§24. Production and Development of Tungsten Materials for High Heat Flux Components Corresponding to Neutron Irradiation Environment of Fusion Reactor

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1. Objective

In this work, the design of the new tungsten (W) alloy based on the previous results of the neutron irradiation experiment and the post irradiation experiments (PIEs) using W materials which were fabricated in laboratory scale and also the fabrication of new designed W alloy in industrial scale with heat and mechanical treatment to improve the resistance to irradiation are going to be carried out. Furthermore, proposals of not only the new W alloy but also the limits of operating temperature and neutron dose of developed W alloys as high heat flux components are the objectives of this work.

In this fiscal year, evaluation of the grain structure and tensile strength anisotropy, thermal diffusivity, specific heat were carried out. The effects of grain structure anisotropy, alloying, and second phase dispersion on some material properties of pure W plate were investigated. For further improvement of the material property, pure W and W-alloy rods were fabricated by swaging and recrystallization behavior of the materials were investigated.

2. Experimental

Evaluation of the effect of grain structure anisotropy on mechanical and thermal properties of pure W and K-doped W plate which fabricated by hot-rolling, and fabrication of rod material were carried out. As the rod material which has finer grain structure than plate material, we fabricated pure W, K-doped W, K-doped W-3%Re rods with 20 mm diameter and 500 mm long. The rod materials were fabricated by the powder metallurgy followed by swaging at high temperature, and finally stress-relief heat treated. In this FY, fabrication of the specimens for each test, investigation of the tensile strength at elevated temperature and effect of heat treatment on mechanical property and its anisotropy were carried out. In addition, design of the small specimen and jigs for experiment in future (i.e. neutron irradiation experiment and tensile test using small specimen) was performed.

3. Results and discussions

Figure 1 shows the test temperature dependence of the ultimate tensile strength (UTS) of pure W, K-doped W, and K-doped W-3%Re plates. Tensile direction of this experiment was parallel to the rolling direction (RD), and strain rate was 10^{-3} s^{-1}. At R.T., all materials were raptured in elastic region. Elongation was observed at above 500 °C. The UTS was decreased with increasing the temperature. K-doped W and K-doped W-3%Re show higher UTS than pure W, and improvement of the mechanical property of W by the K and Re addition was observed.

For the ductile brittle transition behavior of W at low temperature, strain rate and temperature dependence of the fracture strain of as-received pure W and K-doped W plates were investigated as shown in Fig. 2. Tensile direction of this experiment was parallel to the rolling direction. In the case of pure W, plastic deformation was not observed and brittle fracture occurred at R.T. and 100 °C. Ductile-brittle transition was observed at 200 °C, and ductile fracture occurred throughout a range of strain rate at 300 °C. On the other hand, ductile-brittle transition of K-doped W was observed at 100 °C, and this transition temperature was 100 °C lower than that of pure W. In addition, more than 5% of elongation was observed in K-doped W at R.T. with strain rate of 10^{-5} s^{-1}. Difference of the ductile-brittle transition temperature between pure W and K-doped W was caused by finer grain structure of K-doped W than pure W.

Anisotropy of the UTS of pure W was observed at R.T., and UTS of thickness direction was >60% lower than that of parallel to rolling direction. It was considered that the anisotropy of UTS was caused by the layered grain structure.

For the thermal property of pure W and its alloys, doping of K not affected to the thermal diffusivity of pure W, however Re decreases the thermal diffusivity of pure W. Anisotropy of the thermal diffusivity was not observed.

In the next fiscal year, the W materials will be distributed to collaborative researchers, and thermal fatigue and thermal shock properties, hydrogen retention and permeation, and mechanical strength and ductility will be evaluated.

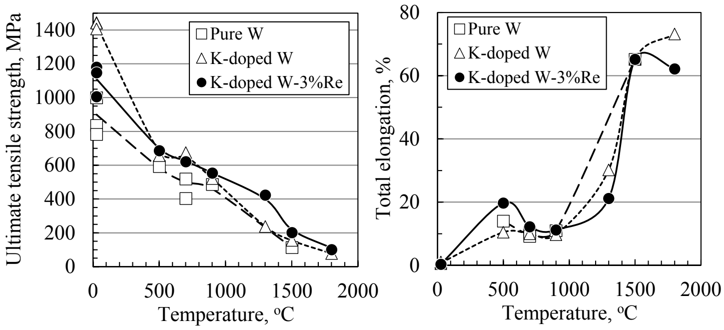

Fig. 1 Temperature dependence of the ultimate tensile strength (left) and total elongation (right) of pure W, K-doped W, and K-doped W-3%Re.

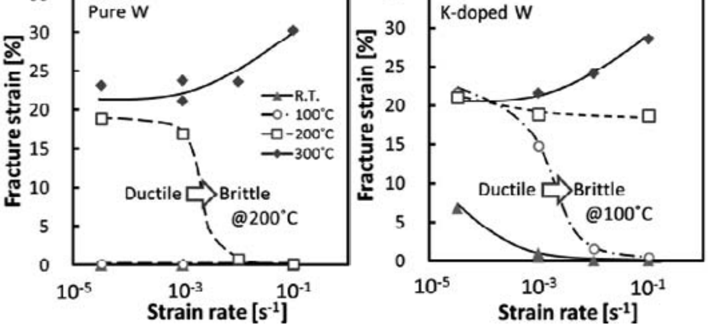

Fig. 2 Strain rate and temperature dependence of the fracture strain of pure W (left) and K-doped W (right).