§26. Development of the Tungsten Materials for High Heat Flux Components Application to Neutron Irradiation Conditions in Fusion Reactor

Hasegawa, A. (Graduate School of Engineering, Tohoku Univ.)

1. Objectives

The objectives of this study are the development of new tungsten (W) alloy which is improved the irradiation- and heat-resistance for high heat flux components (HHFC) in fusion reactor, and the investigations of its operational temperature range and neutron dose limit. The feature of this study is development of new tungsten alloys which have composition and structure to suppress the effect of neutron irradiation in consideration of property and composition changes due to neutron irradiation.

In this study, the optimization of irradiation- and heat-resistance by alloying and the fabrication of new tungsten alloys in industrial scale are being conducted.

2. Experimental procedures

Evaluations of recrystallization behavior, thermal diffusivity, bending strength, and hardness of pure W and tungsten alloys (i.e. potassium (K)-doped W and W-1%Re) fabricated in 2011 were carried out. In addition, we fabricated three kinds of new tungsten alloys (i.e. W-3%Re, K-doped W-3%Re, and lanthanum La-doped W-3%Re), and investigated the hardness change due to heat treatment from 900 to 1500 ^{o}C for 1 hour. The alloys examined in this study were supplied by A.L.M.T. Corp., and its dimensions are 80 x 85 x 5 mm^3. These materials were fabricated by powder metallurgy and hot rolling, followed by heat treatment for stress relieve at 900 ^{o}C for 20 min.

3. Results

An aspect ratio of grains in pure W decreased with increment of the heat treatment temperature. For W-1%Re, the change of aspect ratio due to heat treatments was not observed up to 1500^{o}C. The aspect ratio of grains in K-doped W was larger than that in pure W before and after heat treatments.

The maximum bending strength of pure W decreased with the increment of heat treatment temperature. For W-1%Re, change of maximum bending strength due to the heat treatment was merely observed, although the maximum bending strength of as-received sample was lower than that of as-received pure W. K-doped W shows higher maximum bending strength compared with pure W and W-1%Re. K-doped W keeps the strength after heat treatment up to 1300 ^{o}C. However, the maximum bending strength of K-doped W was nearly identical with pure W after heat treatment at 1500 ^{o}C.

Figure 1 shows Vickers hardness of the samples before and after the heat treatments. Measured surface of Vickers hardness was a side surface of hot rolled plate sample. The Vickers hardness of W-1%Re and K-doped W decreased with the increment of heat treatment temperature, although, the amount of decreases in Vickers hardness of W-1%Re and K-doped W were lower than that of pure W. The Vickers hardness of as-received W-3%Re, K-doped W-3%Re, and La-doped W-3%Re were also lower than that of as-received pure W. The amounts of decrease in Vickers hardness of W-3%Re due to heat treatments was almost the same as pure W. The decrease of Vickers hardness of K-doped W-3%Re and La-doped W-3%Re due to heat treatment was smaller than that of the other materials.

It is well known that the addition of Re rises recrystallization temperature and improves ductility of pure W. Therefore, the decreases of aspect ratio, maximum bending stress, and Vickers hardness due to the heat treatment were suppressed in the W-Re alloys. It was reported that the dope of K or La rose recrystallization temperature and improved strength and ductility. The result of this study also shows the dope of K or La effective for suppression of recrystallization and improvement of mechanical properties.

For thermal property of tungsten alloys, thermal diffusivity measurement of pure W, W-1%Re, and K-doped W using laser-flash method was carried out. The thermal diffusivity of W-1%Re and K-doped W was lower than that of pure W. At 500 ^{o}C, thermal diffusivity of W-1%Re and K-doped W was 10% and 3% lower than that of pure W. At 1100 ^{o}C, thermal diffusivity of W-1%Re was 2% lower than that of pure W, and that of K-doped W was almost the same level compared with pure W. For W-1%Re and K-doped W, decrease of thermal diffusivity was caused by the solute Re atom and fine-grain structure, respectively.

In 2013, investigation of mechanical and thermal properties of W-3%Re, K-doped W-3%Re, and La-doped W-3%Re are scheduled. Furthermore, we are going to distribute the six kinds of tungsten materials (i.e. Pure W, W-1%Re, W-3%Re, K-doped W, K-doped W-3%Re, and La-doped W-3%Re) to co-workers of this project, and evaluate total performance of the alloys based on evaluation of thermal conductivity, thermal fatigue and thermal shock properties, hydrogen retention and permeation, and strength and ductility.

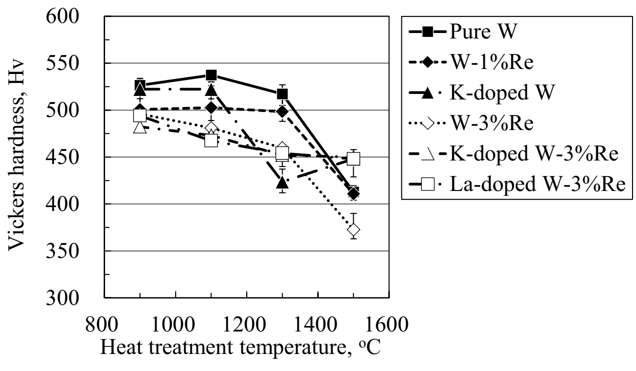

Fig. 1 Vickers hardness of the W alloys before and after heat treatments.