§20. Study of Irradiation Damage Mechanism of Tungsten Caused by Nuclear Transmutation by Neutron Irradiation

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1. Objectives

In fusion reactor, the diverter and first wall will be exposed to not only high heat flux but also energetic hydrogen ions and neutrons. The diverter operating conditions may be the most severe environment for materials of fusion reactor. The maximum heat flux at unstable phase of plasma will be 10-20 MW/m^2. So the diverter has armor plate on the surface to the plasma. In order to maintain its soundness, the armor materials have to have superior properties such as high melting point, high thermal conductivity and high resistance to radiation damage by neutrons and hydrogen ion bombardments. Tungsten(W) is one of candidate materials for the armor plates of diverter because of its highest melting point in metals and higher resistance to physical sputtering by plasma particles.

In order to predict W behavior under the fusion reactor environments, many researchers have been studied neutron irradiation effects of W using fission reactors. Major results of them were about irradiation embrittlement and microstructure changes. On the other hand, heavy neutron irradiation induces not only irradiation damage but also nuclear transmutation products of W such as Rhenium(Re), Osmium(Os) and Tantalum(Ta). Some researchers calculated the amount of transmutation and predicted the chemical composition changes of W during reactor operation. Based on these works, we reported the irradiation behavior of W-Re-Os alloy systems. Re and Os are produced by (n,γ) reaction and are smaller size elements in than W. On the other hand, Ta is produced by (n,α) and (n,p) reactions and an over size elements in W. Re and Os form precipitates in W, but Ta is isomorphous in W. We reported that irradiation induced precipitates were formed in W-Re-Os alloys even in the solid solution compositions and void formation was suppressed, but Ta effects on the damage structure evolution have not been clarified yet.

The final goal of this study was to clarify the irradiation behavior of the W-Re-Os-Ta alloys, but in the first step, solution hardening/softening behavior of the alloy will be investigate. In the next step, irradiation behavior combined with the solution and/or precipitation hardening of W will be investigated. In this study, W model alloys containing Re, Os and Ta were fabricated to clarify solid solution behavior and to prepare specimens for irradiation experiments by ion beam irradiation.

2. Experimental procedure

W base model alloys contained Re and/or Os and/or Ta were fabricated. The examined composition of the alloys were as follows; 1) reference material: pure W, 2) binary alloys: W-3%,5%Re and W-5%Os, W-1%,5%Ta, 3) ternary alloy: W-3%Re-1%Ta, 4) higher Re containing alloys: W-23%Re-0.7%Os-1%Ta. These alloy fabrication was carried out using an argon arc furnace in IMR Tohoku University. The raw materials were pure W (99.96%) and W-26Re (W: 74.0 ± 0.2%, Re: 26.0 ± 0.2%) rods supplied by Plansee ltd. and Os (99.9%) powder and Tantalum flake (99.9%) supplied by Koujundo Chemical Laboratory co., ltd. Interstitial impurity levels of the fabricated alloys were in the range of 40~200 wppm for carbon (C), 20~40 wppm for oxygen (O) and <12 wppm for nitrogen (N). Disk shape specimens with a diameter of 3mm and a thickness of 0.3mm were cut out from the ingots by an electro discharge machine and mechanically grinded and polished to 0.2mm thickness, and annealed at 1400℃ for 1 hour in vacuum .

Vickers hardness test was carried out to measure hardening. The loading conditions of hardness test was 200g weight for 15sec. in air at room temperature. The hardness measurements were carries out 5 times for each specimen.

3. Result

Figure 1 shows ingots of alloys fabricated by the arc melting method. Shinny surface was observed in pure-W and lower binary alloys except for W-5Os. Lusterless surface was observed in W-5Os, W-3Re-1Ta and W-23Re-0.7Os-1Ta alloys.

Table 1 shows the results of hardening . Solution softening was observed in W-Re system up to 5%Re addition. Os addition caused large solution hardening. In the case of W-Ta system, solution hardening was observed but the magnitude of the hardening was smaller than W-Os. In the case of W-3Re-1Ta, softening was observed. These materials will be irradiated by ion-beam accelerator at higher temperature to study the solute elements effects on damage evolution and hardening behavior.

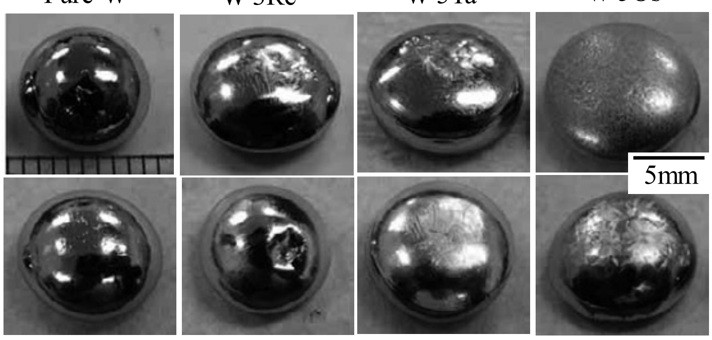

Figure 1 Ingots of fabricated alloys by arc-melting.

Alloys	PureW	W-3Re	W-5Re	W-5Os
Hardness	496	445	438	688
Alloys	W-1Ta	W-5Ta	W-3Re-1Ta	W-23Re-0.7Os-1Ta
Hardness	501	528	455	635

Table 1 Results of Vickers Hardness of alloys.