [403] Error fetching image
```

Based on tungsten radiation and thermal testing under hydrogen and helium environment of the reactor, the synergistic effects of thermal and neutron irradiation in a hydrogen and helium environment at a temperature of 1000 K on the characteristics of the tungsten structural material were established. The study results complement the experimental database for the examining tungsten under long-term neutrons damaging effects.
According to the results of studying the modification of the structure and erosion of the tungsten surface under irradiation with hydrogen plasma, the surface change was established as a relief development resulting from inhomogeneous surface etching.
Figure 2 shows the tungsten fine structure (a-c), observed by transmission electron microscopy. One can clearly see that after irradiation, the tungsten structure is more fragmented and characterized by a defective substructure. The resulting defect is approaching the grain boundaries defect.

Indico rendering error

```
Could not include image: [403] Error fetching image
```

The choice of a tungsten sample was determined by its properties. According to the references data (Figure 3) on hydrogen isotopes solubility in this material, it follows that tungsten (along with molybdenum and a number of other refractory metals and alloys) has one of the lowest values of the solubility constant (fewer than in stainless steel by more than two orders of magnitude).

Indico rendering error

```
Could not include image: [403] Error fetching image
```

Initially, the sample was heated by a 30 mm diameter electron beam, then by an 8 mm diameter electron beam. Changes in the mass spectra were recorded, in particular the changes in the peaks of the corresponding HD, deuterium, hydrogen, and water molecules. (Figure 4).

Indico rendering error

```
Could not include image: [403] Error fetching image
```

Thus, methodical experiments were performed, the results of which allowed us to get an approach to conducting experiments on gas emission on a plasma-beam installation, a number of parameters relative to the temperature field over the sample volume under conditions of saturation and degassing, the electron beam parameters were obtained to provide the necessary sample temperatures, the background values of the gas composition in the chamber with the sample during experiments on gas release, for the saturation/degassing research mode, were estimated.
Based on the results of the performed work, it has been revealed that after plasma irradiation, the tungsten structure becomes more fragmented and is characterized by a more developed defective substructure. The resulting defect is close to the grain boundaries defect. The cause of these structural disturbances appears to be mechanical stresses in the tungsten lattice caused by implanted ions.
Results of methodical experiments on thermal desorption under in-situ mode allowed developing an approach to conduct experiments on gas emission on a plasma-beam installation, a number of parameters have been obtained with respect to the temperature field over the sample volume under conditions of saturation and degassing, the parameters of the electron beam that provide the required sample temperatures have been obtained, the background values of the gas composition in the chamber with the sample during experiments on gas release, for the saturation/degassing research mode, have been estimated.

References:

1. Bolt H., Barabash V., et.al. Materials for the plasma-facing components of fusion reactors. –Journal of Nuclear Materials, 2004, vol. 329-333, p. 66-73.
2. Shimada M. et.al. Overview of the US–Japan collaborative investigation on hydrogen isotope retention in neutron-irradiated and ion-damaged tungsten. –Fusion Engineering and Design, 2012, vol.87, p.1166–1170.
3. Shimada M. et.al. Defect annealing and thermal desorption of deuterium in low dose HFIR neutron-irradiated tungsten. –Journal of Nuclear Materials, 2015, vol.463, p.1005-1008.
4. T.R. Tulenbergenov, M.K. Skakov, A.Zh. Miniyazov, I.A. Sokolov, G.K. Kaiyrdy. Rol' imitatsionnogo stenda s plazmenno-puchkovoy ustanovkoy v issledovaniyakh plazmenno-poverkhnostnogo vzaimodeystviya. NNC RK Bulletin. –Kurchatov, 2019. –Iss. 4. –p. 51-58.
5. Miniyazov A.Zh., Sitnikov A.A., Skakov M.K. Eksperimental'nyye issledovaniya vzaimodeystviya nizkotemperaturnoy plazmy s vol'framom. // Polzumov Bulletin, - Barnaul, 2019. –No.1. –p.181-185. DOI: 10.25712/ASTU.2072-8921.2019.01.033–2019.
6. Study of properties of tungsten irradiated in hydrogen atmosphere. I. Tazhibaeva, M. Skakov, V. Baklanov, E. Koyanbaev, A. Miniyazov, T. Kulsartov etc., Journal "Nuclear Fusion"V57, №12, P. 126062. IF2016: 3,36. 2017. https://doi.org/10.1088/1741-4326/aa7911.
7. Miniyazov A.Z., Sitnikov A.A., Skakov M.K., Tazhibayeva I.L., Yakovlev V.I., Tungsten Izmeneniye mikrostruktury vol'frama v usloviyakh reaktornogo oblucheniya v srede vodoroda // Polzumov Bulletin. –2016.–No. 4. –V.2. –p. 212-216.
8. Mazayev, R. Avarbe, and Y. Vilk, "Solubility of Hydrogen in Tungsten at High Temperatures and Pressures" Izv. Akad.Nauk.USSR Metally 6, 233 (1968).
9. R. Fraunfelder, "Permeation of Hydrogen through Tungsten and Molybdenum"J. Chem. Phys. 48, 3955 (1967).
10. G. Benamati, E. Serra, and C.H. Wu, "Hydrogen and Deuterium Transport and Inventory Parameters through W and W-alloys for Fusion Reactor Applications"J. Nucl. Mater., 283-287, 1033 (2000).
11. A.P. Zakarov, V.M. Sharapov, E.I. Evko, Hydrogen permeability of polycrystalline and monocrystalline molybdenum and tungsten/ Soviet Mater. Sci. 9 (1973) 149–153.

Country or International Organization

Kazakhstan

Affiliation

National Nuclear Center, branch «Institute of Atomic Energy»

Author: Mr MINIYAZOV, Arman (National Nuclear Center, Institute of Atomic Energy Branch)

Co-authors: Prof. SKAKOV, Mazhyn (National nuclear centre of RK); Mr KOYANBAYEV, Erbol (Institute of Atomic Energy NNC RK); SOKOLOV, Igor (National nuclear centre of RK)

Presenter: Mr MINIYAZOV, Arman (National Nuclear Center, Institute of Atomic Energy Branch)

Session Classification: P8 Posters 8

Track Classification: Fusion Energy Technology