§33. Evaluation of Advanced Tungsten Materials as Plasma Facing Materials

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1. Introduction

Tungsten and tungsten based alloys are potential candidates as the plasma facing materials in the next generation fusion experimental devices aiming the steady state operation and D-T burning. The advantages of refractory metals such as tungsten were recognized earlier in Japan. Collaborative research on vacuum plasma sprayed tungsten has been carried on among NIFS and Kyushu University. On the other hand, R&D of ultra-fine crystal grain tungsten alloys dispersed fine TiC particles (UFG W-TiC) are going successfully at Tohoku University. The purpose of the present LHD collaborative reach is, therefore, to progress the development of these innovative tungsten based alloys furthermore by the collaborative comprehensive evaluations of the material properties required as plasma facing materials.

2. Experimental Results and Discussion

2.1 Development and evaluations of UFG W-TiC alloys

(1) Last year it was found that deformation of UFG W-0.5TiC alloyed in hydrogen atmosphere occurred through super plasticity at high temperatures. This year, application of the super plasticity for deformation technique has been studied extensively (Y. Kurishita et al., Tohoku University). Remarkable results are followings.

Tensile test at 1400~1700C, where the super plasticity occurs, has been performed to make clear the effects of TiC addition(0~1.5%) and atmosphere during the MA process on the mechanical properties such as elongation, deformation resistance and strain rate sensitivity. W-1%TiC alloyed in argon atmosphere, which had best mechanical performance in the present work, showed very high fracture strength of about 3.5G Pa at room temperature. It is an epoch-making that this alloy also showed ductility even at room temperature. Improvement of the ductility at room temperature is an important issue for the next year. In order to accelerate the development of the ductile UFG W-TiC alloy an international R&D project has been started.

Concerning UFG W-TiC, following studies also have been carried out extensively.

(2) MeV-class high energy helium ion irradiation effects in UFG W-TiC alloy (A. Hasegawa et al., Tohoku Univ.)

(3) Surface modification of UFG W-TiC alloys by the high flux helium plasma bombardment (N. Ohno et al., Nagoya Univ.)

(4) Mechanism of internal damage evolution in UFG W-TiC alloys by 100~1000eV-class helium ions Iwakiri et al. Kyushu Univ.)

2.2 Evolution of VPS-W coating on carbon materials

Small test pieces of the VPS-W coated IG-430U (isotropic graphite) were exposed to the divertor leg of the hydrogen plasma discharges (75747~#75769) by using the retractable material prove system equipped to LHD. Major discharge conditions and the plasma parameters are following. NBI heating: 3.5MW(2s) +3.5MW(1.5s), total discharge time: 40s (23shots), magnetic axis: 3.60m, $n_e \approx 6 \sim 8 \times 10^{19} m^{-3}$, $E_{div} \approx$ a few 10eV. It is remarkable that no obvious damage such as clacking occurred even at the divertor-leg where very high heat flux was expected. (K. Tokunaga et al., Kyushu Univ.) This result encourages using the VPS-W coated graphite as divertor armor material of LHD.

2.3 Fundamental Studies on plasma irradiation effects in tungsten based-materials

Following fundamental studies on irradiation effects of low energy helium and hydrogen ions were also carried out extensively.

(1) Mechanism of surface modification in tungsten under helium ion irradiation at elevated temperatures (N. Yoshida, Kyushu Univ.)

(2) Helium irradiation effects in tungsten at diverter relevant high temperatures (H. Iwakiri, Kyushu Univ.)

It was cleared that thermal migration and mutual aggregation of nano-scale helium bubbles bring formation of dense meso-scale porous bulges at the irradiated surface. This phenomenon occurs commonly above 1100K under helium ion (plasma) irradiation above 10eV. It is no doubt that tungsten looses good heat load resistance once the surface is covered by such porous bulges. Development of a new tungsten based alloy with high helium irradiation resistance at divertor relevant elevated temperatures is an urgent issue to make a reliable divertor for burning plasma devices such as ITER.

(3) Synergistic effects of simultaneous irradiation of hydrogen and helium (Y. Ueda, Osaka Univ.)

(4) Plasma irradiation effects for metallic materials in LHD (M. Tokitani, NIFS)

3. Final remarks

Most of the planed research programs have been carried as expected. Especially development of UFG W-TiC alloys with ductility even at room temperature is a highlight of this year. Based on the good performance in the LHD test, NIFS is seriously considering the installation of VPS-W coated divertor tiles in LHD. New research program developing tungsten alloys with high helium irradiation resistance will start in 2008.